STELR CHEMISTRY CURRICULUM

TEACHER RESOURCE

THE ATSE STELR PROJECT

This is a hands-on, inquiry-based, in-curriculum program designed for Year 9 or Year 10 students, on the theme of renewable energy. The students are introduced to this theme through exploration of the issue of global warming. A range of directed and student-designed practical investigations are an integral part of the program.

Schools participating in the STELR Project can select from three different curricula, all of which are closely aligned to the *Australian Curriculum: Science.*

1 The STELR Core Curriculum

This is a 6-10 week program designed for Year 9 students. The emphasis in this program is on the physical sciences.

Note:
The print version of the student booklet for this program is a work booklet in full colour, which teachers can support with materials from the STELR website. This program is designed to be accessible to all students.

2 The STELR Integrated Curriculum

This is a 10-12 week program designed for Year 9 students, although it also is very suitable for Year 10 students. In this curriculum, physical and chemical sciences are interwoven. Aspects of earth and space sciences and biological sciences are also included.

Note:
Many of the experiments on electrical circuits, wind turbines and solar cells in this curriculum are the same as those in the core curriculum. However, this program includes a greater range of experiments and is more demanding than the core program.

3 The STELR Chemistry Curriculum

This is a 5-6 week chemistry program designed for Year 9 or Year 10 students. It is very suitable for Year 10 students who completed the STELR physical sciences program in the previous year.

Resources

The resources provided for each of the three STELR curricula include a digital copy of the student booklet and the corresponding teacher guide. The digital copies of these six booklets are in both Word and pdf formats. Teachers can adapt the materials for the curriculum they select to suit their students. Digital copies of a number of PowerPoint presentations are also provided. Full colour hard copies of the student booklet and the accompanying teacher guide for the STELR Core Curriculum are also available.

These materials are fully supported by our dedicated website: www.stelr.org.au. The website provides a range of additional information for students and teachers, including case studies on a range of energy resources, career profiles, and background information. It also will provide teachers with on-line test item banks.

FOR ALL ENQUIRIES ABOUT THE STELR PROJECT:

For general information about the STELR Project or STELR resources, or contacts for advice or support, pleased contact:

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THE STELR PROJECT

THE ATSE STELR PROJECT: AIMS, HISTORY AND ACKNOWLEDGEMENTS

PROJECT OVERVIEW

Our vision

It is well-known that participation rates in the enabling sciences in the senior years of secondary schooling in Australia declined in the 1980s and 1990s, and levelled off over the most recent decade. One of the primary reasons for the lowered participation rates is that most secondary school students do not perceive the enabling sciences or mathematics as relevant to their lives, despite the manifest importance of science and technology in our modern society. As a consequence, a significant proportion of Australian students do not elect to study these subjects at senior levels.

STELR* aims to reverse these lowered participation rates by inspiring and enabling secondary school students to appreciate the role and potential of science, technology and mathematics in the world in which they live, and to learn from their journey of scientific inquiry the essence of evidence-based critical thinking.

STELR achieves this by tapping into the high level of concern the majority of students have about global warming and climate change, shown through surveys of students, using the **theme of global warming and renewable energy**. Since one of the most effective ways of reducing greenhouse gas emissions is the widespread adoption of renewable energy technologies, students see these technologies as being highly relevant to their lives.

STELR is designed to give all Year 9 or 10 students, whatever their background and abilities, the experience, confidence, skills and insights that will inspire and enable them to further their studies in the enabling sciences, mathematics and technology. Whether they eventually choose a career in these areas or not, STELR contributes to their science literacy skills, such as an appreciation of the role of science in society and of the utility of evidence-based thinking.

STELR operates within the curriculum so that ***all*** students at the year level participate in the program, not just selected students. It is our aspiration that ultimately all Australian students, including students who live in remote areas, will have the opportunity to participate in the STELR program.

STELR also inspires and empowers practising teachers to teach science more effectively. To help achieve this, STELR incorporates contemporary teaching and learning practices and, in particular, an inquiry-based learning approach that engages and challenges both students and teachers.

In addition, STELR provides extensive resources to all participating schools, including classroom equipment needed for the program, student and teacher booklets in print and electronic form, a web site, teacher professional learning and ongoing teacher support. In this way the program is accessible to all – no school is disadvantaged.

STELR and the *Australian Curriculum: Science*

STELR is distinctive amongst state and national programs in that it is an excellent vehicle for fulfilling the aims of the *Australian Curriculum: Science,* published December 2010. It exemplifies an inquiry based teaching approach and the development of a coherent learning program in which all three content strands – Science Inquiry Skills, Science as a Human Endeavour and Science Understanding – and the cross curriculum aspects of the curriculum, are interwoven. STELR gives equal importance to, and achieves an ideal balance between, the three content strands.

In addition, through the study of global warming and the investigation of renewable energy resources, STELR demonstrates how the unifying ideas of sustainability, energy, evidence, models, explanations and theories can be developed. Moreover, STELR fosters the eight general capabilities considered to be inherent in science, while the knowledge and skills learned in other areas such as English, mathematics, technology and design are developed throughout.

*STELR is the acronym for Science and Technology Education Leveraging Relevance.

Aims

The primary aim of the STELR Project is to increase Australian student participation rates in physics, chemistry, biology and mathematics subjects at the upper secondary school level.

The secondary aims of the project are to:

1 Improve the level of science literacy and understanding in the community;

2 Prepare students to engage with science ideas and be knowledgeable about the way science and scientists work;

3 Increase the number of students choosing science and engineering careers to address the shortage of science and engineering graduates;

4 Increase students' awareness of careers in technological trades;

5 Improve the quality of science classroom teaching practices and to enable teachers develop the confidence and skills that will help them deliver the new Australian Science Curriculum: Science

6 Use data from the National Solar Schools Program (NSSP) to underpin the development of data-processing and analysis skills in students (when this data becomes available).

Project history 2008-2010

From its inception, the STELR program was designed to be taught within the curriculum so that it is available to all students within the selected year level (Year 9 or Year 10) in each participating school.

To ensure that it was a program for all, the STELR project was initially trialled in a small number of schools across Australia over 2008 and 2009. These were drawn from all sectors, with a mix of government, Catholic and independent schools from metropolitan and rural regions.

Teacher evaluation of the STELR program in these years showed that teachers believed the program had an overall positive effect on students' participation and engagement in learning science and on their perception of the relevance of science in their lives. There also was evidence of teacher change in practice and knowledge of and development of skills in contemporary teaching and learning approaches.

Following these trials, the STELR program and resource materials were re-developed for implementation of the STELR Stage One Project (2010) in 187 schools across Australia. In this process of re-development, recommendations that were made in the evaluation report of the early trials were implemented.

For example:

- New equipment was professionally designed and manufactured by a commercial company so that it was much more accurate and yet easier for students to use, thereby avoiding the frustrations and time delays that can occur, for example, when equipment is difficult to assemble or does not produce reliable, consistent results.
- Some changes were made to the program design, so there was an even greater emphasis on how scientists work, on science inquiry skills and on related mathematical and other skills.
- The teacher resource booklet provided in 2009 was replaced by two booklets, one for teachers and one for students, so that teachers were not required to write all their own student materials. The student resource contained master sheets that could be photocopied for or emailed to the students. The teacher resource contained extensive information and advice for teachers, including a suggested teaching timetable, so that any teacher could run the program, whatever their background training and experience. Since the program was modular, teachers could adapt it to their particular requirements.
- The resources were also supplied electronically in a format that enabled teachers to adapt them to their own school settings.
- The student tests and surveys were re-written to suit the new program.
- The STELR website was further developed and additional career examples and case studies and other curriculum resources were added.
- A DVD was produced featuring an introduction to global warming set in an Australian context. Our experience has shown that before they started the STELR Program, many Year 9 and 10 students already were uninterested in science as they felt it had no relevance to them. When the STELR Program was introduced by means of this thought-provoking DVD, many teachers reported that the students became engaged immediately, recognised how relevant the program was to them and were highly motivated to continue. Our research has shown that this was more effective than the use of an existing documentary on global warming, *An Inconvenient Truth*, which is not set in an Australian context.

The 2010 resource materials were written for the Year 10 level, since this is the level in which students select their subjects for senior years, and in which topics such as the measurement of electrical energy and electrical power are generally taught. A wide-ranging 'smorgasbord' of adaptable activities was provided in print and electronic form so that teachers could select those activities that suited their students and their school curriculum, whether they elected to run the program at the Year 9 or Year 10 level.

These new resources and changes were highly praised by the teachers attending our state-based professional learning programs in March 2010. Many teachers have praised the revised program and the resources provided with great enthusiasm.

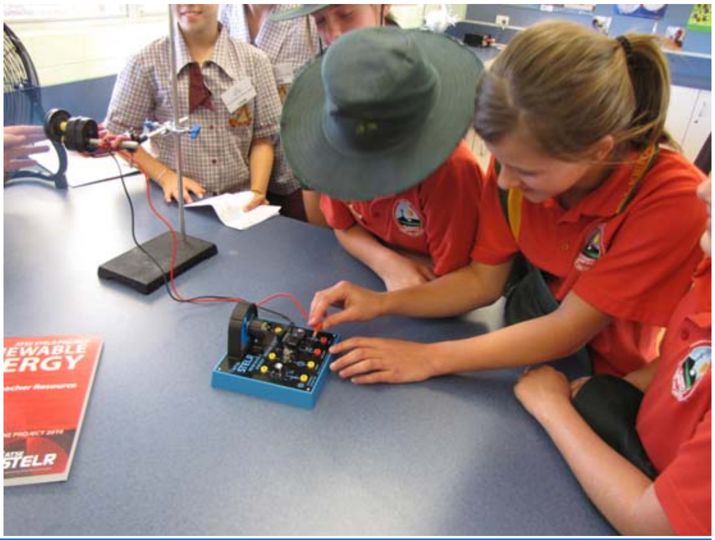


Figure 1 Students trying out the new 2010 resources

However, all these materials have been rewritten to match the *Australian Curriculum: Science*, published in December 2010 and to take into account constructive feedback from 2010 schools. Our quality improvements are also informed by the results of recommendations from the 2010 mentors as well as the evaluation study performed by a team headed by Professor Leonie Rennie (Dean of Postgraduate Studies at Curtin University) and the recommendations provided by our national steering committee headed by Professor Russell Tytler.

As stated on inside cover of this teacher resource, to meet the varying needs of different schools across Australia, STELR now provides teachers with the choice of three different curricula, each with their own set of resources.

Schools need to select which of these three sets of student and teacher resources are best suited to their needs.

To enable teachers to make an informed choice between the three alternative STELR curricula, the program charts for the other two STELR curricula, and charts of how they fit in with the *Australian Curriculum: Science*, are also provided in this resource book (pages 37-40).

The 2010 STELR professional learning program

Figure 2 Some STELR teachers at one of the STELR professional learning programs in March, 2010

In 2010, STELR teachers were given the opportunity to learn the pedagogical and practical skills, and to develop the understandings, insights and experience that they would require, so they could effectively implement the STELR Stage One Project (2010).

Thanks to the funding support we received for 2010, the following provisions were made, at no cost to each participating school:

1 Two full days of a state-based, teacher professional learning program for two teachers from each participating school. The two teachers were then required to provide teacher professional learning and leadership to all other science teachers at their school who would be implementing the STELR program.

2 Online and in-school practical support for all teachers delivering the STELR program, provided by expert mentors.

3 Support for local networking of schools to provide support and professional learning for teachers.

4 Effective, up-to-date resources.

Acknowledgements

The ATSE STELR Project gratefully acknowledges the many STELR teachers, STELR mentors and education and industry experts who have contributed their ideas, advice, sample materials and other resources as the STELR program has evolved. Their contribution has been crucial to the success of the program and is greatly appreciated.

We especially thank the staff and students of Box Hill Senior Secondary College and Northcote High School for trialling our new chemistry materials at the end of 2010.

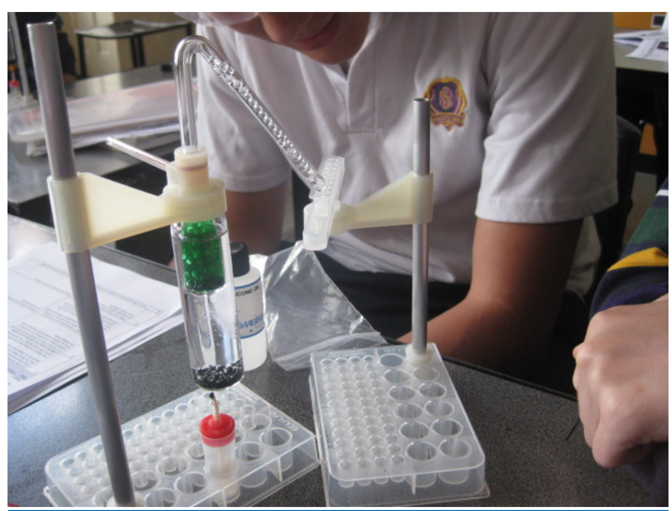


Figure 3 The micro-distillation set (known as a Combo-Still) teachers may wish to use to distill an ethanol mixture.

Funding acknowledgements

The Australian Academy of Technological Sciences and Engineering gratefully acknowledges the leadership ands vision of all sponsors that have contributed to the STELR Project's ongoing success.

The STELR proof-of-concept program (2008) was made possible through the support of:

- Victorian Department of Education and Early Childhood Development
- Australian Academy of Technological Sciences and Engineering (ATSE)
- Australian Academy of Science (AAS)
- Individual Fellows of ATSE (Sir Arvi Parbo, Sir Rupert Myers, Robin Batterham, Alan Finkel)

The STELR Project pilot program (2009) was made possible through the support of:

- Rio Tinto
- Victorian Department of Education and Early Childhood Development
- Victorian Department of Innovation, Industry and Regional Development
- Queensland Department of Education, Training and the Arts
- Tasmanian Department of Education
- South Australian Department of Education and Children's Services
- Western Australian Department of Education & Training
- Victorian Catholic Education Office
- Hydro Tasmania
- Aurora Energy
- Roaring 40s
- Transend Networks
- Alan and Elizabeth Finkel Foundation

The ATSE STELR Stage One Project (2010) was made possible through the principal support of the Australian Government, with substantial sponsorship provided by:

- Orica
- Rio Tinto
- Australian Power Institute

The STELR Project continues in 2011 thanks to:

- Orica
- Australian Power Institute
- Rio Tinto

We thank our sponsors for enabling us to purchase sturdy, reliable equipment for students to perform their hands-on investigations.

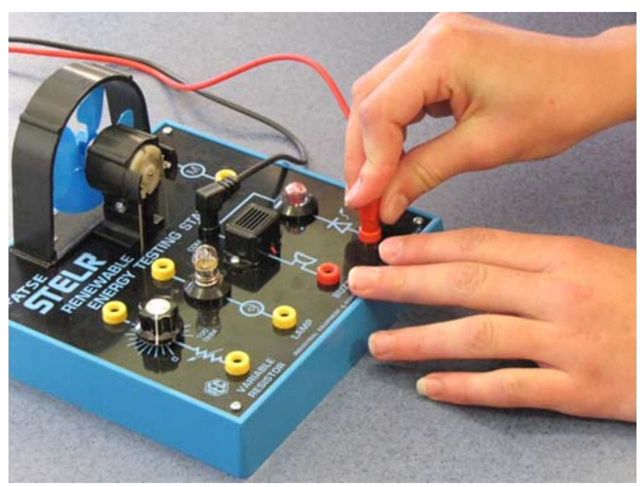


Figure 4 The STELR testing station

THE STELR APPROACH TO TEACHING AND LEARNING

The philosophy behind the STELR approach

A recent and much quoted review of Australian Science education (Goodrum, Hacking & Rennie, 2001) listed, as their first theme for an ideal science curriculum, that : 'The science curriculum is **relevant to the needs**, concerns and personal experiences of students.'

They have argued more recently (Goodrum & Rennie, 2006) that: 'Many students find the school science curriculum on offer to be **unimportant, disengaging, and irrelevant** to their life interests and priorities.'

Glen Aikenhead (2004) has argued that: 'A recurring evidence-based criticism of traditional school science has been its **lack of relevance** for the everyday world', and that we need to emphasise humanistic aspects of science in our curriculum and teaching.

For this reason, the main theme of the STELR program is the highly relevant context of **global warming and renewable energy**.

STELR has adopted a number of principles designed to engage students through evidence-based teaching approaches and strategies. These include:

- Scientific literacy;
- Inquiry-based learning;
- A socio-scientific focus;
- The representation of science as a human endeavour; and
- Embedded assessment.

Inquiry-based learning

Inquiry-based learning helps students actively pursue and use science knowledge rather than experience it as pre-packaged and complete – to be accepted and practised. Thus, in the STELR program there are many points at which students raise questions and explore ideas.

In the introductory activities the principle used is 'guided inquiry', but students are later encouraged to shape their own inquiry around questions that interest them. This involves being able to design investigative approaches. These include experimental as well as web-based research approaches.

A core principle that has been used to describe inquiry is 'explore before explain', meaning that students are introduced to science ideas only after they have explored phenomena and raised questions implying a need for these.

Inquiry-based pedagogies:

- Involve students in initial exploration before ideas are introduced and explanations developed;
- Incorporate and value students' own questions;
- Involve open-ended investigation as part of the teaching sequence;
- Use activities to explore and develop ideas rather than simply demonstrate previously presented ideas; and
- Support students to create new knowledge.

See the outline of the principles of inquiry-based learning on pages 12-13.

The jigsaw approach

An integral part of the STELR program is the **jigsaw approach** to learning in which each student group or student pair becomes the class experts in particular aspects of renewable energy through practical and web-based investigations and various challenges, which they then communicate to the other members of their class. These activities involve students taking responsibility for the direction of their inquiry.

The 'interview about instances' teaching strategy

Many of the activities through which key concepts are introduced are based on the teaching strategy **interview about instances**. In this approach, some stimulus material, in such forms as a series of images, a DVD or demonstrations, is presented to the students and questions about the stimulus material are posed.

The role of the teacher is one of the questionner rather than the transmitter of answers. The teacher may find there is considerable variation in student thinking about the issues or concepts presented, or that alternative conceptions are presented.

Principles of inquiry-based learning

Engagement of Students

An inquiry based approach starts with engagement of the students prior to explaining. This serves several purposes:

- It provides a conflict between prior learning and the new more scientific understanding - such conflict will lead students to ask questions
- It gets students' attention and focus
- It elicits and assesses prior knowledge [students may have constructed alternative conceptions]

During this stage, students:
- ask questions
- show curiosity
- show interest

During this stage, teachers:
- create interest
- generate curiosity
- raise questions
- elicit responses

Exploration without teacher explanation

During this stage, students:
- ask questions
- hypothesise
- work without direct teacher input [but are guided]
- gather evidence
- record and organise information
- share observations
- make evidence-based claims
- draw conclusions
- work cooperatively and / or collaboratively

During this stage, teachers:
• encourage students to work cooperatively and / or collaboratively
• observe and listen as students interact
• ask thought-provoking questions
• allow students time to puzzle through and to explore
• act as a facilitator and / or a consultant
• create a climate where students “want to know” and “want to learn”

Explanation

During this stage, students:
• draw on experiences to offer ideas and explanations in his / her own words
• uses evidence to support ideas
• critically appraise explanations
• listen critically and respectfully to others
• reflect on and assess their own understanding
• produce multiple representations of concepts to improve understanding.

During this stage, teachers:
• elicit the students' explanations of concepts, definitions of words
• ask for evidence and clarification
• formally provide definitions, explanations and new labels
• use students’ experiences to build new concepts
• assess students’ developing understanding of concepts
• provide opportunities for students or represent their ideas in a variety of formats.

Elaboration

During this stage, students:
• apply scientific terms, definitions
• apply understandings to new contexts
• use previous information to ask questions, propose solutions, to make decisions and design investigations
• draw reasoned conclusions from the evidence
• check for understanding with their peers.

During this stage, teachers:
• expect students to use appropriate scientific terms, labels and definitions
• expect students to use their understandings from explanations
• remind students of alternatives
• ask questions such as “What do you think?” and “Why do you think that?”

Assessment

During this stage, students:
• demonstrate their understanding of the ideas and concepts
• answer open-ended questions
• evaluate his / her own progress
• ask questions
• participate in peer assessment.

During this stage, teachers:
• elicit or diagnostically assess students’ prior knowledge and understanding
• explicitly develop the language of science and mediate where students have conflict in their understanding
• use formative assessment or assessment of learning throughout a unit of work to evaluate student understanding, to provide feedback to students and to direct the learning program
• use summative assessment to identify the students’ congruence with the new understandings.
• use conceptual mediation to overcome and reconcile alternative conceptions
• use a variety of assessment strategies.

THE STELR PROJECT

SOME FEEDBACK AND IDEAS FROM STELR TEACHERS

Feedback from the 2008-2009 trials

Teachers involved in the STELR trial programs identified many significant benefits arising out of the inquiry-based learning in the STELR program. They included:

- A definite increase in the level of students' engagement with the material – this included more class discussion and willingness of students to contribute to discussions, as well as increased engagement with practical activities.

- More opportunities to connect what students were learning with current issues in the media and in their daily lives. Students gained insights into how science works in the real world.

- The opportunity for teachers to work as a team, to gain a broader understanding of the applications of science, and to undertake inquiry-based learning on a much larger scale than their time and resources would normally allow.

Feedback and ideas from 2010

Following are quotes from some of the teachers involved in 2010. Notice some of the creative ideas used in some of these schools! Also see the student feedback at one of these schools.

From Mark Darrell Assistant Principal, *Mathematics and Science*, Hallett Cove School R-12, SA
President, Mathematics Association of South Australia

Given the decade long decline in the number of students undertaking advanced studies in Mathematics and Science, it is timely to be able to implement a program that has the potential to significantly address the disengagement that students are expressing towards STEM subjects.

Although there is a range of programs on offer around the country that are attempting to address this situation, I believe that the STELR Program is best placed to create a sustainable impact.

It is imperative that we engage the students in a rigorous pursuit of in depth understanding and appropriate skill development so that, not only do we increase the number of students pursuing advanced studies, but that we also raise the general level of mathematical and scientific literacy of the future populous at large.

At the school level we are well aware that the relationship between teachers and their students, as well as the use of appropriate pedagogies, are essential in the provision of an engaging and rigorous curricula. The desperate need for teacher professional development has been of on-going concern, as has the lack of availability of high quality teacher resources that support the teachers in the provision of said curricula.

The thoroughness of thought and preparation that has obviously been put into the preparation and provision of the STELR Program goes a long way towards addressing both of the above mentioned concerns.

Introducing curriculum and pedagogical change has always proved difficult and frustratingly time consuming at the school level. Teachers are, quite naturally, resistant to change unless they are able to perceive the potential benefits of implementing that change as well as feeling fully supported in the change process. By providing all the necessary curriculum and teacher support materials, as well as the actual physical equipment, the STELR Program has made it quite easy for the science teachers to feel sufficiently confident to be prepared to implement such an inquiry-based, contextualised program.

The enthusiasm for the program expressed by the teachers, as well as the highly topical contexts around which the program was developed, makes it highly likely that the students will also find the program engaging. In fact, we believe that the provision of more units along similar lines to the current STELR program would go a long way towards ensuring that high quality science curricula, in line with the National Curriculum and utilising appropriate pedagogies, would be implemented across the country.

From Heather Omant, Curriculum Manager, Ogilvie High School, Tasmania
*(*Heather has taken up a new appointment at another school for 2011)*

I am curriculum manager at a large city high school in Hobart and we have taken part in this federally-funded program on renewable energy for 2 years.

The program is outstanding in encouraging students in the field of physics (we are an all-girls school) and also in making them aware of the problems around energy usage and the possible alternatives to fossil fuels. It also is a fantastic hands-on program which helps students to understand the processes of scientific inquiry. The materials and teachers' resources are excellent.

From Melody Gabriel, Head of Science, Northcote High School, Victoria

Staff members have been singing its praises. Not being able to teach all the lessons as we don't have the time, we selected a range of activities that would flow and allow students to get the intended overall understandings.

The STELR teachers are really enjoying teaching it. The materials are comprehensive and easy to follow by students and teachers. The equipment is great and easy to operate, and the support in terms of changes has been wonderful -Thanks.

We supplied the students with their own booklets of the activities that they will be doing, and they are used well. The students are thoroughly enjoying the intensive hands on approach, and that is really evident following a unit on genetics & evolution, really mixes up the semester. . .

Next year we have to make serious changes to our Year 10 offerings, so we have decided to use the STELR as a whole unit, and teach from basic principles upwards. This support is offered in the book and staff felt it would have served the students well if we had had the time this year. This will be offered to all Y10 students and will be a pathway into VCE Physics.

All in all, great changes, staff and students feel supported and the resources are very user-friendly. Thanks!

From Louise Macfarlane, Science TLA Co-ordinator, Box Hill Senior Secondary College, Victoria

We have just received the fabulous new equipment from ASTE for the STELR Project Stage One. All of the science teachers here at BHSSC are excited about our ability to teach science with a student-centred, hands-on, inquiry-based approach using this equipment and the program the ASTE STELR Project provides.

In 2009 BHSSC was involved in the STELR pilot project and taught the STELR program to seven classes of Year ten science students over six weeks. This year we will be teaching eight Year 10 science classes on the STELR project.

At BHSSC we have students who come to learn trades skills such as electrical, woodwork, fashion, art, hairdressing, music as well as our specialty sports students. This being the case, science lessons need to have a hands-on approach to learning to engage students and get across concepts. This is exactly what STELR has provided.

At the end of the STELR pilot project students were surveyed and they loved the practical experiments on biofuels, energy transfer, solar cells and wind turbines and said they would not change anything about the project because it was fun. That is a huge vote of confidence for the project because when students are having fun they are engaged and they are learning.

As in all pilot programs we found there were some improvements that could be made. All of the suggestions we made were listened to and acted upon promptly. This was from the little suggestions such as providing batteries in the anemometers, to creating an Australian and up-to-date version of the DVD *An Inconvenient Truth'* The STELR-produced DVD *Global Warming. Cold Facts. Hot Scienc'* is concise and relevant to the lives of Australian Students. I am looking forward to sharing it with the students in a couple of weeks.

The STELR team made the process of teaching the STELR lessons easier by facilitating exchange of teaching materials between teachers, which saved a lot of time.

With the advice and support of the STELR team and the support of our principal, Steve Cook, Charlie Gilbert, the electrical trades teacher, and Simon Hood at our tennis school, we have been able to extend the STELR project to involve the whole BHSSC school community. The electrical trades students have added a wind turbine and solar panels to the roof of our canteen and the electrical trades students are wiring up these green energy supplies to low energy lighting they are installing in the canteen. So we will have green energy installed by students for the students.

On STELR advice we applied for and accessed the Federal Solar in Schools $50,000 grant for solar panels and the $5000 state grant. So we will be installing $55,000 of solar panels on the MYTS tennis school roof this July. We will be able to inform the students and community about the green energy we will generate, and the benefits of decentralising the energy production and the use of non-polluting energy production. Excess energy will be fed back into the grid for the benefit of the community.

ASTE supplied the components for a model solar car race. Each pair of students in Year 10 science built their own model solar car. To our surprise the fashion students were quite as engaged as the trades students, with each car having its own style. Some film students even made a photo journey series of their model. This open-ended learning allowed individual learning journeys.

So in many ways we have benefited from the STELR program. This is only possible due to the enthusiasm and dedication of members of the STELR team. I hope you get the funding to continue with this excellent program. The student science environment is far more stimulating for students (and teachers) as a result of this fabulous program.

From Jane Ganfield, Science Teacher, Dongara District High School, WA

Our application

It’s windy in Dongara. In fact it’s really, really windy. While this is generally looked upon as a curse, for a change it actually was a bonus . . . Dongara is a perfect place to highlight the potential for sustainable energy use.

Dongara is a small town (population about 3000) with a small school. When we were told late last year that we were successful,
. . . our success and what it meant was published in the school newsletter and our local paper. The school, particularly the secondary students, was buzzing about what sort of equipment we would get. I think the students were also a little surprised, being a small school and winning all this gear. Any little boost that suggests that the little guys can be just as worthy and successful as the big guys is a great lesson for our students.

The professional learning

Early this year, successful school representatives met in Perth for two-days of professional learning. It was great to see that a variety of schools (big/small, country/city, public/private) were successful. . . The schools came from as far north as Newman and as far south as Busselton. All costs were covered, so representatives coming from a long way away weren't disadvantaged.
The professional learning went through the STELR philosophy and goals of the project . . . and also involved using the equipment that we were given, as learning to use a whole new set of gear would obviously be time-consuming and would be used most effectively by teachers if shown how. An impromptu talk from a teacher at South Fremantle High School, a pilot STELR school, also gave a realistic perspective on how the gear worked in a classroom and school situation. Feedback from the pilot STELR schools was gratefully accepted. One of the main issues with the equipment originally was that it wasn't robust enough for curious students with the old "If I pull this bit really hard, is it gonna break?" mentality. This was rectified and a whole new set of gear constructed, and from my experience it's almost teenager-proof!

How we use STELR

The program is really flexible and teachers can choose to use all or none of the teacher and student resources and all or none of the equipment. I have almost completed a unit on Energy and Change using the STELR equipment with a group of Year 10 students. The students performed surprisingly well in the pre-test and haven't completed the post-test yet. I still have a few weeks left of the unit. I was a bit surprised about the lack of knowledge about the difference between the greenhouse effect, global warming and the ozone layer. I thought that being in the media so much that students would have a lot more understanding of the topic. The misconception that the depletion of the ozone layer has caused global warming was quite common. . .

Before doing the sustainable energy use part of the course, we visited a wind farm just north of Dongara, close to the town of Walkaway. The students were (pardon the pun) absolutely blown away when they got there. There are 54 wind turbines at the wind farm we visited. They supply enough energy for 60 000 homes. We then estimated that to power Dongara we would only need 3 wind turbines. The effect was huge and a heated discussion was started on the way home as to why Dongara doesn't have wind turbines, where they should go, why WA doesn't have more wind turbines, etc. It was really great to see and hear. The pros and cons of wind turbines were discussed and the students learnt a lot from their discussions with each other as there were differing opinions and varying degrees of understanding. The students' youthful enthusiasm was once again reignited.

After the visit to the wind farm, we spent a week looking at alternative energy sources. The students researched one alternative energy source then did a jigsaw to learn about all the other sources. We then used the wind turbines and solar panels and looked at how to get maximum power out of them. The Year 3's were then invited into the science laboratory as they were learning about energy, and had a competition. Each pair of Year 10 students was put with three or four Year 3's. The competition was for the Year 3's to create the wind turbine that created the most volts. The STELR equipment has different length blades and you can put in as many blades and blade combinations as you like.

The groups also 'played' outside with the solar panels, experimenting with angles and shade and making buzzers sound and lights glow. Both groups of students loved the activity and helped to increase enthusiasm towards Science.

On the last day of term the mainstream Year 10's had a competition against the SWL (vocational pathway) Year 10's to see who could make the fastest solar car. The equipment for the cars is not part of the STELR equipment but STELR is planning on including this kind of equipment into the kits in the future. The students were allowed to use one solar panel, one motor and any combination of wheels, pulleys and gears that they liked.

The learning and problem-solving that happened during the design process was immense. Some students' cars were going backwards, so they had to figure out that they needed to swap over wires. Others had a gear ratio that required more torque to get the car moving than what the motor could provide. Others designed intricate systems to make sure their car went in a straight line. Next time I would probably do little experiments beforehand such as the impact of the angle of the panel in relation to the sun and the voltage output. The students didn't seem to realize that getting the angle right was crucial. The students really embraced the challenge. It was reiterated to the SWL students that their problem-solving abilities and practical skills would be advantageous for the challenge, whereas the knowledge and technical side of the challenge may mean the mainstream group performed better. The challenge highlighted the fact that the strengths and skills possessed by the SWL group were just as useful as the more academic groups' skills and knowledge.

Feedback from some Year 10 students:

"I feel that using the STELR equipment has helped my learning a lot, because it's very "hands on" and I understand how electricity works a lot easier now." **Zoe**

"I learnt more about how wind creates electricity and how solar systems work and I think it's a great way of teaching kids about Science." **Hayley**

"I find while using the STELR equipment I have learnt faster than copying out of a book" **Matt**

"The STELR equipment was interesting and fun to play around with. It showed that electricity can be produced in different ways, eg. wind turbines and solar panels". **Barry.**

Thank you

The Science Staff and students at our school would like to thank the STELR team and ATSE for helping to improve Science outcomes and enjoyment. It has had a huge impact on the students enthusiasm for Science, especially Energy and Change. It is amazing how two-days of PD, a teacher and student-friendly resource and some well thought-out equipment can make such a difference.

THE STELR PROJECT

ASSUMED LEARNING

In the writing of the STELR Chemistry Curriculum, it is assumed that the students have the following background understanding and skills. These will then be reinforced and extended throughout the program.

Mathematical skills

- Substitution of values into a formula
- Unit conversion
- Calculation of percentages
- Calculation of averages, including identifying and omitting outliers
- Drawing and interpreting graphs
- Selecting a suitable graph format for a particular set of data

Note: Examples are provided for the calculations required in the student booklet of the STELR Chemistry Curriculum.

Science understandings

- The meaning of energy terms, including kinetic energy, potential energy, and energy transformations
- The meanings of the terms atom and molecule

Note: In the STELR Chemistry Curriculum, energy concepts are reviewed before extending them.

Science skills

- Practical science inquiry skills, including making predictions and taking accurate, repeat measurements and recording them in tables
- Using basic science equipment carefully and safely

ICT skills

- Web research
- Setting up and using spreadsheet applications
- Using graphing software

Note: Experience in taking digital photos and videos would be an advantage.

THE STELR CHEMISTRY CURRICULUM

OVERVIEW OF THE STELR CHEMISTRY CURRICULUM

The STELR Chemistry Curriculum has been written principally for Year 10 students who completed the STELR Physical Sciences Curriculum in Year 9.

The design of the STELR Chemistry Curriculum

The STELR Chemistry Curriculum is designed to enable students to develop key understandings, skills and insights in a logical and systematic fashion, through a series of topics based on the theme of global warming and renewable energy.

These topics are principally drawn from the chemical sciences, as shown in the STELR Chemistry Curriculum Chart on page 21. However, the aspects of physical sciences, earth and space sciences and biological sciences also are included. This models the fact that identifying, monitoring and addressing important issues like global warming requires scientists from different disciplines to work in partnership with one another.

The STELR Chemistry Curriculum is closely aligned with the *Australian Curriculum: Science*, not only in relation to the three content strands, but also in relation to its underlying philosophy, aims and emphasis on inquiry-based learning.

In fact, the *Australian Curriculum: Science* was informed by key international curriculum documents, including:
•*Re-imagining Science Education: Engaging students in science for Australia's future* (Tytler, 2007)
•*Australian School Science Education National Action Plan 2008 – 2012* (Goodrum and Rennie, 2007)

As shown in the Chemistry Program Chart on page 20, the curriculum is designed to give equal importance to the three content strands. Woven around practical investigations and a range of class activities, it exemplifies how the three content strands can be interwoven into a coherent, logical program.

The practical investigations

The practical investigations enable students to build up a range of science inquiry skills and develop many relevant key science understandings. Students first undertake directed practical investigations and then assisted student-designed investigations. These enable the students to develop confidence and competence with the equipment and an understanding of experimental design.

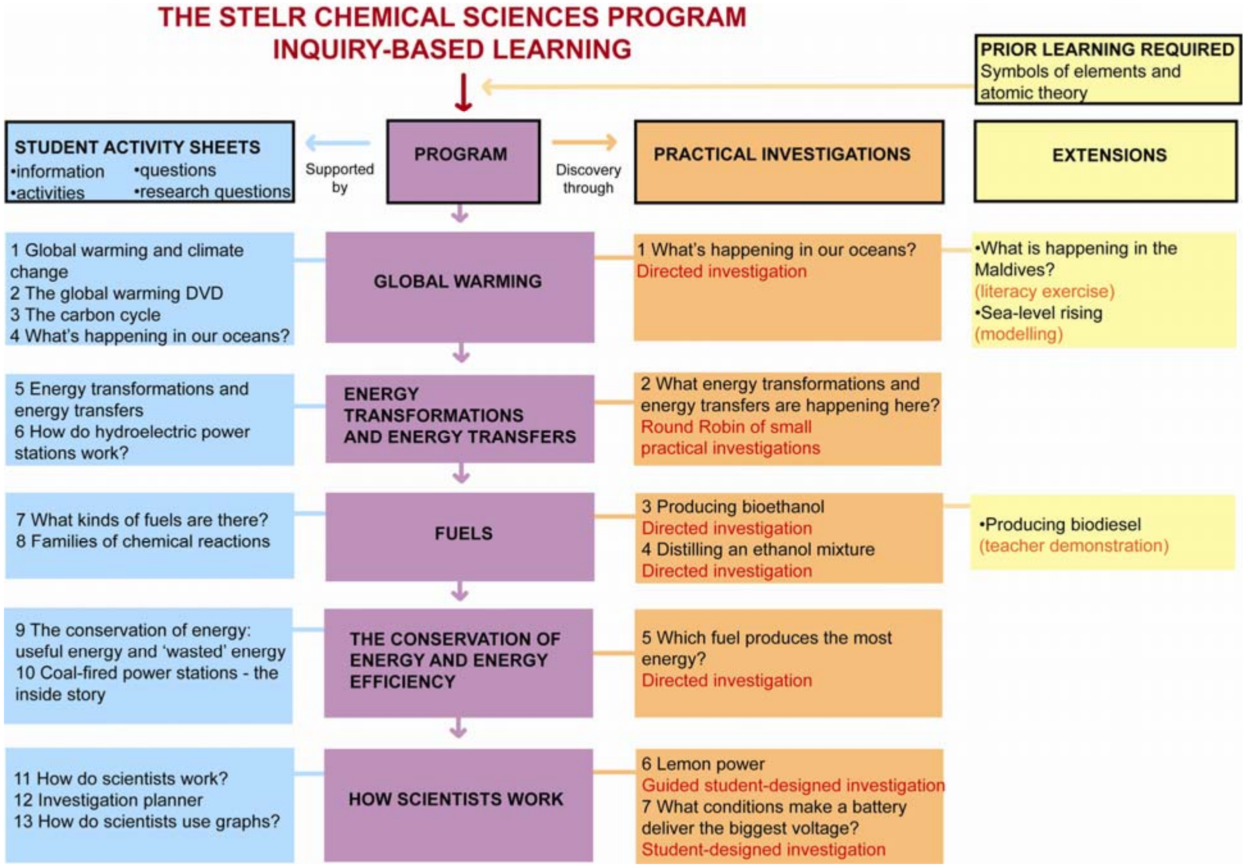
The student activity sheets

The student activity sheets offer students a range of experiences and tasks to enable them to develop key science understandings and thinking skills and to give them opportunities to explore issues that are relevant and meaningful to them, as well as possible future careers.

Personal development

By undertaking the STELR Chemistry Curriculum, students will be given the opportunity to develop:

• Confidence and self-esteem
• An insight into how science is relevant to their future and how science can be challenging and fun
• Reasoning and reflection
• A disposition to ask questions, problem solve and argue using evidence
• Communication skills
• Creativity and imagination
• An ability to collaborate with others and work effectively in a team
• Effective time-management and organisational skills


THE STELR CHEMICAL SCIENCES PROGRAM
INQUIRY-BASED LEARNING
PRIOR LEARNING REQUIRED
Symbols of elements and atomic theory
STUDENT ACTIVITY SHEETS
•information •questions
•activities •research questions
Supported by
PROGRAM
Discovery through
PRACTICAL INVESTIGATIONS
EXTENSIONS
1 Global warming and climate change
2 The global warming DVD
3 The carbon cycle
4 What's happening in our oceans?
GLOBAL WARMING
1 What's happening in our oceans?
Directed investigation
•What is happening in the Maldives?
(literacy exercise)
•Sea-level rising
(modelling)
5 Energy transformations and energy transfers
6 How do hydroelectric power stations work?
ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS
2 What energy transformations and energy transfers are happening here?
Round Robin of small practical investigations
7 What kinds of fuels are there?
8 Families of chemical reactions
FUELS
3 Producing bioethanol
Directed investigation
4 Distilling an ethanol mixture
Directed investigation
•Producing biodiesel
(teacher demonstration)
9 The conservation of energy: useful energy and 'wasted' energy
10 Coal-fired power stations - the inside story
THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY
5 Which fuel produces the most energy?
Directed investigation
11 How do scientists work?
12 Investigation planner
13 How do scientists use graphs?
HOW SCIENTISTS WORK
6 Lemon power
Guided student-designed investigation
7 What conditions make a battery deliver the biggest voltage?
Student-designed investigation

THE STELR CHEMICAL SCIENCES CURRICULUM AND THE AUSTRALIAN CURRICULUM: SCIENCE

SCIENCE AS A HUMAN ENDEAVOUR

NATURE AND DEVELOPMENT OF SCIENCE

- Scientific understanding is contestable and is refined over time through a process of review by the scientific community.

USE AND INFLUENCE OF SCIENCE

Evidence-based critical thinking

- People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions

Solving contemporary issues

- Science understandings influence the development of practices in areas of human activity such as marine and terrestrial resource management
- Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations
- The values and needs of contemporary society can influence the focus of scientific research

Career opportunities

- People use understanding and skills from across the disciplines of science in their occupations
- Advances in sciences and emerging sciences and technologies can significantly affect peoples' lives, including generating new career opportunities

SCIENCE UNDERSTANDING

CHEMICAL SCIENCES

- Chemical change involves substances reacting to form new substances
- All matter is made of atoms, which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (*Context: Geothermal power stations)
- Chemical reactions involve rearranging atoms to form new substances
- Chemical reactions, including combustion and the reactions of acids, are important in both living and non-living systems, and involve energy transfer
- Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere.

PHYSICAL SCIENCES

- Energy appears in different forms including heat energy and potential energy, and causes change within systems
- Forms of energy can be transferred in a variety of ways through different mediums
- Energy conservation in a system can be explained by describing energy transfers and transformations

EARTH AND SPACE SCIENCES

- Some of the Earth's resources are renewable, but others are non-renewable
- The theory of plate tectonics explains global patterns of geological activity and continental movement (*Context: Geothermal power stations)

BIOLOGICAL SCIENCES

- Matter and energy flow through ecosystems

SCIENCE INQUIRY SKILLS

Questioning and predicting

- Formulate questions or hypotheses that can be investigated scientifically

Planning and conducting

- Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods
- Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data

Processing and analysing data and information

- Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence

Evaluating

- Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data

Communicating

- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations

GROUP PRESENTATIONS

Communicating findings using scientific language and meaningful representations and making evidence-based arguments

THE STELR INTEGRATED CURRICULUM

MAP OF THE STELR INTEGRATED CURRICULUM AGAINST *THE AUSTRALIAN CURRICULUM: SCIENCE*

Following is an outline of how the STELR Chemistry Curriculum fulfills much of the Australian Curriculum: Science, particularly at Years 9 and 10. Also see the outline of the development of science inquiry skills (pages 25-26) and the curriculum chart on page 21.

Curriculum focus

In the STELR Chemistry Curriculum, students further develop their understanding of important science concepts across the major science disciplines, within contemporary contexts that enhance a richer understanding of science. They are motivated and engaged through learning about current science research and its human application. In particular, the students move from an experiential appreciation of the effects of energy to a more abstract understanding of the nature of energy.

Unifying ideas

The STELR Chemistry Curriculum centres on the following three unifying ideas:

- Sustainability
- Energy
- Evidence, models and theories

General capabilities

In the STELR Chemistry Curriculum, students further develop skills in:

- **Literacy:** through different modes of communication, observing, investigating and discussing phenomena and issues in appropriate scientific and technical terms.
- **Numeracy:** through measurement, numerical calculations using formulas, analysis of data, graphing and interpretation of graphs and statistical procedures, in practical meaningful contexts.
- **ICT competence:** through the use of information, communication and digital technologies, for research, measurement and communication of their findings.
- **Critical and creative thinking:** through active scientific inquiry, analysis of issues and developing creative solutions, problem-solving, practical investigations, and analysis of secondary data.
- **Ethical behaviour:** through application of ethical principles and guidelines in their investigations and research, and evaluation of claims based on science.
- **Personal and social competence:** through collaborative team work, decision-making, and planning, performance and reporting of guided and student-designed practical investigations.

Cross-curriculum priority

In the STELR Chemistry Curriculum, the cross-curriculum priority is sustainability, through the study of global warming and climate change and renewable energy.

Links to other learning areas

Learning in the STELR Chemistry Curriculum links strongly to English and Mathematics. It also links to Geography.

Teaching, assessment and reporting

The STELR Chemistry Curriculum is based on an inquiry-based model of teaching and learning. Through ongoing support provided to STELR teachers, the teachers are inspired and enabled to develop a balanced and engaging approach to teaching, using a context that is relevant and meaningful to students. Teachers are assisted with a range of modes of assessment and reporting.

Note: The Science Inquiry Skills expected for Years 7/8 will be reinforced and for Years 9/10 they will be developed throughout the inquiry-based STELR program. For this reason they are listed separately. (See pages 25-26.)

THE STELR CHEMISTRY CURRICULUM			THE AUSTRALIAN CURRICULUM: SCIENCE Foundation to Year 10 Science Understanding (SU), and Science as a Human Endeavour (SHE)
CORE TOPICS	**DEVELOPMENT OF SCIENCE UNDERSTANDING AND SCIENCE AS A HUMAN ENDEAVOUR**	**DEVELOPMENT OF SCIENCE INQUIRY SKILLS AND SCIENCE UNDERSTANDING**	
GLOBAL WARMING	**1 Global warming and climate change** **2 The global warming DVD** **3 The carbon cycle** **4 What's happening in our oceans?**	**1 What's happening in our oceans?** *Directed investigation*	**SHE (7/8)** •Science understandings influence the development of practices in areas of human activity such as marine and terrestrial resource management •Science and technology contribute to finding solutions to a range of contemporary issues **SU (9)** •Matter and energy flow through ecosystems •Chemical reactions involve rearranging atoms to form new substances •Chemical reactions, including the reactions of acids, are important in both living and non-living systems, and involve energy transfer **SHE (9/10)** •People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions **SU(10)** •Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere.
ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS	**5 Energy transformations and energy transfers** **6 How do hydroelectric power stations work?**	**2 What energy transformations and energy transfers are happening here?** *Round Robin of small practical investigations in Chemistry*	**SU(8)** •Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems **SU(9)** •Forms of energy can be transferred in a variety of ways through different mediums **SU(10)** •Energy conservation in a system can be explained by describing energy transfers and transformations
FUELS	**7 What kinds of fuels are there?** **8 Families of chemical reactions**	**3 Producing bioethanol** **4 Distilling an ethanol mixture** *Directed investigations*	**SU(7)** •Some of the Earth's resources are renewable, but others are non-renewable **SU(8)** •Chemical change involves substances reacting to form new substances **SU(9)** •Chemical reactions involve rearranging atoms to form new substances •Chemical reactions, including combustion, are important in both living and non-living systems and involve energy transfer. •All matter is made of atoms which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (*Context: Geothermal power stations) •The theory of plate tectonics explains global patterns of geological activity and continental movement (*Context:

FUELS **(CONTINUED)**			geothermal power stations.) **SHE (9/10)** •People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions •Advances in sciences and emerging sciences and technologies can significantly affect peoples' lives, including generating new career opportunities •The values and needs of contemporary society can influence the focus of scientific research
THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY	**9 The conservation of energy: useful energy and 'wasted' energy** **10 Coal-fired power stations – the inside story**	**5 Which fuel produces the most energy?** *Directed investigation*	**SU(9)** •Forms of energy can be transferred in a variety of ways through different mediums •Chemical reactions, including combustion, are important in both living and non-living systems and involve energy transfer **SU(10)** •Energy conservation in a system can be explained by describing energy transfers and transformations
HOW SCIENTISTS WORK	**11 How do scientists work?** **12 Investigation planner** **13 How do scientists use graphs?**	**6 Lemon Power** **7 What conditions make a battery deliver the biggest voltage?** *Guided student-designed investigations*	**SU(9)** •Forms of energy can be transferred in a variety of ways through different mediums **SHE (9/10)** •People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions •The values and needs of contemporary society can influence the focus of scientific research

THE STELR CHEMISTRY CURRICULUM

THE DEVELOPMENT OF SCIENCE INQUIRY SKILLS IN THE STELR CHEMISTRY CURRICULUM

Table 1 Directed practical activities

<table>
<tr><th rowspan="2">Science Inquiry Skill</th><th colspan="5">Code number of directed practical activity</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td rowspan="2">Questioning and predicting
Formulate questions or hypotheses that can be investigated scientifically</td><td>✓</td><td>✓</td><td></td><td>✓</td><td>✓</td></tr>
<tr><td colspan="5">In these directed laboratory investigations, students are provided with inquiry questions but are asked to predict outcomes</td></tr>
<tr><td rowspan="2">Planning and conducting
Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="5">In these directed laboratory investigations, students do not plan or select the laboratory investigation methods; students do participate in the risk assessment, however. It is expected that teachers will raise ethical issues in the context of class discussions</td></tr>
<tr><td rowspan="2">Planning and conducting
Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="5">In these directed laboratory investigations, students do not select the equipment but are trained to use it</td></tr>
<tr><td>Processing and analysing data and information
Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies</td><td>✓</td><td></td><td></td><td></td><td>✓</td></tr>
<tr><td>Processing and analysing data and information
Use knowledge of scientific concepts to draw conclusions that are consistent with evidence</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td rowspan="2">Evaluating
Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data</td><td>✓</td><td></td><td>✓</td><td></td><td>✓</td></tr>
<tr><td colspan="5">In these directed laboratory investigations, this evaluation process is mostly carried out in the context of a class discussion</td></tr>
<tr><td>Evaluating
Critically analyse the validity of information in secondary sources and evaluate the approaches used to solve problems</td><td colspan="5">This skill is applied in other activities instead of in these practical investigations</td></tr>
<tr><td>Communicating
Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
</table>

Table 2 Student-designed practical activities

Science Inquiry Skill	Code number of practical activity	
	6 Guided	7 Guided
Questioning and predicting Formulate questions or hypotheses that can be investigated scientifically In these guided student-designed laboratory investigations, students are provided with inquiry questions.	✓	✓
Planning and conducting Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods In these laboratory investigations, it is expected that teachers will raise ethical issues in the context of class discussions.	✓	✓
Planning and conducting Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data In these guided student-designed laboratory investigations, students do not select the equipment.	✓	✓
Processing and analysing data and information Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies	✓	✓
Processing and analysing data and information Use knowledge of scientific concepts to draw conclusions that are consistent with evidence	✓	✓
Evaluating Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data	✓	✓
Evaluating Critically analyse the validity of information in secondary sources and evaluate the approaches used to solve problems As part of their class discussions, students should be asked to compare and evaluate their methodologies with those of other groups in the class, and also to do so in their reports where appropriate.	✓	✓
Communicating Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations	✓	✓

Note: The teacher is expected to:

- **Decide when to use ICT to record and process results. Students should be exposed to as wide a range of different strategies as possible.**
- **Draw the class together at the end of each investigation to discuss such aspects of the investigation as their conclusions, explaining observations and patterns and relationships in numerical data and relating them to scientific concepts, sources of error and improvements that would reduce error, ways of reducing risk and critiquing reports, noting flaws in design and inconsistencies of data.**

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THE STELR CHEMISTRY CURRICULUM

HOW TO RUN THE STELR CHEMISTRY PROGRAM

As stated earlier, the STELR Chemistry Curriculum has primarily been written for Year 10 students who completed the STELR Physical Sciences program when in Year 9. It is designed to meet many of the requirements of the *Australian Curriculum: Science*, published December 2010.

The advantage of this is that you can fulfill much of the *Australian Curriculum: Science* within a meaningful context.

To cater for the wide range of schools implementing the program, however, a variety of activities that can be used to introduce each key topic, and optional extension activities, have been provided.

In addition, to cater for schools that decide to use the STELR program to introduce students to electrical circuits, current and voltage, some optional introductory practical investigations are also provided.

As the teacher, you must decide which of our three STELR programs you will deliver to your students, taking into account their background, your school's timetabling arrangements and other restrictions.

We would expect that the STELR Chemistry Curriculum will take approximately 6 weeks.

NO TEACHER IS EXPECTED TO RUN EVERYTHING WE OFFER!

BUT WE DO ENCOURAGE YOU TO SELECT AS MUCH AS YOU CAN FROM OUR 'SMORGASBORD', SO THAT STUDENTS ARE GIVEN A RICH EXPERIENCE AND CAN GAIN THE MOST FROM THE PROGRAM.

WE ALSO STRONGLY ADVISE YOU TO RUN THE PROGRAM IN THE ONE TERM, AND AVOID SPLITTING IT ACROSS DIFFERENT TERMS, WHICH BREAKS THE CONTINUITY OF THE PROGRAM AND REDUCES ITS IMPACT.

The key ideas in the STELR Chemistry Curriculum

The STELR Chemistry Curriculum focuses on the following key ideas:

- Global warming and climate change
- Acids and bases and pH
- Ocean acidification
- Energy transformations and energy transfers
- Fuels – fossil fuels and biofuels, how they are produced, their classification as renewable or non-renewable, and their advantages and disadvantages
- Classes of chemical reactions – acid-base, as well as combustion and fermentation and other key reactions such as photosynthesis and cellular respiration
- The conservation of energy, useful energy and 'wasted' energy
- Energy efficiency
- How hydroelectric and coal-fired power stations work; their advantages and disadvantages.
- How scientists work – designing experiments
- Interpreting and using graphs in science

The practical activities

Overview

To a large extent the inquiry-based learning approach consists of first-hand practical investigations of a range of inquiry questions. These are in the form of directed investigations and guided student-designed investigations. Most are small group investigations; some are class experiments.

Safety!

Student practical investigations in the chemistry component of this program have been designed in such a way that they pose little or virtually no risk, as they mostly involve foods, mild domestic cleaning products, and salt water.

The directed practical activities

Purpose

Overall, the set of directed practical investigations has been designed to:

- Model the way scientists work by providing experience in conducting hands-on investigations that are designed to explore one or more inquiry questions. This includes risk management, prediction and analysis of results, recording and displaying results effectively, identifying sources of error and evaluating their investigation.
- Reflect the principles of inquiry-based learning, by providing first-hand experiences through which new concepts are introduced and a greater depth of understanding of important concepts can be developed.
- Introduce or reinforce practical laboratory skills, including the use of the STELR equipment, so students can develop competence and confidence.
- Develop good time-management, organisational and communication skills.
- Provide a strong background to enable students to design and perform their own relevant investigations.
- Foster the ability to work in collaboration and co-operation with others, by working in small groups and with the whole class.
- Foster important values, including open-mindedness and ethical practice.

Advice on running the directed practical activities

Teachers are advised to:

1 Vary the way in which the students record and process their experimental data. Teachers are encouraged to give students the opportunity to use spreadsheets and graphing software for at least one of the investigations.

2 Trial each investigation before class, so that they know exactly what to expect and can predict problems that might arise in class. This will help streamline the process, reduce risk and avoid embarrassment.

3 Always ensure that the students are clear about what to do and how to set up and use the equipment risk and that they perform the risk assessment first. Then monitor what they do throughout the investigation very closely to ensure they comply with all expectations.

4 Always ensure enough time is left at the end of each investigation (approximately 15 minutes) for a productive class discussion, in which student findings are compared, analyse, and evaluated and explanations are proposed, and further inquiry questions or improvements to the experimental design are suggested.

The student-designed practical activities

Purpose

Overall, the set of student-designed practical investigations has been designed to:

- Model the way scientists work by providing experience in designing and conducting hands-on investigations to explore the answer to one or more inquiry questions. This includes developing a hypothesis, identifying variables, designing fair tests, taking accurate measurements, identifying and managing risks, predicting and analysing results, recording and displaying results effectively, identifying sources of error and evaluating their investigation.

- Reflect the principles of inquiry-based learning, by providing first-hand experiences through which new concepts are introduced and a greater depth of understanding of important concepts is developed.

- Further train students in practical laboratory skills so they can develop greater competence and confidence.

- Develop good time-management, organisational and communication skills.

- Foster the ability to work in collaboration and co-operation with others, through working in small groups and with the whole class.

- Foster important values, including open-mindedness and ethical practice.

Advice on running the student-designed practical activities

Teachers are advised to:

1 Encourage the students to make full use of appropriate ICT to record and process their experimental data. This includes the use of spreadsheets and graphing software.

2 Avoid advising the student on how to design and perform their own investigations, as they need to be given the freedom to be inventive and to use their own creativity and initiative, and to make their own mistakes. They will learn from their mistakes as well as from their successes. The chemicals they will use pose virtually no risk.

Introducing a new key topic

Overview

For each new topic, a selection of some of the big ideas behind the topic is provided in the form of questions on the cover sheet for the topic in the student booklet. These are intended to stimulate discussion and to encourage students to pose some of their own big questions.

A range of multiple choice items on chemistry topics will be available in the teacher portal on the STELR website for any teachers who wish to conduct a pre-test on each new topic.

A range of ideas for introductory activities is provided in this resource, as part of the provisions for each key topic. Many of these activities are based on the teaching strategy **'Interview about instances'**. In this technique, some stimulus material, in such forms as a series of images, a DVD or demonstrations, is presented to the students and questions about the stimulus material are posed.

Background information on most key topics is also provided in this resource, to assist the teacher.

Purpose

The introductory activities are designed to:

- Introduce each new area of the curriculum in a way that will involve all students and stimulate their interest.
- Enable the teacher to gauge what the students already know and understand of the concepts involved and any alternative conceptions they have, to assist in the planning of future lessons.
- Clarify or reinforce concepts or to understand new concepts.
- Promote effective communication and student confidence.

Advice on running the introductory activities

For some key topics, more than one idea for an introductory activity is provided. Teachers are advised to:

1 Select the activity that will best suit their students and time restrictions.

2 Use a variety of styles of introductory activities over the program, so that students remain engaged.

3 The role of the teacher should be one of the questioner rather than the transmitter of answers. The teacher may find there is considerable variation in student thinking about the issues or concepts presented, or that alternative conceptions are presented.

Incursions and excursions to places such as hydroelectric, gas-fired, coal-fired or geothermal power stations or plants where biofuels or fossil fuels are researched and/or produced can also play a significant role in stimulating student interest and are highly recommended, as they can help make the program more exciting and more meaningful for the students. (See the feedback from a teacher who took the students on an excursion to a wind farm on pages 16-17.)

The student activity sheets

Overview

The student activity sheets in the student booklet offer students a range of information, experiences and tasks to enable them to develop key science understandings and thinking skills and to give them opportunities to explore issues that are relevant and meaningful to them, and possible future careers.

Advice and suggested answers are provided for each activity sheet, later in this resource.

NB It is assumed that the teacher will support the activity sheets with further material, including web links and some of the optional introductory activities.

Purpose

Overall, the set of student activity sheets is designed to:

- Enable the students to build up or extend and then apply their science skills, knowledge and understanding.
- Prepare students for a particular practical investigation, including essential background information and sample calculations.
- Enable the students to develop insights into science as a human endeavour, and to challenge their thinking about important contemporary issues and future pathways and careers.
- Encourage students to undertake further research into a fascinating aspect of a topic.
- Link students to other resources.

Advice on using the student activity sheets

Teachers are advised to:

1 Ensure that the activity sheets are woven around the practical investigations, so that students are well prepared for the investigations and can then apply what they have discovered through their investigations.

2 Give students the opportunity to discuss and compare their responses to any set questions in small groups or as a class. This will help build up their communication skills and help clarify concepts. It also will provide the teacher with an insight into the student's understandings and any alternative conceptions they may hold. This will also be a chance to encourage the students to raise their own questions.

The use of ICT in the STELR Chemistry Curriculum

Overview

Students should have the opportunity to use a range of technology, to conduct web research, to record process experimental results using spreadsheets and graphing programs and other technology such as video recorders and digital cameras, and to present their findings using a range of technologies.

Advice

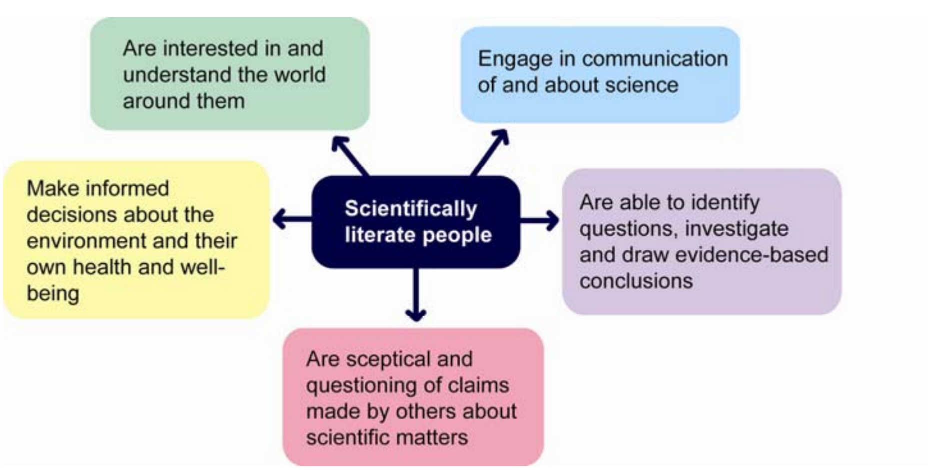
Teachers are advised to provide as many opportunities as possible for students to use the range of ICT available within the school.

This should include extensive use of the STELR website.

Teaching scientific literacy

Overview

The STELR Project prepares students to engage with science ideas in their work and their lives generally, as citizens. Leonie Rennie (2006) described scientifically literate citizens to have the following attributes:



The scientific literacy focus is strongly represented the in the STELR Chemistry Curriculum as follows:

- Thinking and working scientifically are major aspects, with a particular emphasis on evidence-based thinking.
- Engaging with the science-technology-society interface is emphasised.
- Social, ethical and economic issues are incorporated into the learning.
- The nature of science and its contemporary setting is strongly represented.
- Students are supported to develop a critical, objective, committed stance.

Advice

Teachers are strongly advised to use every opportunity within the program to:

1 Foster the students' ability to think and work scientifically, through class discussions, activities and practical investigations.

2 Encourage evidence-based critical thinking about the issues of global warming and climate change and society's and their own use of energy resources, including an examination of statements and information disseminated in the public arena.

3 Foster an appreciation of the way science and technology can be used to identify and address global issues.

Assessment

Overview

It is expected that teachers will choose modes of internal assessment that suit the school and their students. Assessment advice and an assessment rubric proforma for assessment of science inquiry skills are included in this resource should teachers wish to use these for their assessment of students (pages 142-144).These are provided in Word format so teachers can adapt them to their needs.

In addition, multiple choice item banks will be provided on the STELR website, which teachers will be able to access through the teacher portal. Teachers will be able to download these tests and select any questions they wish to use for pre-tests or post-tests.

THE STELR CHEMISTRY CURRICULUM

SAMPLE TEACHING TIMETABLE FOR THE CHEMISTRY CURRICULUM

OVERVIEW

The sample teaching timetable provided on the next page:

- **Is based on sessions that are 45-60 minutes long.**
- **Includes a column for homework, so that students can receive a copy of the timetable as well.**
- **Assumes that formal assessment will be centred on practical work. Tests are not included.**
- **Is provided electronically in Word format so the teacher can modify it to suit the school's timetabling arrangements and the program the school decides to run, and can insert appropriate dates. The timetable can then be submitted as part of the set of curriculum planning documents for that year level required by the school.**

Note: The electronic version of the sample teaching timetable can be downloaded from the teacher portal at: www.stelr.org.au.

How to develop a timetable that is tailored to the school

1 Download the electronic copy of the sample timetable. Since the table is in Word format, you can extend the length of rows and delete rows. You also can change column headings and widths. You may even wish to delete one of the first two columns.

2 Delete any activities that you do not plan to run, and insert any other activities you do plan to include, such as an excursion or one or more tests. This means you may need to delete rows and/or insert new rows.

3 Insert the weeks or dates of the sessions in the first column of the timetable, to fit in with the school's timetabling arrangements. Highlight any 'doubles' in some way.

4 Adapt the number of activities per session to suit your students and the actual length of the sessions at the school, including allowing for sessions that are 'doubles'.

SAMPLE TIMETABLE FOR THE STELR CHEMISTRY CURRICULUM

Note: Optional activities are shaded orange.

WEEK	SESSION	TOPIC(S)	CLASS ACTIVITIES	STUDENT BOOK PAGES	HOMEWORK
	1	**GLOBAL WARMING**	Introductory activity and discussion on global warming, greenhouse gases, the enhanced greenhouse effect, climate change and sea-level rising	1-14	Answer the questions on Student Activity Sheet 1: Global warming and climate change
	2	**Sea level rising**	Modelling activity: Sea-level rising Literacy exercise: What is happening in the Maldives?		Complete the questions set in these two activities
	3	**GLOBAL WARMING**	Discussion on the carbon cycle and ocean acidification	15-19	Answer the questions on Student Activity Sheet 3: The carbon cycle
	4	**GLOBAL WARMING**	Practical Activity 1: What's happening in our oceans?	20-26	
	5	**ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS**	Check the progress of the solutions in Part C of Practical Investigation 1. Introductory activity and discussion on energy transformations and energy transfers	27-32	
	6	**ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS**	Check the progress of the solutions in Part C of Practical Activity 1. Practical Activity 2: What energy transformations and energy transfers are happening here?	33-42	Answer the questions on Student Activity Sheet 6: How do hydroelectric power stations work?
	7	**FUELS**	Final check on the progress of the solutions in Part C of Practical Activity 1. Introductory activity and discussion on fossil fuels and biofuels. Teacher demonstration on producing biodiesel	43-52	Complete the report on Practical Activity 1
	8	**FUELS**	Check on biodiesel formation; testing the product Practical Activity 3: Producing bioethanol	53-57	Answer the questions on Student Activity Sheet 7: What kind of fuels are there?

	9	**FUELS**	Check the progress of the solutions in Practical Investigation 3. Introductory activity and discussion on families of chemical reactions	66-72	Answer the questions on Student Activity Sheet 8: Families of chemical reactions
	10	**PURIFYING FUELS BY DISTILLATION**	Final check the progress of the solutions in Practical Activity 3. Practical Activity 4: Distilling an ethanol mixture	58-65	Complete the report on Practical Activity 3.
	11	**THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY**	Introductory activity and discussion on the conservation of energy and energy efficiency	73-77	Complete the report on Practical Activity 4
	12	**THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY**	Practical Activity 5: Which fuel produces the most energy?	78-82	Complete the report on Practical Activity 5
	13	**THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY**	Coal-fired power stations	83-88	Answer the questions on Student Activity Sheet 10: Coal-fired power stations – the inside story
	14	**HOW SCIENTISTS WORK**	Discussion on how scientists work Start planning Practical Investigation 6, using the investigation planner	89-96	Answer the questions on Student Activity Sheet 11: How do scientists work?
	15	**HOW SCIENTISTS WORK**	Practical Activity 6: Lemon power	97-98	Complete the report on Practical Activity 6
	16	**HOW SCIENTISTS WORK**	Discussion on how scientists use graphs	99-107	Answer the questions on Student Activity Sheet 13: How do scientists use graphs?
	17	**HOW SCIENTISTS WORK**	Practical Activity 7: What conditions make a battery deliver the biggest voltage?	108-110	Complete the report on Practical Activity 7

ALTERNATIVE

STELR

CURRICULA

THE FOLLOWING CHARTS OUTLINE

THE

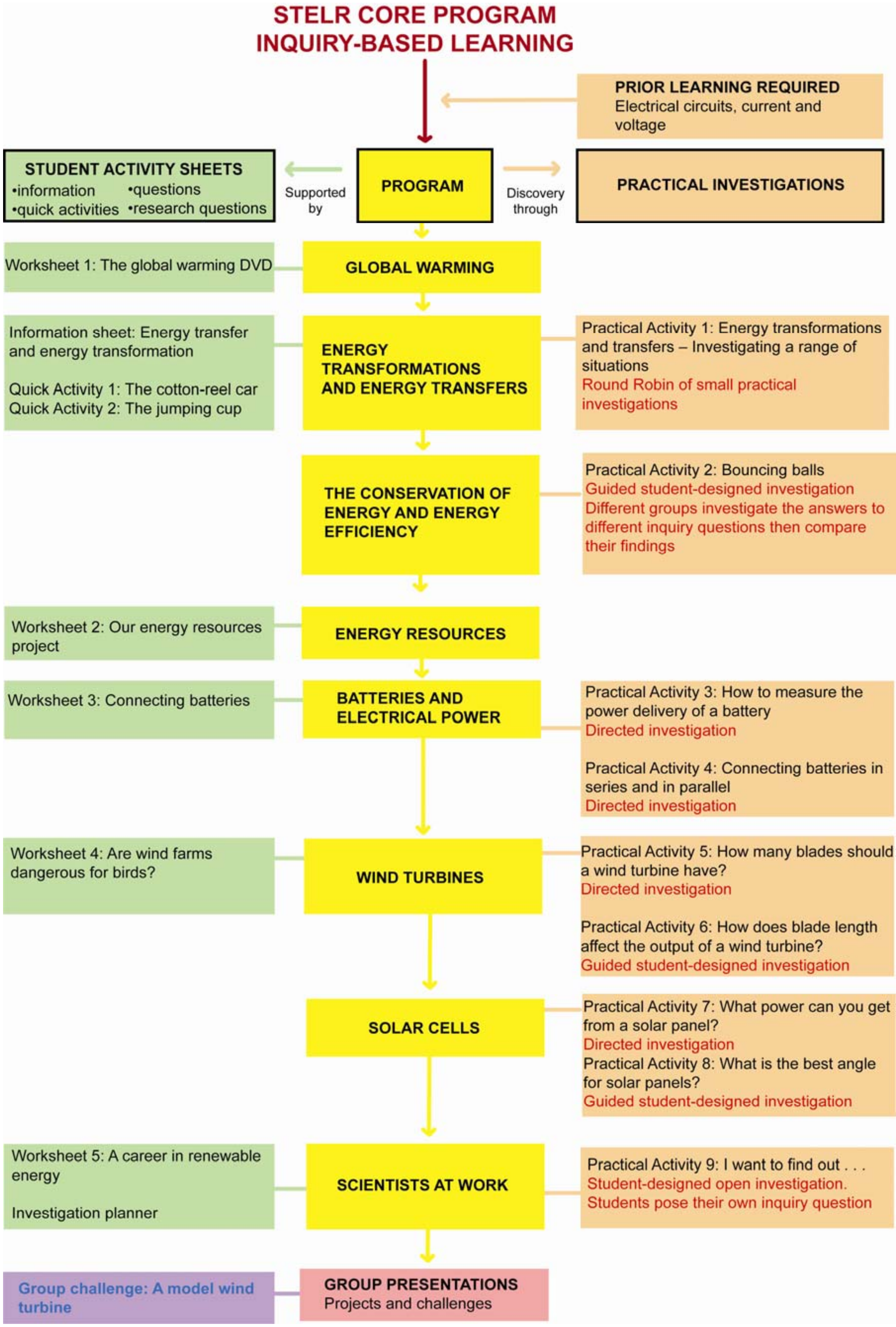
STELR CORE CURRICULUM

AND THE

STELR INTEGRATED CURRICULUM

AND HOW THEY MATCH THE

AUSTRALIAN CURRICULUM: SCIENCE


STELR CORE PROGRAM
INQUIRY-BASED LEARNING
PRIOR LEARNING REQUIRED
Electrical circuits, current and voltage
STUDENT ACTIVITY SHEETS
•information •questions
•quick activities •research questions
Supported by
PROGRAM
Discovery through
PRACTICAL INVESTIGATIONS
Worksheet 1: The global warming DVD
GLOBAL WARMING
Information sheet: Energy transfer and energy transformation
Quick Activity 1: The cotton-reel car
Quick Activity 2: The jumping cup
ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS
Practical Activity 1: Energy transformations and transfers – Investigating a range of situations
Round Robin of small practical investigations
THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY
Practical Activity 2: Bouncing balls
Guided student-designed investigation
Different groups investigate the answers to different inquiry questions then compare their findings
Worksheet 2: Our energy resources project
ENERGY RESOURCES
Worksheet 3: Connecting batteries
BATTERIES AND ELECTRICAL POWER
Practical Activity 3: How to measure the power delivery of a battery
Directed investigation
Practical Activity 4: Connecting batteries in series and in parallel
Directed investigation
Worksheet 4: Are wind farms dangerous for birds?
WIND TURBINES
Practical Activity 5: How many blades should a wind turbine have?
Directed investigation
Practical Activity 6: How does blade length affect the output of a wind turbine?
Guided student-designed investigation
SOLAR CELLS
Practical Activity 7: What power can you get from a solar panel?
Directed investigation
Practical Activity 8: What is the best angle for solar panels?
Guided student-designed investigation
Worksheet 5: A career in renewable energy
Investigation planner
SCIENTISTS AT WORK
Practical Activity 9: I want to find out . . .
Student-designed open investigation.
Students pose their own inquiry question
Group challenge: A model wind turbine
GROUP PRESENTATIONS
Projects and challenges

THE STELR CORE CURRICULUM AND THE AUSTRALIAN CURRICULUM: SCIENCE

SCIENCE AS A HUMAN ENDEAVOUR

NATURE AND DEVELOPMENT OF SCIENCE

- Scientific understanding is contestable and is refined over time through a process of review by the scientific community.

USE AND INFLUENCE OF SCIENCE

Evidence-based critical thinking

- People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions

Solving contemporary issues

- Science understandings influence the development of practices in areas of human activity such as marine and terrestrial resource management
- Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations
- The values and needs of contemporary society can influence the focus of scientific research

Career opportunities

- People use understanding and skills from across the disciplines of science in their occupations
- Advances in sciences and emerging sciences and technologies can significantly affect peoples' lives, including generating new career opportunities

SCIENCE UNDERSTANDING

PHYSICAL SCIENCES

- Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems
- Forms of energy can be transferred in a variety of ways through different mediums
- Energy conservation in a system can be explained by describing energy transfers and transformations
- Earth's gravity pulls objects towards the centre of the Earth

EARTH AND SPACE SCIENCES

- Some of the Earth's resources are renewable, but others are non-renewable
- The theory of plate tectonics explains global patterns of geological activity and continental movement (*Context: Geothermal power stations)

CHEMICAL SCIENCES

- All matter is made of atoms, which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (*Context: Geothermal power stations)

SCIENCE INQUIRY SKILLS

Questioning and predicting

- Formulate questions or hypotheses that can be investigated scientifically

Planning and conducting

- Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods
- Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data

Processing and analysing data and information

- Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence

Evaluating

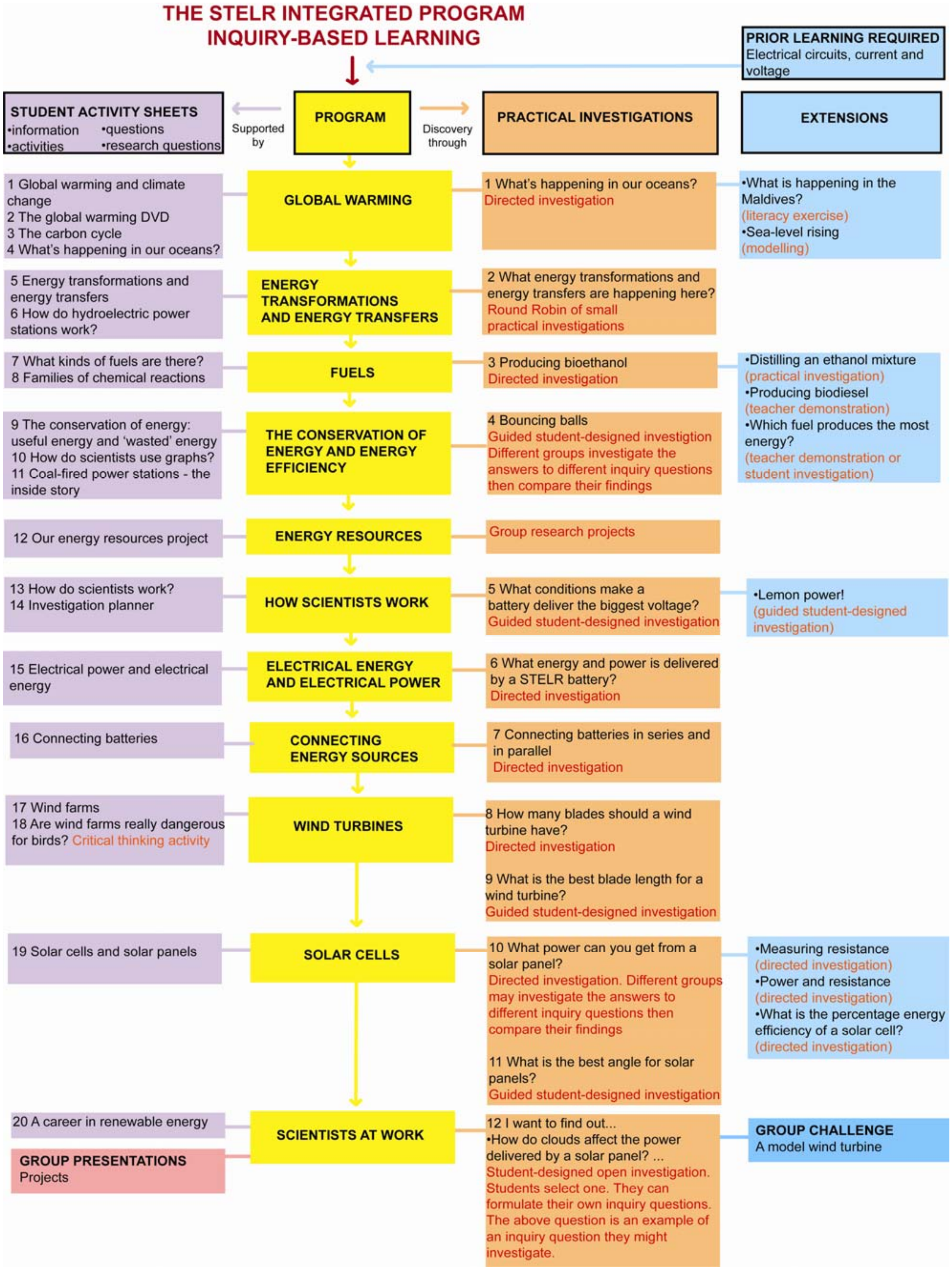
- Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data

Communicating

- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations

GROUP PRESENTATIONS

Communicating findings using scientific language and meaningful representations and making evidence-based arguments



THE STELR INTEGRATED PROGRAM
INQUIRY-BASED LEARNING
PRIOR LEARNING REQUIRED
Electrical circuits, current and voltage
STUDENT ACTIVITY SHEETS
•information •questions
•activities •research questions
Supported by
PROGRAM
Discovery through
PRACTICAL INVESTIGATIONS
EXTENSIONS
1 Global warming and climate change
2 The global warming DVD
3 The carbon cycle
4 What's happening in our oceans?
GLOBAL WARMING
1 What's happening in our oceans?
Directed investigation
•What is happening in the Maldives?
(literacy exercise)
•Sea-level rising
(modelling)
5 Energy transformations and energy transfers
6 How do hydroelectric power stations work?
ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS
2 What energy transformations and energy transfers are happening here?
Round Robin of small practical investigations
7 What kinds of fuels are there?
8 Families of chemical reactions
FUELS
3 Producing bioethanol
Directed investigation
•Distilling an ethanol mixture
(practical investigation)
•Producing biodiesel
(teacher demonstration)
•Which fuel produces the most energy?
(teacher demonstration or student investigation)
9 The conservation of energy: useful energy and 'wasted' energy
10 How do scientists use graphs?
11 Coal-fired power stations - the inside story
THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY
4 Bouncing balls
Guided student-designed investigation
Different groups investigate the answers to different inquiry questions then compare their findings
12 Our energy resources project
ENERGY RESOURCES
Group research projects
13 How do scientists work?
14 Investigation planner
HOW SCIENTISTS WORK
5 What conditions make a battery deliver the biggest voltage?
Guided student-designed investigation
•Lemon power!
(guided student-designed investigation)
15 Electrical power and electrical energy
ELECTRICAL ENERGY AND ELECTRICAL POWER
6 What energy and power is delivered by a STELR battery?
Directed investigation
16 Connecting batteries
CONNECTING ENERGY SOURCES
7 Connecting batteries in series and in parallel
Directed investigation
17 Wind farms
18 Are wind farms really dangerous for birds? Critical thinking activity
WIND TURBINES
8 How many blades should a wind turbine have?
Directed investigation
9 What is the best blade length for a wind turbine?
Guided student-designed investigation
19 Solar cells and solar panels
SOLAR CELLS
10 What power can you get from a solar panel?
Directed investigation. Different groups may investigate the answers to different inquiry questions then compare their findings
11 What is the best angle for solar panels?
Guided student-designed investigation
•Measuring resistance
(directed investigation)
•Power and resistance
(directed investigation)
•What is the percentage energy efficiency of a solar cell?
(directed investigation)
20 A career in renewable energy
GROUP PRESENTATIONS
Projects
SCIENTISTS AT WORK
12 I want to find out...
•How do clouds affect the power delivered by a solar panel? ...
Student-designed open investigation. Students select one. They can formulate their own inquiry questions. The above question is an example of an inquiry question they might investigate.
GROUP CHALLENGE
A model wind turbine

THE STELR INTEGRATED CURRICULUM AND THE AUSTRALIAN CURRICULUM: SCIENCE

SCIENCE AS A HUMAN ENDEAVOUR

NATURE AND DEVELOPMENT OF SCIENCE

- Scientific understanding is contestable and is refined over time through a process of review by the scientific community.

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- Science understandings influence the development of practices in areas of human activity such as marine and terrestrial resource management
- Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations
- The values and needs of contemporary society can influence the focus of scientific research

Career opportunities
- People use understanding and skills from across the disciplines of science in their occupations
- Advances in sciences and emerging sciences and technologies can significantly affect peoples' lives, including generating new career opportunities

SCIENCE UNDERSTANDING

CHEMICAL SCIENCES

- Chemical change involves substances reacting to form new substances
- All matter is made of atoms, which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (*Context: Geothermal power stations)
- Chemical reactions involve rearranging atoms to form new substances
- Chemical reactions, including combustion and the reactions of acids, are important in both living and non-living systems, and involve energy transfer
- Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere.

PHYSICAL SCIENCES

- Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems
- Forms of energy can be transferred in a variety of ways through different mediums
- Energy conservation in a system can be explained by describing energy transfers and transformations
- Earth's gravity pulls objects towards the centre of the Earth

EARTH AND SPACE SCIENCES

- Some of the Earth's resources are renewable, but others are non-renewable
- The theory of plate tectonics explains global patterns of geological activity and continental movement (*Context: Geothermal power stations)

BIOLOGICAL SCIENCES

- Matter and energy flow through ecosystems

SCIENCE INQUIRY SKILLS

Questioning and predicting

- Formulate questions or hypotheses that can be investigated scientifically

Planning and conducting

- Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods
- Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data

Processing and analysing data and information

- Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence

Evaluating

- Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data

Communicating

- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations

GROUP PRESENTATIONS

Communicating findings using scientific language and meaningful representations and making evidence-based arguments

TEACHER

SUPPORT

DOCUMENTS

FOR THE

STELR INTEGRATED CURRICULUM

STUDENT

BOOKLET

INCLUDING:

BACKGROUND INFORMATION FOR THE TEACHER

HOW TO RUN THE STUDENT PRACTICAL ACTIVITIES

IDEAS FOR OPTIONAL INTRODUCTORY ACTIVITIES FOR NEW TOPICS

OPTIONAL EXTENSION ACTIVITIES AND HOW TO RUN THEM

SUGGESTED ANSWERS TO QUESTIONS

TOPIC: GLOBAL WARMING

INTRODUCTION

ADVICE

The teacher may wish to start this topic with one or more of the following:

- **The global warming DVD activity**
- **One of the optional introductory activities outlined on page 47.**
- **Asking students what they think are the answers to the big ideas listed on page 1 of the student booklet**
- **Eliciting from the students their own big questions on this issue and what they think the answers are.**

A worthwhile introduction to or follow-up from learning about sea-level rising is provided in the optional short practical activities on pages 48-50. A teacher guide to these activities is also provided (pages 51-53). This can be followed up by the optional literacy exercise on this issue (pages 57-59). Possible solutions to this exercise are provided on page 60.

Whatever activities are chosen, the following must be borne in mind throughout this topic:

1 Some or all the students will have one or more alternative conceptions (or misconceptions) on this issue. Typical alternative conceptions are listed on pages 45-46. The teacher should be aware of these possible conceptions before starting this topic.

2 Global warming is an issue that concerns many students. It can be a very emotive issue for some, especially if they are very fearful of the future or are opposed to the actions or lack of action of particular countries or ethnic groups. It therefore needs to be handled sensitively. Insist that the students treat those who have other viewpoints with respect.

3 Often students of this age find it hard to separate cause and effect, especially if they have been protected time and again from the consequences of their own actions. (Some concerned educators refer to these students as the 'bubble wrap' generation.)

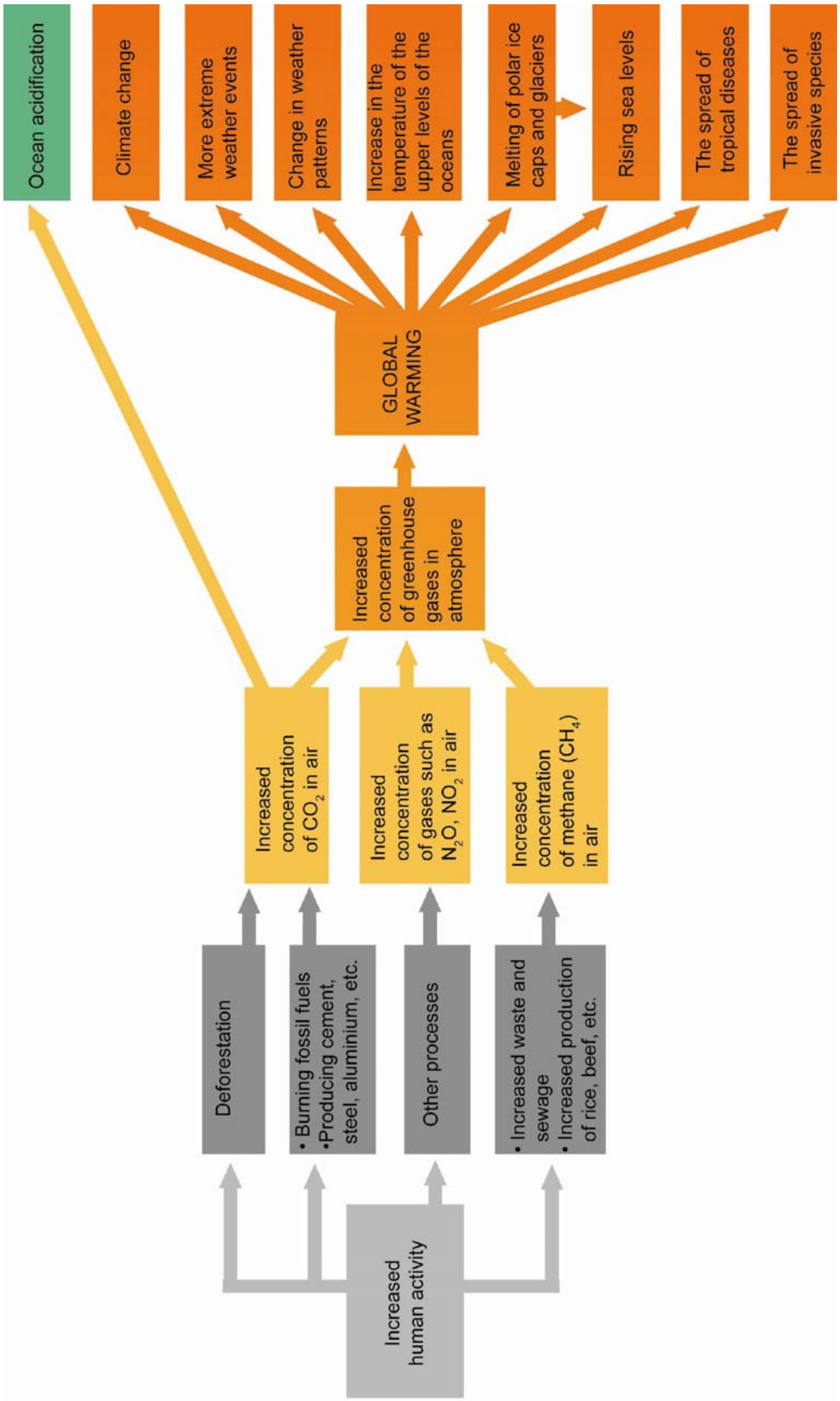
The flow chart on the next page may be useful for the teacher in helping the students sort out for themselves the flow-on effects of recent human activity, principally driven by the population explosion and unsustainable lifestyles. In addition to the completed flow chart, a 'blank' flow chart (print version only) is provided in case the teacher would like to use it to ask the students deduce the missing contents of some or all of the boxes, at some stage during this topic. An electronic copy will also be provided on the STELR website. This may be before or after seeing the completed version.

Note:

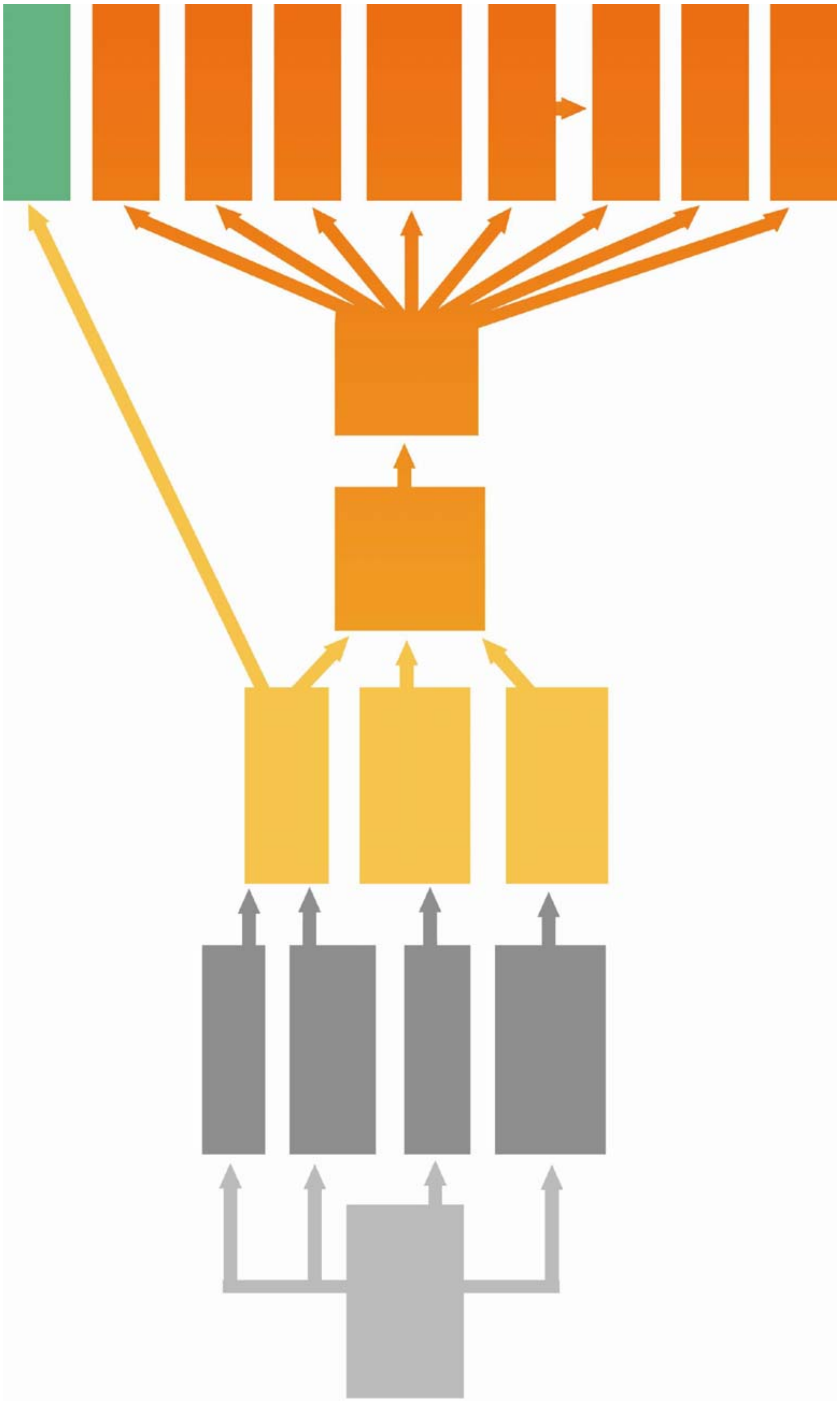
1 Students can add to the flow chart as well. For example, they could be asked to show the flow-on consequences of sea-level rising, more extreme weather events, and so on.

2 The teacher may prefer to have the students design and discuss their own flow chart. This would reveal their level of understanding of the causes and consequences of global warming.

A flow chart summarising the causes and consequences of global warming



The blank version of the flow chart on the cause and consequences of global warming:



TOPIC: GLOBAL WARMING

GLOBAL WARMING – ALTERNATIVE CONCEPTIONS

SYNOPSIS

Studies into student understanding of global warming, greenhouse effect and climate change have found that students across all levels of schooling have a general understanding that the greenhouse effect will cause changes in weather patterns and global warming. However, such studies also point out that there are several alternative conceptions that students, as well as the general public, hold about these areas of science.

COMMON ALTERNATIVE CONCEPTIONS

A common alternative conception among people of all ages is:

- Ozone layer depletion is a major cause of global warming. The hole in the ozone layer allows more radiation in heating up the Earth leading to global warming.

People often conceptualise the two phenomena of ozone depletion and greenhouse effect as being one. Therefore, the causes, impact on the environment and solutions to these quite separate phenomena are seen as the same. This leads to such alternative conceptions as:

- If the holes in the ozone layer get larger:
  - The greenhouse effect will get worse too.
  - There will be more flooding in the world.

- If the greenhouse effect gets larger:
  - More people will get skin cancer.

- Carbon dioxide and methane layer traps UV radiation coming in from the ozone holes.

- Carbon dioxide causes global warming exclusively by destroying the ozone layer.

- Power stations and/or cars damage the ozone layer.

- Carbon dioxide destroys the ozone layer.

- Air pollution ruins the ozone layer, to the extent that the Sun's rays melt the poles and the sea level rises.

- People can recycle and repair the ozone layer by not driving cars.

- The greenhouse effect is made worse because of:
  - Acid in the rain.
  - Holes in the ozone layer
  - Radioactive waste from nuclear power stations.

- The holes in the ozone layer are made worse:
  - Because the rainforests are being destroyed.
  - By fumes from car exhausts.
  - Gases used for making some plastics.
  - Radioactivity from nuclear power stations.
  - By volcanoes blowing up.

Students don't distinguish between the natural greenhouse effect and the enhanced greenhouse effect, leading them to think that the greenhouse effect is bad for the environment. The natural greenhouse effect is essential for life as we know it. Without the natural greenhouse effect the Earth would be more than 30 degrees cooler.

OTHER ALTERNATIVE CONCEPTIONS ABOUT THE GREENHOUSE EFFECT

1 The greenhouse effect is a kind of atmospheric pollution.

2 The greenhouse effect is heat that does not come out or bounces back to the earth because of an implicit barrier, which is formed by diverse substances like carbon dioxide, in some cases 'greenhouse gases'.

3 If the greenhouse effect gets bigger:

- More people will die of heart attacks.
- More people will get food poisoning.
- Some of our tap water will become unsafe to drink.
- There will be more earthquakes.

4The greenhouse effect can be made smaller:

- By eating healthy foods.
- By keeping beaches clean.
- By protecting rare plants and animals.
- By reducing starvation in the world.
- By reducing the number of nuclear bombs in the world.
- By using unleaded petrol.

SOME REPRESENTATIVE RESEARCH STUDIES

Anderson, B. & Wallin, A. (2000) *Students' understanding of the greenhouse effect, the societal consequences of reducing CO2 emissions and the problem of ozone layer depletion* Journal of Research in Science Teaching, 37(10), 1096-1111

Bord, R., Robert E. O'Connor, R. & Fisher, A. (2000) *In what sense does the public need to understand global climate change?* Public Understanding of Science, 9, 205-218

Boyes, E. & Stranisstreet, M. (1993) *The 'greenhouse effect': children's perceptions of causes, consequences and cures* International Journal of Science Education, 15(5), 531 - 552

Bulkeley, H. (2000) *Common knowledge? Public understanding of climate change in Newcastle, Australia*. Public Understanding of Science. 9, 313–333

Daniel, B., Stanisstreet, M. & Boyes, E. (2004) *How can we best reduce global warming? School students' ideas and misconceptions* International Journal of Environmental Studies, 61(2), pp. 211–222

Papadimitriou, V. (2004) *Prospective Primary Teachers' Understanding of Climate Change, Greenhouse Effect, and Ozone Layer Depletion*.Journal of Science Education and Technology, Vol. 13, No. 2

Rye, A. J. (1997) *An investigation of middle school students' alternative conceptions of global warming* International Journal of Science Education, 19 (5), 527 - 551

TOPIC: GLOBAL WARMING

IDEAS FOR INTRODUCTORY ACTIVITIES ON GLOBAL WARMING

SYNOPSIS

These are additional ideas that may be tried on top of, or in place of, the Global Warming DVD , and/or the simulations of sea-level rising. The first works very well, and ensures all the students become actively involved. For this reason it works better than a formal debate, in which most of the class would be spectators only. The second can be very worthwhile, since it can alert students to strong bias shown by some parts of the media. However, it may take time unless the students themselves are given the responsibility of collecting articles or record television programs.

Note: See the general advice about introductory activities on pages 29-30.

OPTIONAL INTRODUCTORY ACTIVITY 1: TAKING A POSITION

This is a very lively form of debate that requires everyone to be involved.

Designate different parts of the room for different viewpoints on climate change. These viewpoints can be elicited from the students (their own views or the views they have heard expressed in their community and/or in the media).

Ask the students to move to the corner that best matches their viewpoint. (They cannot 'sit on the fence'.) Tell them they will need to defend this viewpoint.

Give each group a few minutes to produce a list of arguments and to elect a spokesperson to argue their case. Each spokesperson has two minutes to speak.

After the speakers have finished, have the class analyse their arguments.

• Were these arguments based on reliable evidence?

•Where did their ideas come from?

Then give the students the opportunity to move to another part of the room as a result.

Advice for the classroom

Do not put students who have problems in verbalising their thoughts in an embarrassing position in this activity. Maintain a positive and encouraging atmosphere.

OPTIONAL INTRODUCTORY ACTIVITY 2: MEDIA WATCH

Have the students collect newspaper cuttings about global warming, including opinion pieces, and put these on display. After the STELR curriculum is complete, have the class analyse the way the media has handled the issue over that time.

Advice

This can be time-consuming to maintain, and hence impractical in many schools.

But if there is a huge event occurring that is receiving a large amount of media attention, like Cyclone Yasi and the 2011 Queensland floods, teachers should capitalise on if at all possible, even if the time over which media reports are gathered is restricted to a day or two. It is important for students to see how relevant science is to their daily lives.

TOPIC: GLOBAL WARMING

EXTENSION: MODELLING ACTIVITY FOR STUDENTS: SEA-LEVEL RISING

Introduction

Activity 1: Do our sea levels really rise if the temperature of the water increases?

In this activity you will seal cold tap water in a container and have a tube inserted into it, as shown in Figure 1. The tube has a very fine hole bored down its centre. The water will be dyed with food colouring so you can see it better.

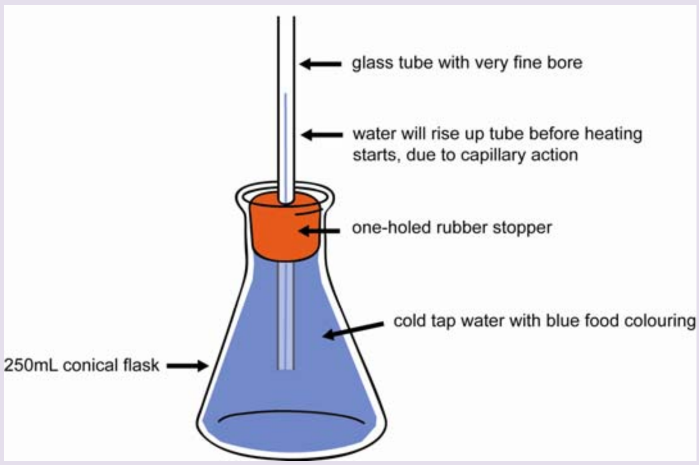


Figure 1 Cold tap water containing blue food colouring, sealed in a container

Before you warm the water, some will naturally rise up in the tube, as shown in Figure 1. This process is called **capillary action**, and is the process by which groundwater moves up inside plants. What do you think will happen to the level of water in this capillary tube when the water is warmed? Why do you think this?

Activity 2: What happens to the sea level when ice from glaciers, and so on, melts into the sea?

In this activity, you are going to set up a model of some coastline that has ice on it, and a nearby 'island'. You will place blocks of ice on the 'land', as shown in Figure 2, then warm the ice up. What do you think will happen? Why do you think this?

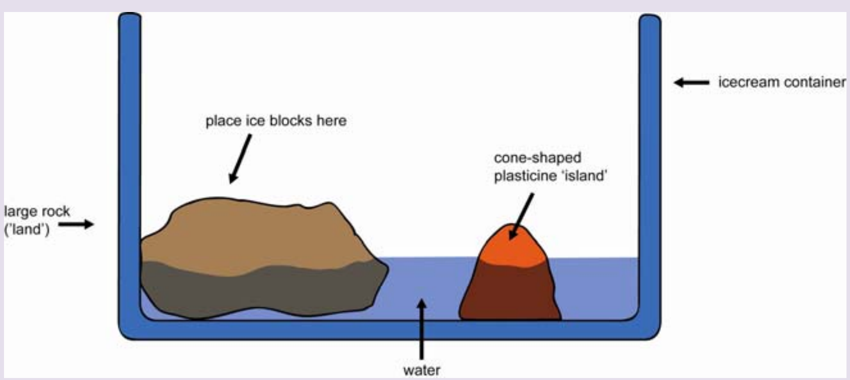


Figure 2 What happens when ice melts into the sea?

You need:

Activity 1
• 250 mL tap water in a beaker, coloured with dark blue food colouring
• 250 mL conical flask
• Fine-bored glass capillary tube inserted through a one-holed rubber stopper
• 2 x hot lamps
• Plastic tray (optional)

Activity 2
• 250 mL tap water in a beaker, coloured with dark blue food colouring
• Ice-cream container
• Rock
• Plasticine
• 2 x hot lamps
• IR thermometer or temperature sensor (optional)
• Plastic tray (optional)

Risk assessment

Look at the equipment shown in Figures 1 and 2. What do you think could go wrong? Identify two problems that might arise and state how you could avoid them.

____

____

Activity 1: Do our sea levels really rise if the temperature of the water increases?

What to do

Step	What to do
1	Completely fill the conical flask with the coloured tap water.
2	Gently holding the capillary tube that is just above the rubber stopper in one hand, and the conical flask in the other hand, insert the rubber stopper into the mouth of the flask, as shown in Figure 1. What do you see happening inside the tube?
3	Wait until the level of water in the tube remains steady, then direct two hot lamps onto the water in the flask to heat it. What happens to the level of water in the tube? Is this what you predicted?
4	When you have observed the effect of the lamps on the water level, turn them off. Pack up the equipment as directed by your teacher.

What do you think?

Discuss these questions with your class. What other questions do you have?

1 Did the water expand when it was heated? How did you tell?

2 What might this have to do with global warming?

3 Why do you think this apparatus used for the simulation rather than simply heating the flask over a Bunsen burner?

4 Why do you think a tube with a fine bore used? What might have happened if a wider bore was used instead?

5 Do other materials expand on heating? Give an example. What problems can this expansion cause?

Activity 2: What happens to the sea level when ice from glaciers, and so on, melts into the sea?

What to do

Step	What to do
1	Set up a shallow ice-cream container with the contents shown in Figure 2. The plasticine 'island' should be cone-shaped.
2	Add about 10 ice blocks to the 'land'. (You may wish to take the water temperature just before you do.
3	Shine the hot lamps onto the ice and water, and observe what occurs. (You may wish to track the water temperature during this heating process.) What happens as the ice and water warm up? Is this what you predicted?
4	When you have observed all the changes, turn the lamps off. Pack up the equipment as directed by your teacher.

What do you think?

Discuss these questions with your class. What other questions do you have?

1 Can you explain the changes you saw?

2 What implications does this have for small islands and our coasts if global warming is not acted on?

3 Why do you think island nations were so vocal at the Copenhagen Summit?

4 Do you think that modeling like this is helpful? Discuss.

5 What do you think are the problems with setting up small models like this? Are the conditions close to the real situation, or very different and unrealistic?

TOPIC: GLOBAL WARMING

RUNNING EXTENSION MODELLING ACTIVITY FOR STUDENTS: SEA-LEVEL RISING

SYNOPSIS

This activity assumes that students have been exposed to the proposition that one consequence of global warming is that it will cause sea levels to rise.

These two activities are designed to enable students to discover that global warming can cause sea-levels to rise. They are based on the inquiry questions:

1 Do our sea levels really rise if the temperature of the water increases?

2 What happens to the sea level when ice from glaciers, and so on, melts into the sea?

The first activity is designed to answer the first inquiry question. This demonstrates the thermal expansion of water very clearly, and is a good introduction to the modelling activity designed to answer the second. Students will see the water rising further up a capillary tube inserted into it, since this is the only way it can expand.

In the second activity, students see that when ice warms and melts, the level of water in a container rises. However, because they have seen what happens when water is warmed in the first activity, they should also realise that two factors are operating here. Even without the melting ice, the sea level would be rising due to the increase in temperature of the water, which causes it to expand.

Students then consider what this can mean for nearby coastal land, including small islands.

These activities can be used as a teacher demonstration, if time and other constraints make this necessary.

APPROXIMATE TIME REQUIRED

Approximately 50 minutes, if both activities are performed.

LIST OF MATERIALS REQUIRED

Per group:

Activity 1
- 250 mL tap water in a beaker, coloured with dark blue food colouring
- 250 mL conical flask
- Fine-bored glass capillary tube inserted through a one-holed rubber stopper
- 2 x hot lamps
- Plastic tray (optional)

Activity 2
- 250 mL tap water in a beaker, coloured with dark blue food colouring
- Ice-cream container
- Rock
- Plasticine
- 2 x hot lamps
- IR thermometer or temperature sensor (optional)
- Plastic tray (optional)

PRACTICAL ADVICE AND HINTS

1 As with all practical activities, you are advised to **try** *the activity first. This will help you identify any potential problems in the classroom and hence put in place strategies to avoid them.*

2 The dark blue food colouring will make it easier to see the level of the water in each activity, and to see the narrow column of water rising up the narrow bore in Activity 1. The choice of blue colour makes it easier for students to relate to the fact it is water.

3 Check that the rubber stopper fits well into the top of the flask, but can be gently eased out.

4 Activity 2 could be extended to include floating ice (to model icebergs melting).

RISK MANAGEMENT

Advice:

Always actively supervise students in any activity.

First ask the students to predict what the risks might be, and how they can minimise them, as indicated on the student sheet. This will help prepare them for all the practical activities, since this process will be required in every experiment.

Possible risks	Minimising the risks
1 Cuts from breaking glass, in Activity 1. 2 Burns from touching hot lamps, in Activity 1. 3 Electric shock from getting water onto the mains power point or touching the switch with wet hands, in Activity 1.	Students must proactively avoid these problems. The students must be actively supervised to ensure they follow the agreed procedures. If they are likely to be careless handling the glass equipment and lamps and electric leads, then it may be better to perform this as demonstration.
4 Spilling water and/or ice on the floor and slipping on the wet surface, in either activity.	The students must be actively supervised to ensure they follow the agreed procedures and behave sensibly. Plastic trays may be useful in reducing this risk.

ADVICE FOR THE CLASSROOM

Modelling a process can aid understanding. However, there are always limitations to the application of any model. Students need to realise the importance of this.

In the session at end of the activity, elicit from students what they thought were some of the ways in which this modelling was helpful and ways in which it was different to the real situation.

EXPECTED RESULTS

The students should find that in both cases the water level will rise as the water becomes warmer.

In Activity 2, with the expansion of the water due to warming, plus the additional water volume from the melting ice, the water level will rise and possibly cover the ‘island’.

SUGGESTED SOLUTIONS TO QUESTIONS

Activity 1

1 The water did expand as it was heated. You can tell because it moves up the tube, which meant it has a larger volume. *[Note: This is evident because the glass in the tube and flask does not expand as much as the water. Some students may raise this complication.]*

2 Global warming is warming the water in our oceans. This activity shows that this must make sea levels rise.

3 The temperature rise from a Bunsen burner would be far greater than what would occur due to global warming. The lamps cause a more moderate temperature rise.

4 The smaller the bore, the higher the water rises for a given temperature increase. This means the water rise will be more visible.

5 Yes, other materials such as metals also expand when they are heated. This is why there are expansion gaps built into bridges and other structures. An example of a problem is that railway tracks and tram tracks can buckle in the heat.

Activity 2

1 The melting ice adds to the volume of the 'sea water' as it drains down off the rock. The 'sea water' also expands as it heats. As the water is contained, its height must increase.

2 Low-lying islands can disappear if the sea level rises sufficiently.

3 Sea-level rising will displace communities of islanders from their home. Naturally they wish to prevent this.

4 [*Student opinions may vary*]

5 [*Students may recognise that the temperature rise in an ocean will be lower because of its far greater volume, and there are complications for the ocean that were not included in this modelling, such as ocean currents and waves, but nevertheless there is evidence that what they saw is actually happening*.]

FOLLOW-UP ACTIVITY

Try the extension activity 'What is happening in the Maldives?' on pages 57-59 of this book. As a case study on the effect of sea-level rising on small islands, it is very relevant to this activity. Suggested solutions are provided on page 60.

TOPIC: GLOBAL WARMING

STUDENT ACTIVITY SHEET 1: GLOBAL WARMING AND CLIMATE CHANGE – INFORMATION AND SUGGESTED SOLUTIONS

STUDENT BOOKLET pages 2-13

INFORMATION

See the websites on global warming listed on pages 256-257 of this book.

SUGGESTED SOLUTIONS TO QUESTIONS

1 B, C, E, F

2 A, B, D, E, F

3 No – the main cause has been thermal expansion of the water in the oceans.

4 a The greenhouse effect is the 'trapping' of some of the infra-red radiation from the Earth's surface by greenhouse gases, which moderates the temperatures at the Earth's surface. The enhanced greenhouse effect is the additional trapping of this radiation by increased amounts of greenhouse gases, which have concentrations beyond the normal levels. These are produced by human activity.

b The greenhouse effect has enabled to life to exist because it moderates the temperatures on Earth to a range in which life as we know it could evolve. The enhanced greenhouse effect is likely to lead to serious consequences because it is likely to cause ocean levels to rise, resulting in coastal flooding. It also is likely to cause more frequent extreme weather events, such as the devastating floods that occurred in the eastern states of Australia, particularly Queensland, in January 2011, and Cyclone Yasi.

5 The missing words are shown.

The ozone layer is a layer of ozone located about **16** km above the Earth's surface. Ozone is a form of **OXYGEN** in which there are **3** atoms instead of the usual **2**. Also present in this layer is **NORMAL OXYGEN**. In this layer chemical reactions are continually taking place. In one reaction ozone is converted to **OXYGEN** and in the other reaction **OXYGEN** is converted to **OZONE**. These reactions are in **BALANCE** with one another and keep the concentration of ozone **STEADY**. (Concentration means **THE AMOUNT OF OZONE PER LITRE OF AIR**.)

These reactions both require a lot of energy, and so much of the **ULTRAVIOLET** radiation from the Sun is absorbed by the molecules as they react. This means that the amount of **ULTRAVIOLET** radiation reaching the Earth's surface is **DECREASED**.

The problem is that in some regions, especially above Antarctica, the concentration of ozone is **LOWER**. We say there is a **HOLE** in the ozone layer in these regions. This means that people and other animals living under these regions are more likely to develop **CATARACTS** and **SKIN CANCERS**.

6 It was discovered that these chemicals were able to move up to the ozone layer and react with the ozone, causing its concentration to decrease significantly.

7 The ozone up in the ozone layer brings health benefits, as it reduces the incidence of skin cancers and cataracts. But the ozone produced at ground level is harmful - it causes a number of health problems, particularly respiratory problems.

TOPIC: GLOBAL WARMING

STUDENT ACTIVITY SHEET 2: THE GLOBAL WARMING DVD – ADVICE

STUDENT BOOKLET page 14

SYNOPSIS

This DVD was produced to introduce global warming using an Australian context and to stimulate class discussion.

The ensuing class discussion should help the teacher identify students' background knowledge and understandings, as well as any common alternative conceptions.

The follow-up concept map activity designed for pairs or small groups is an effective means of gauging the students' understanding of global warming, knowledge of the relevant terminology and their ability to connect ideas. It also will help identify alternative conceptions which should then be discussed.

APPROXIMATE TIME REQUIRED

Approximately 50 – 60 minutes, including discussions and drawing a concept map.

LIST OF MATERIALS REQUIRED

- STELR global warming DVD: *Global warming. Cold facts. Hot Science*
- Student activity sheet 2 'The global warming DVD (optional)
- Large sheets of poster paper and poster pens

PRACTICAL ADVICE AND HINTS

1 THE DVD

1 The teacher may decide to use the student activity sheet as the basis for the follow-up discussion, or to just conduct a lively class discussion.

2 If the activity sheet is used, then it is advisable to ask the students to read the stimulus questions prior to watching the DVD, so they can watch the DVD with these questions in mind. Alternatively, have the students devise their own list of questions through class discussion. Display these questions on a whiteboard so the students can easily see them whilst watching the DVD.

3 Show the STELR global warming DVD at least once and ask the students to write their responses to the questions, so they can contribute actively to the follow-up class discussion.

4 After the students have viewed the DVD, elicit from them their responses to the stimulus questions, their understanding of the terms used in the DVD, their opinion of the DVD and any questions that they would have liked answered about global warming. Collect and display their different responses

5 If there is time, then have the students complete the concept map.

2 THE CONCEPT MAP

1 Outline to the students the general principles of drawing a concept map. That is, the key words should be placed in boxes which are arranged on the page in such a way that they can be connected by sentences. Often this is in the form of a wheel with spokes. One key word or more (such as 'global warming') forms the start of each sentence and another, the end of the sentence. There is no single right answer. However, some sentences are more helpful than others as they contain more information.

2 The concept maps should be drawn on large sheets of paper and displayed.

ADVICE FOR THE CLASSROOM

1 Global warming is a very important issue which concerns many students. It can be a very emotive issue for some, especially if they are very fearful of the future or are opposed to the actions or lack of action of particular countries or ethnic groups. It therefore needs to be handled sensitively. Insist that the students treat those who have other viewpoints with respect.

2 The level of sophistication of the sentences in the concept maps will vary from student to student. Avoid placing students who have learning difficulties, or who have difficulty expressing themselves, in a position of embarrassment. If that is likely, do not put the responses on display, but instead display some of the most helpful sentences found without identifying the source.

TOPIC: GLOBAL WARMING

EXTENSION: LITERACY EXERCISE FOR STUDENTS: WHAT IS HAPPENING IN THE MALDIVES?

MALDIVES: PARADISE SOON TO BE LOST

Read the following article, then answer the questions.

By Nick Bryant, **BBC correspondent in Maldives 28 July, 2004**

To visit the Maldives is to witness the slow death of a nation.

For as well as being blessed with sun-kissed paradise islands and pale, white sands, this tourist haven is cursed with mounting evidence of an environmental catastrophe.
To the naked eye, the signs of climate change are almost imperceptible, but government scientists fear the sea level is rising up to 0.9 cm a year.

Since 80% of its 1200 islands are no more than 1 m above sea level, within 100 years the Maldives could become uninhabitable.

The country's 360 000 citizens would be forced to evacuate.

The Maldives' survival as a sovereign nation is truly at stake.

The country is portrayed by travel companies as a tropical paradise

No wonder it was the first country to sign up to the Kyoto Protocol, which sets targets for cuts in industrialised countries' greenhouse gas emissions.

No wonder that Male, the capital, is surrounded by a 3 m high (9.8 ft) wall, which took 14 years to construct at a cost of $63m. Unable to foot the bill themselves, the government happily accepted aid from Japan, which paid for 99% of the cost.

But the wall offers protection for just one of the Maldives' 200 inhabited islands – and then only against tidal surges rather than the rising sea level, the longer-term threat.

In Kandholhudhoo, a densely-populated island in the north of the Maldives, 60% of residents have volunteered to evacuate over the next 15 years – those remaining behind will eventually be compelled to do the same.

Tidal surges flood their homes every fortnight, and recently hammered a 3 m (9.8 ft) hole in their concrete flood defences.

The country's fishermen no longer use the 'Nakiy', a centuries-old weather guide based on stellar constellations which climate change has made all but irrelevant.

The weather here is becoming more volatile and less predictable. The alignment of the stars no longer offers much guidance.

Mitigation

The Maldives government is trying to alleviate the worst effects of climate change.

Future generations face an uncertain future

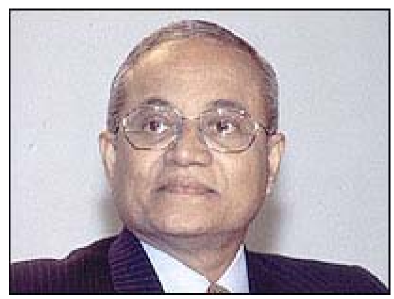
It is encouraging forestation to prevent beach erosion and is backing a plan to clean litter and debris from the country's coral reefs – a natural barrier against tidal surges which changes to the fragile eco-system have placed in peril.

Environmental science is taught in every school, and given the same importance as writing and arithmetic. All new resorts are subject to a rigorous environmental impact study and developers are allowed to build on only 20% of the islands.

But the efforts are aimed at mitigation rather than prevention.

Moral pressure

As policy-makers in Male are depressingly aware, their ultimate fate lies in the hands of politicians in Delhi, Beijing, Moscow and Washington.



President Gayoom has written to President Bush

In June, the President of the Maldives, Maumoon Abdul Gayoom, wrote to the US President George W Bush, in a rather optimistic attempt to persuade him to ratify the Kyoto Protocol. So far he is yet to receive a response.

This minnow of a nation faces a mammoth task – to persuade members of the US government, whether officials in the Bush administration or lawmakers on Capitol Hill, to make long-term decisions from a global perspective, rather than short-term choices based on national self-interest.

The Maldives can exert moral pressure and press its strong scientific case. But not much more.

So come here fast, before it disappears. This is a paradise faced with extinction.

Questions

Read the article again then answer the following questions.

1 Explain what the title of the article ‘Maldives: Paradise Soon To Be Lost’ means.

____

2 a What is the predicted sea level change by next century? ________________________

b Who predicted this rise? Does the article show the evidence used to make the prediction?

____

3 Complete the table to show some of the impacts of global warming on the islands.

Aspect affected	Problems they are experiencing as a result of global warming
Tides	
Weather	
Coral reefs	
Fishing industry	
Lifestyle and living conditions of the people	

4 a Outline some of the solutions that the people of the Maldives are already trying.

____

____

b How effective might these solutions be? What else is needed?

____

____

5 Suppose you have been asked to give a presentation on the threat to the Maldives at the next world summit on global warming, which will be attended by world leaders. Create a visual representation of the predicted effect of climate change on the Maldives that would be suitable for the big screen behind you when you speak at the summit.

6 Do you think the article will convince other countries to take strong action on global warming? Discuss.

TOPIC: GLOBAL WARMING

EXTENSION LITERACY EXERCISE FOR STUDENTS: WHAT IS HAPPENING IN THE MALDIVES? – SUGGESTED SOLUTIONS

Note: The source of this article is the website: http://news.bbc.co.uk/2/hi/south_asia/3930765.stm (Accessed: 05-01-2010)

1 It means that the Maldives is an island paradise that is in danger of being covered with the rising sea.
2 a 90 cm (0.9 x 100)

b This is based on an estimation by the government scientists. However, the article does not state the source of the data and how reliable it is.

3

Aspect affected	Problems they are experiencing as a result of global warming
Tides	In a densely populated island in the north, tidal surges flood people's homes every fortnight and hammered a 3 m hole in their concrete flood defences. As a result, the inhabitants are being forced to leave the island. In addition, beaches are being eroded.
Weather	The weather is becoming more volatile and less predictable.
Coral reefs	The coral reefs are a fragile ecosystem that is at risk with the tidal surges. They are becoming covered with debris and litter.
Fishing industry	The fishermen can no longer use a centuries old weather guide based on stellar constellations.
Lifestyle and living conditions of the people	The people living in the capital live within a 3 m high wall, instead of having a clear view to the sea. The people in Kandholhudhoo are being forced to leave their homes because of the flooding. The fisherman can no longer use their traditional way of telling when they can go fishing. Fewer places can be developed.

4 a The solutions include:

• Constructing big walls to help stop tidal surges flooding their buildings.

• Controlling where developers can build.

• Encouraging the plantation of trees to stop beach erosion.

• Planning to remove litter and debris from the coral reefs

•Teaching environmental science in every school and giving it the same importance as writing and arithmetic.

• Only allowing developers to build on 20% of the islands.

• Subjecting all resorts to a rigorous environmental impact study.

b These solutions can help slow down the number of buildings that get flooded, but cannot reduce global warming or prevent sea-level rising. What else is needed is for the rest of the world to act fast on global warming, to prevent further climate change and sea-level rising.

5 [*Student response*]

6 [*Student response*]

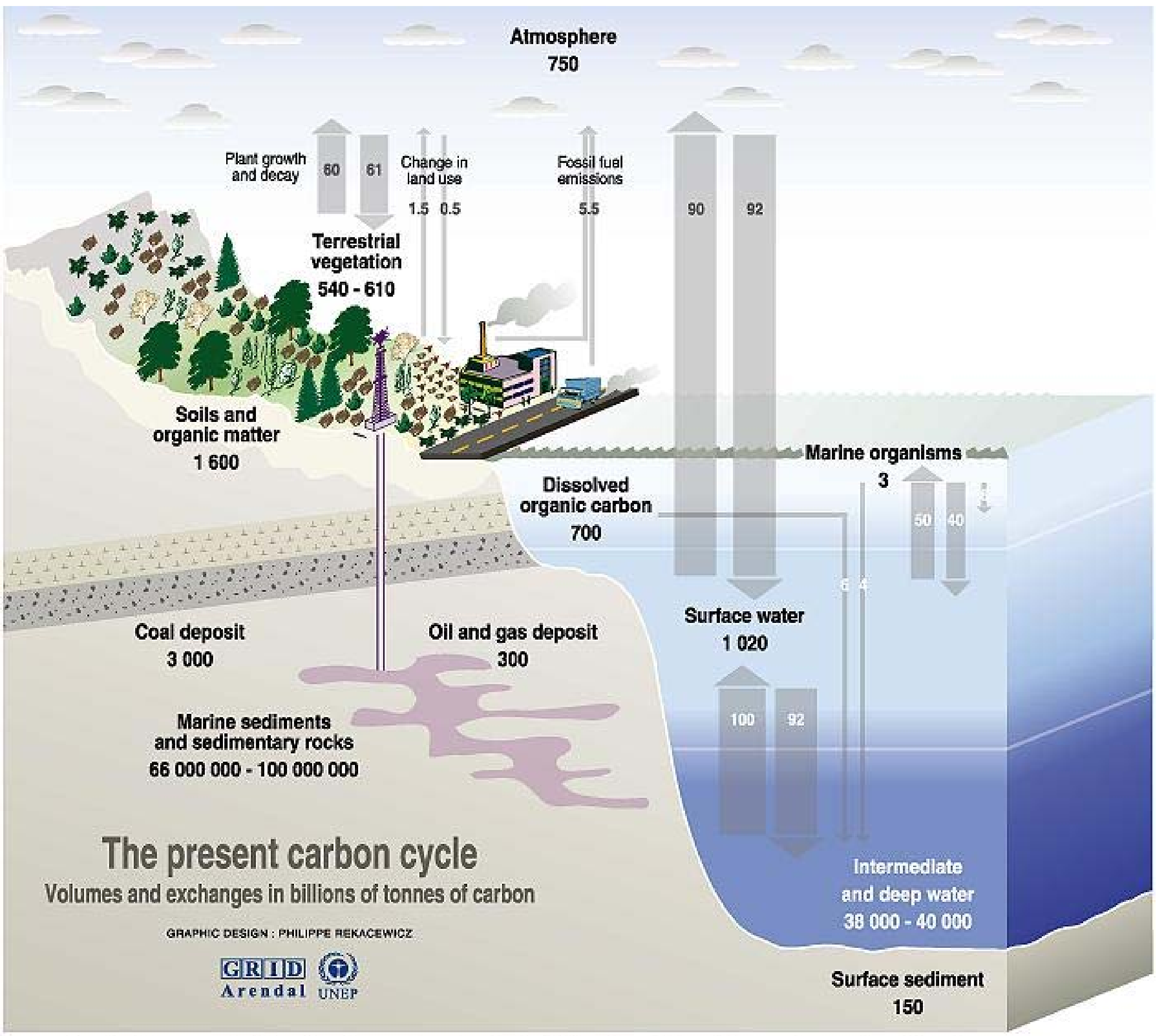
TOPIC: GLOBAL WARMING

STUDENT ACTIVITY SHEET 3: THE CARBON CYCLE – INFORMATION AND SUGGESTED SOLUTIONS

STUDENT BOOKLET pages 15-17

INFORMATION

The following image provides more detailed information about the carbon cycle.



Sources: Center for climatic research, Institute for environmental studies, university of Wisconsin at Madison; Okanagan university college in Canada, Department of geography; World Watch, November-December 1998; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Source: http://oceanworld.tamu.edu/resources/oceanography-book/Images/carboncycle.jpg
Date accessed: 9 February, 2011

Other useful websites include:

The Wikipedia site: http://en.wikipedia.org/wiki/Carbon_cycle

The website of the National Earth Science Teachers' Association:
http://www.windows2universe.org/earth/Water/co2_cycle.html

SUGGESTED SOLUTIONS TO QUESTIONS

1 The only TRUE statement is B.

A could say: Almost all of the substances in your body contain carbon atoms; exceptions include water.

C could say: The carbon cycle refers to the cycling of carbon via carbon dioxide gas, through processes in which it is released and processes in which it is used up.

D could say: In the process of photosynthesis, plants remove carbon dioxide from the atmosphere.

E could say: Once carbon is converted to a fossil fuel, it is locked out of the carbon cycle for thousands or millions of years. (*If it is not extracted and used, then it is locked out of the carbon cycle forever.)*

F could say: Once a carbon atom enters your body, how long it stays will depend on where it is used and what it forms.

2 [*Student response*]

3 [*Student response*]

4 [*Student response*]

5 a Carbon is often called the element of life because it is the element from which our muscles, bones, DNA, skin, hair, and so on, are constructed.

b Carbon atoms cannot be created on Earth, so what we have must be cycled around.

c Our food (which includes anything we drink) is the source of all the carbon atoms and almost all of the other atoms our body needs to create our skin, hair, bones, muscles, and so on. (*We also take in oxygen and some water from the air.)*

d Because the amount of carbon dioxide added to the atmosphere is now greater than the amount being removed from it due to human activity, the concentration of greenhouse gases in the air is greater than its natural levels. This is resulting in the global warming, with consequences such as climate change and sea-level rising.

TOPIC: GLOBAL WARMING

STUDENT ACTIVITY SHEET 4: WHAT'S HAPPENING IN OUR OCEANS? – INFORMATION AND SUGGESTED SOLUTIONS

STUDENT BOOKLET pages 18-19

BACKGROUND INFORMATION

What really happens in acid-base reactions?

You may have noticed that all acids have at least one hydrogen atom in their formula. (Examples: HCl, H_2SO_4, HNO_3, H_3PO_4)

When an acid reacts with a base, it donates one or more of these hydrogen atoms to the base. However, in the process the hydrogen atoms leave their electrons behind. A hydrogen atom without its electron is called a hydrogen ion, formula H^+. Since a hydrogen atom just consists of one proton and one electron, what really transfers to the base is just the proton.

This is why chemists define acids as substances that donate a proton to a base and bases as substances that accept a proton from an acid.

It also is why acidity is measured in terms of H^+ ions, as shown next.

The pH scale

The pH scale is a logarithmic scale with base 10, like the Richter scale for the intensity of earthquakes and the decibel scale for the intensity of sound. The reason for this is that if the huge range of possible measurements were displayed on a normal arithmetic scale, it would require an instrument with a scale that is more than 1 km long!

Because it is a logarithmic scale with base 10:
- A solution of pH 2 is 10 times more acidic than a solution of pH 3.
- A solution of pH 1 is 10 more times acidic than a solution of pH 2 and 100 times more acidic than a solution of pH 3, and so on.

Even small differences in pH are significant, due to the logarithmic nature of the scale. For example:
- A solution of pH 1.7 is twice as acidic as a solution of pH 2.0, which in turn is twice as acidic as a solution of pH 2.3.
- A solution of pH 1.9 is 1.25 times (or 25 %) more acidic than a solution of pH 2.0, which in turn is 1.25 times (or 25 %) more acidic than a solution of pH 2.1.

For pH, the quantity measured is the concentration of hydrogen ions (H^+) in solution. (pH means 'hydrogen power'.) The concentration of H^+ ions in solution can range from just over 1 M in strongly acidic solutions to below 10^{-14} M (0.000 000 000 000 01 M) in strongly basic solutions. In pure water it is 10^{-7} M (0.000 000 1 M).

The formula for pH is: $pH = -\log_{10}[H^+]$
This means that:
- If $[H^+] = 10^{-11}$ M, then the pH is 11.
- If $[H^+] = 10^{-3}$ M, then the pH is 3, and so on.

Blood pH

Our blood pH is regulated to stay within the narrow range of 7.35 to 7.45, making it slightly alkaline (basic). It is crucial that it stays within this range, or serious health consequences will result. Many enzymes, for example, cannot perform their essential function if the blood is more acidic or more alkaline than it should be.

The pH of sea water

The natural pH of sea water varies from location to location but generally ranges from 7.5 to 8.4. Thus seawater is very weakly basic – just a little more basic than our blood.

What substances affect its pH? The presence of sodium chloride does not affect its pH. A solution of sodium chloride has a pH of 7. However, a number of substances present in sea water do affect its pH.

Some of these substances are present as a result of natural processes. For example, fish urine contains ammonia, a weak base. A number of other substances are discharged into sea water as a result of geological activity on land masses and along the ocean floors.

For a fascinating and very readable account of the chemicals entering the ocean as result of the geological activity occurring on the ocean floors, visit the following website: http://www.waterencyclopedia.com/Ge-Hy/Hot-Springs-on-the-Ocean-Floor.html.

However, increasing amounts of other substances are entering the oceans as a result of our rapidly increasing world population and large-scale industrial, mining and agricultural activities. These include the raw and treated sewage discharged directly into the ocean, and fertilisers as well as sulfuric acid (from the exposure of sulfide minerals to the air) that leach into the ocean.

Most importantly, the vital role that the oceans play in the carbon cycle impacts significantly on its pH.

Processes within the carbon cycle that help lower the pH of seawater include:
- The absorption of carbon dioxide from the atmosphere.
- The production of carbon dioxide by marine organisms that undergo cellular respiration.

Processes within the carbon cycle that help raise the pH of seawater include:
- The removal of carbon dioxide from the water by marine species to produce carbonate minerals, which are the main constituents of shells and corals.
- The removal of carbon dioxide from the water by marine organisms that undergo photosynthesis.

These processes have been in balance for millions of years. However, with the excessive build-up of carbon dioxide in the atmosphere due to human activities in the past century or so, such as the large-scale production of steel, aluminium and cement, more carbon dioxide is dissolving than occurred in the past.

The problem is that even a small decrease in the pH of sea water as a result of human activity, a change known as **ocean acidification**, can significantly affect the viability of many species, just as a small decrease in our blood pH can significantly affect us. (See the links on the student notes for this activity.)

NASA studies of the carbon cycle and ocean salinity

See the news update on this project at the following website. Teachers may be interested in following this project.

http://www.nasa.gov/home/hqnews/2011/may/HQ_11-150_Aquarius.html

SUGGESTED SOLUTIONS TO QUESTIONS

1 B and D are correct.

- *A is incorrect because acids have a pH lower than 7*
- *C is incorrect because many foods contain acids and are safe to eat.*

2 A, B and C are correct.

- *D is incorrect because only bases that are soluble in water are also called alkalis.*

3 B , C and D are correct.

- *A is incorrect because most indicators are simply one colour in an acid and another colour in a base.*

TOPIC: GLOBAL WARMING

RUNNING PRACTICAL ACTIVITY 1: WHAT'S HAPPENING IN OUR OCEANS?

STUDENT BOOKLET pages 20-26

SYNOPSIS

This activity consists of a 'circus' of small experiments on a very topical issue, the results of which will fascinate students.

First students discover how acids and bases can be identified by systematically testing different foods and mild soaps and detergents with universal indicator. (The suggested foods are mostly acidic and the soaps and detergents are mostly basic.)

They then explore what happens to the pH of sea water when they blow carbon dioxide into it.

Finally they discover what happens to sea shells (or equivalent alternatives) when placed in different solutions (sea water, sea water into which extra carbon dioxide has been bubbled, tap water, vinegar and soda water) for several days.

The experiment is designed so there is minimal risk. The only laboratory chemical involved is universal indicator solution. The only other substances involved are foods, mild soaps and detergents used in the home, and sea water and sea shells or equivalent. Students will not handle any strong acids or caustic solutions.

Note: A range of interesting extensions and demonstrations is also possible, which are outlined below.

APPROXIMATE TIME REQUIRED

50 minutes for the initial experiment (not including responding to discussion questions).

Part C requires some brief observations over the next two days, since the reactions are slow.

Answering the discussion questions, and the optional additional demonstrations and extensions, will each take extra time.

BACKGROUND INFORMATION FOR THE TEACHER

Carbon dioxide gas in water

When carbon dioxide gas dissolves in pure water, it forms an acidic solution. The acid is known as carbonic acid, formula H_2CO_3. However, this acid cannot be isolated - that is, you cannot obtain a pure sample of carbonic acid. Carbonic acid is classified as a weak acid.

Drinks such as sparkling mineral water, soda water (so-named because it contains sodium salts), sparkling wines or soft drinks, contain carbon dioxide dissolved under pressure. That is, they all contain carbonic acid and are weakly acidic. (Most also contain other acids.) When the seal is broken, much of the carbon dioxide comes out of solution, since more is dissolved than usually would be dissolved at that temperature. The warmer the drink, the lower the solubility of carbon dioxide in the solution. The loss of the carbon dioxide, of course, makes the solution less acidic, which means its taste is not as 'sharp'. This is why a drink that has 'gone flat' is considered less 'refreshing'.

It is interesting to note that as mineral water does not contain sugar, a sparkling mineral water is considered safer to drink than a flat mineral water because the acid present reduces the chance that the water contains harmful bacteria.

Salinity of sea water

The total concentration of salts dissolved in sea water is about 35 g/L on average. However, this varies considerably across the oceans, depending on factors such as location and depth. The principal salt is sodium chloride, NaCl. Many websites provide interesting data on this. One excellent site is: http://www.oceanplasma.org/documents/chemistry.html

The reaction between acids and carbonates

This reaction produces a salt of the acid, carbon dioxide and water. For example, the reaction between the main constituent of a sea shell and the active ingredient of vinegar is as follows. This shows that a gas is produced, which should be seen in the form of bubbles.

$$\underset{\text{ethanoic acid}}{2CH_3COOH(aq)} + \underset{\text{calcium carbonate}}{CaCO_3(s)} \rightarrow \underset{\text{calcium ethanoate}}{(CH_3COO)_2Ca(aq)} + \underset{\text{carbon dioxide}}{CO_2(g)} + \underset{\text{water}}{H_2O(l)}$$

This reaction will be observed by students in Part C of the experiment. Note that calcium ethanoate is a weakly basic salt. (Not all salts are neutral. Many salts are weakly acidic or weakly basic.)

See also the background information on pH etc. on pages 68-69.

LIST OF MATERIALS REQUIRED

For each student pair or group:

- Small dropper bottle of universal indicator and colour chart
- Large dropper bottle of sea water*
- Small-scale testing equipment, as supplied*
- Droppers and small plastic teaspoons
- 5 x 100 mL conical flasks
- A4 sheet of white paper (or large white tiles)
- Labelling system for testing, as supplied*
- Small samples of foods and soaps and detergents*
- Small jar of broken sea shells*
- Small spatula
- Small beaker of tap water
- 1 x drinking straw
- Paper towel

Note: * See the section 'Practical advice and hints' regarding these items.

In addition you need:
- Small unopened bottles of soda water (each bottle shared by about 4 groups)
- Waste bin for paper towels and slices of fruit and vegetable
- Tub of cold water for used containers in which the testing for Part A has been conducted
- Bag of cotton balls (optional – see section on Practical advice and hints)
- Tub containing 1 pair safety glasses per student (optional)
- Box containing 1 pair tight-fitting plastic gloves per student (optional)

For the optional additional demonstrations for Part A outlined in the section on Practical advice and hints below, you need:
- pH probe
- Small beakers
- Samples of coloured foods and drinks and diluted household cloudy ammonia

For the optional additional demonstration for Part B outlined in the section on Practical advice and hints below, you need:
- Piece of dry ice (solid carbon dioxide) stored in a thermos
- Small dropper bottle of universal indicator solution
- Glass stirring rod
- Tongs for picking up the dry ice, or thick insulated gloves
- 1 L beaker half-filled with water

For the optional extensions for Part C outlined in the section on Practical advice and hints below, you need one or more of:
- Stereomicroscopes, 5 Petri dishes and forceps for each group
- Bowls of hot, warm and iced water, for selected groups
- Samples of the same kind of shell with different sized pieces, for selected groups
- Samples of different kinds of shells, for selected groups.

SAFETY WARNING!

1 Ensure that no student tries to eat any of the food samples, before or after universal indicator solution is added. Remind them of the rule that no food or drink should ever be eaten in the laboratory, as the lab surfaces and equipment may have traces of toxic substances or harmful organisms on them.

2 Do NOT give students dishwasher detergent, or drain cleaner to test. These are very caustic and hence very dangerous to handle.

3 Do NOT give students household cloudy ammonia to test. It gives off toxic ammonia fumes, particularly when used straight from the supply bottle.

4 If dry ice is used, only handle it with thick insulated gloves or tongs, as it will blister the skin.

5 Ensure you work through the risk assessment section in the student instruction sheets with the students BEFORE letting them start the experiment.

PRACTICAL ADVICE AND HINTS

Overall:

1 Universal indicator solution is much more effective for these tests than universal indicator paper. The differences in colour are more marked. Moreover, students enjoy the experiment far more when each sample becomes brightly coloured. Make it clear that it is always the indicator in the mixture that is changing colour.

2 If the school is near the sea, then it is very worthwhile to collect bottles of seawater for this activity. This will be all the more meaningful to the students. But in this case they must be used within 3-4 days, because then the water starts to become malodorous to due to microflora dying in it.

If the school does not have ready access to sea water, then a solution of sea water can be prepared from aquarium sea salt, which has been specially produced for aquariums containing salt water species. This can be purchased directly from aquarium suppliers or through the internet, and is made up with water. The solution should have approximately the same pH as sea water as well as a very similar salt composition.

Check that the pH of the solution is approximately 8. If it is lower than 8, add 0.1 M NaOH to the solution drop by drop, with stirring, until the pH is 8. (It may only take 1-2 drops per litre of solution.) In the unlikely event it is higher than 8, then add 0.1 M HCl to the solution drop by drop, with stirring, until the pH is 8. (Again, it may only take 1-2 drops per litre of solution.)

Alternatively, if this is not available, make up a solution of cooking salt or sea salt at a concentration of 35 g/L, and adjust the pH to 8 as described above.

3 If the school is near the sea, you could also collect some sea shells, PROVIDED IT IS PERMITTED ON THAT BEACH. White or cream-coloured shells (like those shown on the first page of the student instructions) produce good results. These should be washed in mild detergent, rinsed and dried. They will then last for years.

See the Practical advice and hints for Part C for alternatives to sea shells.

4 Encourage the students to complete the 'Find out' activity at the end, and report on their findings. Discuss how this ties in with the activity.

For Part A:

1 It is essential that you demonstrate how to perform these tests. (For the demonstration, you may wish to test a substance that the students will not be testing - see extensions.)

2 Foods that produce excellent results include cow's milk, lemon juice, vinegar, lemonade, soda water, egg white, plain or vanilla yoghurt, cream, sparkling mineral water, lemonade and soda water. (For a more complete list, see the table of expected results later in this document. Fruits and vegetables that are suitable for testing include apple, banana and potato. It is NOT advisable to test coloured foods or drinks, as their colour will mask the colour of the universal indicator.

3 Domestic soaps and detergents that produce excellent results and are safe are: dishwashing liquid, soft soap for hands, eucalyptus floor cleaner or eucalyptus wool wash. Each should be diluted to the same extent they would be when used in the home.

4 Bicarb soda (sodium hydrogen carbonate) is used in cooking as well as in some cleaning products. A solution of bicarb soda is interesting to test, as it is weakly basic. (In fact it will act as a weak acid when a strong base is added to it and as a weak base when a strong acid is added to it, which is why solid bicarb soda is often used to soak up and neutralise spills of strong acids or bases.)

5 Ensure that any fizzy drinks are kept sealed except for the brief time it takes to extract a sample. (As the gas escapes their pH will rise.)

6 Have tubs of cold water for the used equipment. Soaking then rinsing in cold water will help remove dairy products and egg white, which would 'cook' if the equipment is placed in hot water. The equipment then should be washed in hot water containing dishwashing liquid, rinsed and left to drain.

7 Equipment that would be suitable for systematic testing includes:

- ***Comboplates, as shown in Figure 1 below. In Australia these are only obtainable from Westlab (www.westlab.com.au)***
- ***Reaction palettes***
- ***Acetate sheet previously ruled up in a grid of squares, set over white paper that is placed on a plastic tray***
- ***Very small beakers***
- ***Small watch glasses***
- ***Small plastic Petri dishes***

Figure 1 A comboplate set up for testing. Only the large wells are used in this experiment. Each large well has a capacity of 2 mL, but would only be half-filled with the samples. The advantage of this over a reaction palette or acetate sheet is that spillage is much less likely. They are easily washed and should last for years. The advantages over test tubes, watch glasses or Petri dishes are that just one piece of equipment has to be washed at the end of the activity, and smaller amounts of the samples are used, which means there is less waste.

6 For labelling, you can print off white sheets with labels already on, or give students black lead pencils (not pens) to write their own labels onto the white paper. Avoid using adhesive labels that are then difficult to remove.

Additional demonstrations:

- ***You may wish to perform a demonstration using 1-2 mL of diluted household cloudy ammonia solution. Dilute it just prior to the demonstration in a ratio of about 1 part in 10, with cold water. Ammonia is classified as a weak base, but the solution will be more strongly basic than the milder cleaners. For this reason it will turn universal indicator solution purple. (In fact, when diluted with hot water and with some dishwashing liquid added, it is a very effective and inexpensive cleaner that will remove grease and other deposits off most surfaces very well.) Remember that fish urine is an ammonia solution. (Decaying fish also give off ammonia.) It would be advisable to wear safety glasses and latex gloves for this demonstration.***
- ***If you have a pH probe available, then you could test coloured foods such as coloured, fizzy soft drinks such as cola drinks, orange juice, tomato juice, crushed strawberries, cold black tea and cold black coffee. These can be placed in small beakers just before being tested. However, ensure that the pH probe has been freshly standardised using buffers so that its readings are reliable.***

For Part B:

You are strongly advised to issue each group with one straw only. Ensure that just one student uses it (for hygiene reasons) and that the straw is immediately discarded afterwards, before the students start Part C.

Additional demonstration:

An excellent demonstration that is best run after students have completed Part B, is to add a piece of dry ice (solid carbon dioxide) to a 1 L beaker half-filled with tap water to which a few drops of universal indicator has been added. As the solid sublimes, which causes rapid effervescence, much of the carbon dioxide gas produced dissolves in the water and of course makes it quite acidic. So students should see the universal indicator rapidly go from green to yellow to orange to red.

For Part C:

1 If sea shells have been collected from a beach, then they should be washed to remove sea water and sand, dried and then broken into smaller pieces about the size of a 5-cent coin, using a large mortar and pestle.

If this source of shells is not feasible, the following alternatives can be used:

- ***Shell grit from pet shops and other suppliers for aviaries. This consists of crushed shells and works very well.***
- ***Sea shells from aquarium suppliers. These have been thoroughly cleaned already, so they do not contaminate the aquariums.***
- ***Shells from raw hens' eggs. These should be washed in cold soapy water to remove any remaining egg white, then rinsed.***
- ***Discarded shells from oysters or mussels or other shell fish. These should be thoroughly washed in hot soapy water, rinsed and boiled before use to ensure that students do not come in contact with any toxins.***
- ***Marble chips***
- ***Powdered calcium carbonate***

2 The more finely the source of calcium carbonate is broken down, the faster it will react. This is because the reactions of a solid can only occur on its surface. The smaller the particle size, the greater total surface area available for the reaction.

3 The flasks should be left open to the air or, if necessary, plugged loosely with cotton wool, to allow any gas produced to escape.

Possible extensions:

- ***An excellent idea that will make Part C even more meaningful and fascinating is to have the students examine the bits of shells placed on a Petri dish under a stereomicroscope before they are added to the flasks. They then should collect the same shells afterwards using the forceps top extract them from the flasks, rinse them with cold water, dry them, place them on separate Petri dishes, and examine them under the stereomicroscope again. They should see clear signs of etching where a reaction has occurred.***

- ***You could vary the sizes of the bits of shell and allocate different sizes to different groups. Have them compare their results, and hence discover for themselves that the smaller the particle size the faster their reaction with an acid, provided all other factors, including the kind of shell, are kept the same. This has implications for colonies of tiny coral organisms and tiny immature shellfish, which will be much more susceptible to increased acidity of sea water than mature shellfish that have thicker, larger shells.***

- ***You also could vary the temperatures of the solutions, and allocate different temperatures to different groups. The temperatures of solutions can be modified by sitting the set of flasks in dishes of hot or warm water or icy water. Have the groups compare their results, and hence discover for themselves that the greater the temperature the faster their reaction with an acid, provided all other factors, including solid particle size, are kept the same. This has implications for colonies of shellfish and corals in warmer waters. However, bear in mind that the solubility of carbon dioxide decreases with increase in temperature. So the acidity of the carbonic acid solutions will decrease with increased temperature.***

RISK MANAGEMENT

Teachers need to actively supervise this activity.

Possible responses to the students' risk assessment activity are shown below. The teacher should decide whether the students will use safety glasses and gloves, based on the known behavior of the students. They should not be required for this activity if the students are mature and careful in practical classes.

Student activity sheet: Table 1

The facts	What might be the risks?	What precautions will we take?
1 Acidic solutions can sting your eyes or broken skin. Basic solutions can irritate eyes. (Strongly acidic or basic solutions can burn eyes and even cause blindness, but these will not be tested.)	People could have an acidic solution on their fingers and accidentally rub it into their eyes, or else they could accidentally splash it into their eyes or on cuts or abrasions.	Handle the substances carefully. Wipe up any spills immediately with paper towel. Safety glasses could be worn.
2 Universal indicator solution can stain skin and clothes etc.	The solution could be accidentally spilt on clothes, skin or bench tops.	Be careful with the dropper bottle. Put the lid back on straight after use. Wipe up any spills immediately with paper towel. Safety glasses and gloves could be worn.
3 Universal indicator solution is poisonous.	The solution could be accidentally ingested if students get some on their fingers or if students suck some solution up the straw in Part B.	As for Point 2. Do not eat any food or drink that is being tested. Also, follow instructions very carefully and wash hands with soap and water at the end of the activity.

ADVICE FOR THE CLASSROOM

See also the general advice provided on pages 28-29.

Teachers are strongly advised to:

1 Trial the activity prior to the class, to identify problems the students might encounter and to judge the time they need.
2 Decide how to best manage the activity, particularly how to efficiently distribute the food and soap and detergent samples for Part A. You may wish to have a set of the substances shared between 2-4 groups, for example, with each substance having its own spoon or small container, to reduce the total number of droppers, spoons and containers needed. Certainly this should be applied to bottles of soda water, lemonade and any other fizzy drink being tested, and tubs of yoghurt, as indicated in the above list of what is needed.
3 Decide which (if any) additional demonstrations and extensions you will include in the activity, which student groups will perform any extension you will run, and when in the session you will introduce and run them.

Setting up:

Have a demonstration set of equipment and materials ready to show the students during the introductory discussion.

Introducing the activity:

1 Elicit from the students what they already know about acids, bases, indicators, pH, the composition of sea water and sea shells, and the role the oceans play in controlling the concentration of carbon dioxide in the atmosphere.
2 Talk about the activity and demonstrate the most important points about how to perform the different tests.
3 Emphasise the necessity of avoiding cross-contamination in all tests.
4 Work through the risk assessment and safety precautions to be taken, eliciting as much as possible from the students.

During the session:

1 Watch that the students wipe up any drips and spills immediately and that they observe all of the agreed-upon procedures and safety precautions.
2 At a suitable time, stop the class and perform any additional demonstrations you decide to do, including how to perform any of the extensions in Part C you wish to run. This can help draw the class together and keep the students on track.

At the end of the session:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report their findings. They should discuss what they found interesting or unexpected, problems they encountered, and their responses to some or all of the discussion questions. Ensure each group contributes to the discussion.

Have the students place their mixtures from Part C somewhere safe for observing over the next two days. Discuss the results they observe with them at these later times, encouraging the students to suggest reasons for any changes seen.

This part of the session should take about 10 -15 minutes.

EXPECTED RESULTS

Typical results for Part A

Student activity sheet: Table 3

Substance under test	Colour of universal indicator solution	Approximate pH	What kind of substance is it?
Tap water	Green	7	neutral
Vinegar	Red	4 or less	acidic
Lemon juice	Red	4 or less	acidic
Apple juice or slice of fresh apple	Red	4 or less	acidic
Cow's milk	Brownish yellow	6	acidic
Soy milk	Brownish yellow	6	acidic
Vanilla yoghurt	Red	4 or less	acidic
Cream (for whipping)	Yellow-green	6	acidic
Egg white	Emerald green	8	basic
Lemonade	Red	4 or less	acidic
Soda water	Red	4 or less	acidic
Sparkling mineral water	Red	4 or less	acidic
Banana (slice)	Red	4 or less	acidic
Celery (slice)	Brownish yellow	6	acidic
Potato (slice)	Brownish yellow	6	acidic
Diluted soft soap hand wash	Brownish yellow	6	acidic
Diluted dishwashing liquid	Orange	5	acidic
Diluted eucalyptus floor cleaner	Emerald green	8	basic
Solution of bicarb soda	Emerald green	8	basic
Extension: Diluted cloudy ammonia solution	Purple	10 or higher	basic

Note:

1 Distilled water and rain water are generally slightly acidic, since they contain some dissolved carbon dioxide. (Rain water may also contain other weakly acidic substances that have dissolved in it from the air.)

2 The pH of tap water will depend on the water source, the age and type of pipes delivering it, and so on. In many schools with old pipes it may be 8, for example.

3 The approximate pH values listed in Table 3 above were from universal indicator that did not clearly distinguish between solutions of pH 4 or less, or of 11 or more. A pH probe or universal indicator solution with a wider pH range would be needed to determine a more precise value.

4 A lot of cleaning detergents are made up of basic substances because bases react with fats and oils to produce soaps, and hence can remove greasy deposits and stains.

Note: Dishwasher detergent, drain cleaners and oven cleaners manufactured for domestic use are generally strongly basic. For this reason they must be handled with great care, and all provided safety advice must be followed. In particular if they get into eyes, they can cause blindness or permanent scarring of eye tissue because they react with certain proteins in the eye. (Thus is why teachers are strongly advised not to use them in this practical activity.)

Typical results for Part B

Step	What do you see?
1	*The universal indicator solution should turn emerald green (pH approx 8).*
2	*The universal indicator solution should turn the same green as for tap water (pH 7). With further blowing it should go a greenish yellow (pH approx 6).*

Typical results for Part C

Student activity sheet: Table 6

Solutions to which the sea shells were added	Colour of universal indicator before the sea shells were added	Colour of universal indicator about 30 minutes later	Colour of universal indicator after 3 days	What else did you observe?
Tap water	Green	Green	Emerald green	The shells barely changed
Sea water	Emerald green	Emerald green	Blue (pH approx 9)	No observable change
Vinegar	Red	Red	Orange (pH approx 5)	Formation of a lot of small bubbles, which slowed down over time. Shells were etched.
Sea water into which extra CO_2 was bubbled	Greenish yellow	Green	Emerald green	Some small bubbles forms at the start. Slight etching of shells.
Soda water	Red	Red	Green	Vigorous bubbling for some time the first day. The shells were etched, though not as much as for the vinegar.

SUGGESTED SOLUTIONS TO QUESTIONS

1 a What everyday substances are acidic, basic or neutral:

Student activity sheet: Table 7   (From Student activity sheet Table 3)

Acidic substances			Basic substances	Neutral substances
Vinegar Lemon juice Lemonade Soda water Sparkling mineral water Celery	Banana Cream (for whipping) Yoghurt Apple Potato	Cow's milk Soy milk Dishwashing detergent (diluted) Soft soap (diluted)	Egg white Solution of bicarb soda Eucalyptus floor cleaner (Household cloudy ammonia)	Tap water

Key:

Substances are highlighted in yellow in response to Question 1 c.

Substances are highlighted in blue in response to Question 1 d.

2 It is very dangerous to swallow most substances. They may be poisonous, or corrosive, or may contain harmful organisms.

3 a It decreases.
b It would decrease.

4 The shells would become thinner because they would be eaten away to some extent.

5 The shells in the areas where the acids entered the sea would become quite a lot thinner.

6 a All the shellfish in affected areas would have thinner shells. Smaller shell fish might lose so much of their protective shell they might die. Drinking in the more acidic water would harm all the shellfish. This could seriously affect their ability to survive.

b Student responses might include the fact that some basic compounds in the broken shells might have dissolved to an extent now the shells are broken up. The reactions between the calcium carbonate and acids present would have started to neutralise them. Both of these would cause the solutions to be more basic, which would explain the pH rise in all cases.

7 a This is to be sure what was the effect of the acids and the added carbon dioxide. If the tap water and sea water were not also tested, you could not be sure if the changes would have happened anyhow.
b So no gas pressure built up in the flasks, which may have caused them to explode.

TOPIC: ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS

ENERGY - ALTERNATIVE CONCEPTIONS

SYNOPSIS

Studies into students understanding of the concept of energy have found that students hold several alternative conceptions, confusing energy with force or movement or fuels, or believing that energy is just associated with eating foods, for example.

COMMON ALTERNATIVE CONCEPTIONS

Some of the more common alternative conceptions found include:

- There is confusion between what is meant by the terms ‘energy’ and ‘force’. Other terms, such as ‘motion’ and ‘power’, are also frequently used interchangeably with energy.
- Energy is considered a by-product of a situation that is generated, is active, and then disappears or fades. The scientists’ conservation of energy principle is not well understood by students.
  - Conservation of energy can sometimes be associated with everyday care not to waste energy, which differs from scientists’ conservation of energy principle.
  - Energy is not an entity that is conserved because one has to pay for it. The energy required for devices such as light globes and engines gets consumed.
- Energy is only associated with movement of an object.
- Stationary objects relate to energy only from the perspective of an energy store, for example, batteries, power stations, oil and coal store energy. Energy is therefore a causal agent, a source of activity based or stored within certain objects.
- Energy is related only to living things – an anthropocentric view. Living things get tired and less active without energy. Human energy is rechargeable through food or by resting. Some students have contradictory uses for human energy. For example, there may be the view that energy is built up as a result of sports training, but is expended in digging the garden.
- Energy is a concrete entity. In some circumstances, such as heating an object, energy is a fluid type material that flows from hot objects to cooler ones.
  - Energy is associated with fluids or ingredients that are dormant and are released suddenly by a trigger.
- Energy is found in foods; it only gets harnessed when the food is eaten. Some students believe that ‘high energy’ foods convert directly into energy or somehow crack open to release their ‘store of energy’ when consumed.
- Energy is considered a fuel. Fuel is energy, rather than fuel contains or is a source of energy.

SOME REPRESENTATIVE RESEARCH STUDIES

Kruger, C, Summers, M., Mant, J., Childs, A. & McNicholl, J. (1998) *Teaching Energy and Energy Efficiently Effectively*. Hatfield: Association for Science Education.

Kruger, C. (1990). *Some primary teachers’ ideas about energy*. Physics Education, 25, pp. 86–91.

Liu, X. & McKeough, A. (2005). *Developmental Growth in Students’ Concept of Energy: Analysis of Selected Items from the TIMSS Database*. Journal of Research in Science Teaching, 42, 5, 493–517.

Stylianidou, F., (1995), *Children's learning about energy and processes of change*, School Science Review 79, 91-97.

Trumper, R. (1993). *Children’s energy concepts: A cross-age study. International Journal of Science Education*, 15 (2), pp. 139–48.

Warren, M. (1983). *Some alternative views of energy*, Physics Education 18, 213-217.

TOPIC: ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS

IDEAS FOR INTRODUCTORY ACTIVITIES ON ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS

SYNOPSIS

These optional activities are different ways in which you might introduce or reinforce the concepts of energy, energy transformations and energy transfers. They will enable you to discover what the students already know and what alternative conceptions they may have.

The first idea is a PowerPoint presentation that covers a range of forms of energy. **NOTE: This should not be used if students were shown this in a previous STELR program.**

The second idea is a fun quick hands-on exploration of heat packs and/or cold packs. The third idea is a stimulating You Tube video involving multiple energy transformations that will appeal to many students of this age.

ADVICE

Rather than converging too quickly to the key science ideas, whichever activity you select, treat it as principally one in which ideas from the students are expressed, shared and discussed. But by the end of the discussion students should have at least begun to develop a common understanding of what energy is and of how energy changes from one form to another. They should also develop a common understanding of the meaning of different forms of energy.

OPTIONAL INTRODUCTORY ACTIVITY 1: IMAGES OF ENERGY (POWERPOINT PRESENTATION)

Activity outline

Show the students the series of PowerPoint slides on Energy provided on the ATSE STELR USB memory stick. Ask them to write down what kind of energy (or energies) they think each depicted object possesses. The PowerPoint presentation file includes some suggested questions.

At the end of the slide show, bring the class together to compare their answers. Include a discussion about whether their response concerning the rock changed when they saw the second slide showing its position. Some further stimulus questions are shown in Table 1.

Elicit from the students what they understand by the terms they use, which may include kinetic energy and gravitational potential energy. Display their different ideas or understandings of the kinds of energy that were possessed by the objects and what these terms mean.

Table 1 shows possible responses and further stimulus questions that could be asked.

Time required

Approx 50 minutes (not including the follow-up activities)

Materials

• White board and data projector or other devices to display PowerPoint presentation

Note: Students require pen and paper or electronic means of recording their responses.

Discussion

Table 1 Discussion of slides

Slide	Comments	Further stimulus questions
2	Students may identify chemical potential energy, electrical energy, light energy, heat energy (the globe gets hot). They may consider this in terms of energy transformations: chemical potential energy to electrical energy to light energy and heat energy.	If the students do not realise the battery contains chemicals, or do not list chemical potential energy, you could ask them where does the circuit get its energy from?
3	Students may identify light energy, electrical energy and kinetic energy/mechanical energy. They may view this as a series of energy transformations.	Is energy created or destroyed as it changes form?
4	Students may identify chemical potential energy (of the grass), kinetic energy (cow chewing), thermal energy (the cow is warm), gravitational potential energy (of cow), and so on. There is a common alternative conception amongst students that some or all of the food that animals eat is transformed into energy (that is, matter is converted to energy) and the rest is stored by the body or expelled from the body.	Can new atoms be made on Earth? If some of the atoms of the chemicals in food were converted into energy, would the Earth eventually run out of the atoms plants and animals are made out of?
5	Students may identify electrical energy, heat energy and light energy or consider the energy transformations involved.	Where does the electrical energy come from?
6	The satellite is in a geostationary orbit, which means it is always located above one point on the Earth's rotating surface. The students may identify gravitational potential energy. They may consider the source of energy used to power the satellite (solar energy) and the forms of energy this is transformed into, such as electrical energy.	If it is geostationary, does the satellite have kinetic energy? Where does the satellite get its energy from that enables it to transmit signals and so on? What kind of energy would be required to transmit signals?
7	The students may identify elastic potential energy and kinetic energy. They may also identify heat/thermal energy, as the cotton reel toy gets hot as it moves over the surface, or the transfer of heat energy to the environment. They may identify the energy transformations involved. Watch out for the alternative conception that the kinetic energy is transformed into friction, due to rubbing against the surface or due to air resistance, thus equating energy and force.	When the toy stops moving, does it still have any energy? What other forms of energy has it been transformed into? If not, has its energy been destroyed?
8	For the jumping toy, the students may identify elastic potential energy, kinetic energy and gravitational potential energy. They may consider this in terms of the energy transformations involved. For the wheeled toys, the students may identify elastic potential energy and kinetic energy. They may also identify heat/thermal energy, as the wheels get hot, or the transfer of heat energy to the surrounding environment. They may consider this in terms of the energy transformations involved. Watch out for the alternative conception that the kinetic energy is transformed into friction in the wheels, thus equating energy and force.	When the jumping toy is half-way up, does it only have kinetic energy?
9	The students may identify gravitational potential energy and/or thermal energy. Watch out for the alternative conception that an object on the ground has no gravitational potential energy.	Would the large rock have more energy than a stone at the same spot? Why?
10	If the students did not identify gravitational potential energy for Slide 9, they should be encouraged to identify it now.	Would the rock have more energy than if it were down on the ground below? Why?
11	The students may identify gravitational potential energy and kinetic energy. They may say the twin up higher has greater gravitational	Why would we compare twins? Would the twins have the same total amount of

	potential energy and less kinetic energy that the twin further down the slope. They may also consider the energy transformation involved. Some may identify heat energy and its transfer to the environment.	energy?
12	The students may consider chemical potential energy, kinetic energy and thermal energy, or the transformation of energy. Again, watch out for the common misconception outlined in Slide 4.	Does this mean that carbohydrates possess more chemical potential energy than other types of foods?

OPTIONAL INTRODUCTORY ACTIVITY 2: OK GO RUBE GOLDBERG MACHINE

Activity outline

Hand out small pocket-sized heat packs for hiking or ski trips and/or cold packs supplied in first aid kits and ask the students to follow the instructions to set them going, then suggest how they might work and identify the energy transformations and energy transfers that occur.

Time required

Approx 10 minutes

Materials

• Heat packs for hiking/skiing and/or cold packs for first aid to distribute to groups of students

Note:

1 If supplies are limited or too expensive, this could be used as a teacher demonstration, but the students should all be given the opportunity to feel the packs after they have been set going.
2 The heat packs are usually available from camping and hiking and skiing supply stores, usually just before the winter season.

Discussion

1 The heat packs usually contain just iron filings and sawdust. When the air-hole is uncovered, the iron reacts with oxygen in the air and rusts. The product of the reaction is iron oxide. This reaction is rapid because of the small size of the iron particles. It is exothermic. The energy transformation is:

Chemical potential energy →Heat energy

The heat energy is transferred to the sawdust, which help hold in the heat and transfer it evenly and slowly to the paper packaging and hence the person's hands.

Note: There is a question about these heat packs on page 70 of the student book, in the section on families of chemical reactions.

2 The cold packs usually work because they contain water and a chemical sealed a container inside the pack. When the container is broken, the chemical mixes with the water and dissolves in it. This solution process is endothermic. The heat energy required for the solution process is obtained by transforming some of the thermal energy of the water particles into chemical potential energy. This makes the water colder.

OPTIONAL INTRODUCTORY ACTIVITY 3: OK GO RUBE GOLDBERG MACHINE

Activity outline

As an extension, the teacher may wish to use the You Tube video by OK Go as a stimulus for discussion.

Go to: http://www.youtube.com/watch?v=qybUFnY7Y8w

Watch the video and ask the students to identify some of the energy transformations that occur during the video clip.

TOPIC: ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS

STUDENT ACTIVITY SHEET 5: ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS –SUGGESTED SOLUTIONS

STUDENT BOOKLET pages 28-32

What do you think?

The law of conservation of energy is conveyed in the Sankey diagram by keeping the total arrow width constant.

Students might suggest ideas like acting out the transformations, using items like marbles or sweets to represent 'parcels' of energy. These start off in one pile but are then distributed into three piles that have appropriate relative amounts in them.

TOPIC: ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS

RUNNING PRACTICAL ACTIVITY 2: WHAT ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS ARE HAPPENING HERE?

STUDENT BOOKLET pages 33-40

SYNOPSIS

This is a fun Round Robin activity for small groups in which the students rotate between different work stations. At each work station they investigate a device or process in which energy transfers and energy transformations take place. This will build on and reinforce their understanding of the concepts of energy, energy transfers and energy transformations.

Each group answers questions about the devices and processes they have investigated. This is to enable them to think about what they are seeing, so they can contribute meaningfully to the class discussion at the end.

No written reports need to be submitted, but this investigation should be followed up by a homework activity on hydroelectric power stations (student booklet pages 41-42).

At some of the work stations students will use STELR multimeters and STELR batteries, or suitable alternatives. It is assumed they are familiar with and have confidence and skills in using this equipment.

A work station involving a simple and safe chemical battery is included .This leads well into later practical activities (Practical Activities 6 and 7) in which the students learn the principles of experimental design.

APPROXIMATE TIME REQUIRED

60 minutes, if students are to experience as many of the work stations as possible. They should spend about 10 minutes at each work station; this time should include answering at least one of the questions.

BACKGROUND INFORMATION FOR THE TEACHER

Station A: Light sticks

There are some useful websites that explain how light sticks work. In their case the energy released in the reaction is in the form of light energy. These include:

http://science.howstuffworks.com/innovation/everyday-innovations/light-stick.htm

http://science.howstuffworks.com/innovation/everyday-innovations/light-stick1.htm

http://en.wikipedia.org/wiki/Glow_stick

A useful 6 minute YouTube video which features a chemistry teacher demonstrating to students how glow sticks work and the effect of temperature on their rate of reaction is at:

http://www.youtube.com/watch?v=W4xKJ3LHlVM

Station B: A chemical reaction

Bicarb soda (sodium hydrogen carbonate, $NaHCO_3$) is classified as a weak base. The active ingredient of vinegar is ethanoic acid (a weak acid commonly known as acetic acid.) When solid bicarb soda is mixed with vinegar, the following acid-base reaction takes place:

sodium hydrogen carbonate + ethanoic acid → sodium ethanoate + water + carbon dioxide

The carbon dioxide gas bubbles out of the mixture very rapidly, causing it to froth. The universal indicator will go red when added to the vinegar, because vinegar is moderately acidic. When the bicarb soda is added, it starts to neutralise the ethanoic acid and so the universal indicator should go orange then yellow then possibly green, depending on the relative amounts of the acid and base.

This reaction is exothermic, although the temperature of the mixture will rise by only a small amount.

Station C: Dissolving some crystals

The solution of crystals can be an endothermic or exothermic process. (See pages 68-70 of the student book.) In the case of anhydrous copper(II) sulfate, the solution process is exothermic.

Dissolving a solid in a solvent is not regarded as a chemical reaction. However, a chemical reaction can ensue. For example, if solid crystals of 'bicarb soda', $NaHCO_3$, are dissolved in water, at first the Na^+ ions and HCO_3^- ions present in the crystals separate and move amongst the water molecules. This separation is the solution process. But then an acid-base reaction occurs between the HCO_3^- ions and the water molecules, in which OH^- ions are produced. As a result, the final solution is weakly basic.

NOTE: The reason that copper solutions must not be poured into waterways is that copper is toxic to aquatic organisms.

Station D: A chemical cell

In the student book, this is termed a chemical cell and not a chemical battery since thisis the correct terminology. (In fact, chemists classify this cell as a **galvanic cell**.) Strictly speaking, a chemical battery is a source of electrical energy in which two or more chemical cells are connected together in series to deliver a great voltage.

This situation is parallel to the terminology used in the solar energy industry. A single unit is called a solar cell. When more than one solar cell is connected together, the set of cells is termed a solar panel.

The cell investigated at this work station is an early cell design. In this cell, when (and only when) the circuit is complete, the more active metal (zinc) gives up electrons, forming Zn^{2+} ions, which dissolve in water and hence migrate into the solution. Thus if the cell is run for long enough, you will clearly see the zinc electrode being 'eaten away' (corroded).

The electrons from the zinc electrode travel around the wires towards the other electrode, which is composed of a less active metal (copper).

The electrons then migrate down the copper electrode and react with water molecules that come in contact with its surface. This reaction splits the water molecules up, producing hydrogen gas (H_2) and hydroxide ions (OH^-). The hydrogen gas will be seen as small bubbles of gas forming around the copper electrode, which then rise to the surface.

Today cells are designed so that hydrogen gas is not produced, since this gas is explosive and hence hazardous. (The small amount produced in this cell when operating for only a couple of minutes will not be a safety concern.)

The role of the salt is to increase the conductivity of the water. (In the solution the electric current consists of moving charged ions, not electrons.)

Substances that give up electrons are termed **reductants** and substances that accept them are termed **oxidants**. An oxidant and a reductant must both be present if an electric current is to be produced. In this case the reductant is zinc and the oxidant is water.

Station E: Electrolysis

The net balanced chemical equation for the electrolysis of water is: $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

The oxygen is produced at the positive electrode (the electrode connected to the positive terminal on the STELR battery).

The hydrogen is produced at the negative electrode (the electrode connected to the negative terminal on the STELR battery). There should be more bubbling at this electrode, because twice as much hydrogen gas as oxygen gas is produced, as shown in the above equation. (In fact, it was the relative proportions of hydrogen and oxygen produced during the electrolysis of water that led chemist to deduce the formula of water is H_2O!)

Because of the presence of a chloride salt in the solution, chlorine gas is likely produced at the positive electrode as well as oxygen. The chlorine will be detected by its odour.

Note:

1 The very small amount of chlorine produced in this teacher demonstration should not cause any safety concern. The chlorine concentration will be far lower than that encountered at any chlorinated swimming pool.

2 Sodium hydroxide and chlorine are produced industrially on a large scale by the electrolysis of concentrated sodium chloride solution (known as brine).

LIST OF MATERIALS REQUIRED

Station A: Light sticks

- One light stick per group

Practical advice:
Make sure the light stick is n made of flexible plastic rather than breakable glass.

Station B: A chemical reaction

- Large bottle vinegar
- Sealed jar of solid bicarb soda (sodium hydrogen carbonate)
- Dropper bottle of universal indicator solution
- Alcohol thermometer or IR thermometer or temperature sensor
- 100 mL measuring cylinder
- One 100 mL conical flask per group
- Plastic spoon
- Plastic tray
- Plastic tub for used conical flasks

Practical advice:
1 Make sure the students perform the reaction over a plastic tray, so any overflow from the flask due to the effervescence, and any spills, are contained.
2 Locate this work station next to a sink, so students can rinse out the flask.
3 Successive groups of students should use the same measuring cylinder, spoon, etc.

Station C: Dissolving some crystals

- Sealed jar of anhydrous copper (II) sulfate crystals
- Alcohol thermometer or IR thermometer or temperature sensor
- 100 mL measuring cylinder
- One 100 mL beaker per group
- Large spatula per group
- Plastic tray
- Plastic tub for used beakers
- Residue bottle for copper solutions

Practical advice:
1 To prepare anhydrous copper(II) sulfate, crush some hydrated crystals using a mortar and pestle, place them in a large evaporating dish then heat them in a warm oven or over a low Bunsen flame until they turn white. Store them in a desiccator ready for the experiment so they do not absorb moisture from the air.
2 Make sure the students perform the process over a plastic tray, so any spills are contained.
3 Locate this work station next to a sink, so students can rinse out the flask.
4 Successive groups of students should use the same measuring cylinder, thermometer, etc.

Station D: A chemical cell

- Enough pairs of safety glasses for each group member
- Bottle containing 1 L of approx 0.5 M sodium chloride solution (30 g NaCl per litre)
- Copper electrode or rod or metal strip
- Zinc electrode or rod or metal strip
- 100 mL measuring cylinder
- 100 mL beaker
- Emery paper
- Wooden board
- Plastic tray
- Paper towel
- Two connecting leads (banana plug one end and alligator clip at the other)
- STELR multimeter

Practical advice:
1 If metal strips are used, ensure they do not have sharp edges.
2 The metal should be sanded over the wooden board

Station E: Electrolysis

- STELR battery or 2 x AA cells and holder with leads
- 2 x graphite rods
- 100 mL measuring cylinder
- 100 mL beaker

Practical advice:
1 Pre-test the battery to ensure it works.
2 It can be useful to secure the electrodes with a large wooden peg or clamps to ensure they do not touch each other, which would cause a short circuit and rapidly flatten the battery.

Station F: An oil burner

- Ceramic oil burner
- Small dropper bottle containing an aromatic oil
- Tea-light candle
- Box of matches
- Small beaker of water

Practical advice:
Most candle shops can supply tea-light candles and oils suitable for ceramic oil burners. Do NOT purchase oil that is meant to be burnt directly, or tea-light candles that are perfumed.

RISK MANAGEMENT

Teachers need to actively supervise this activity.
Note the following specific advice for the work stations.

Station A: Light sticks

Ensure there is no possibility of broken glass. Students must not try to pull them apart to determine how they work. This could lead to injuries.

Station B: A chemical reaction

1 Ensure the students do not get any vinegar in their eyes.
2 Ensure any spills are wiped up immediately so no-one gets the reaction mixture on their clothes or slips on a wet floor.
3 Have the students wash their hands if they get any mixture on them.

Station C: Dissolving some crystals

1Tthe teacher may be required by law to examine the Material Safety Data Sheet for copper sulfate and perform a risk assessment based on the information provided. See pages 261-263 of this book for advice and a sample risk assessment proforma.
2 Have the students wash their hands if they get any solution on them.
3 Ensure the students do not pour the solution down the sink; it is toxic to aquatic organisms.

Station D: A chemical battery

1 The chemicals are generally regarded as very safe. The salt water is less concentrated than sea water. However, the teacher may be required by law to examine the Material Safety Data Sheet for each chemical, and perform a risk assessment based on the information provided.
2 If metal strips are used rather than rods or bars, ensure that their edges are not sharp.
3 Ensure the students do not injure themselves when sanding the metal and that they wear the safety glasses as instructed.
4 Ensure the students only sand the previously dried metal electrodes over the wooden board. This should protect benches from damage.
5 Ensure the students have the solution and beaker on the metal tray, to avoid spills.

Station E: Electrolysis

Students should be warned to avoid touching the two graphite rods together as this makes a short circuit and will quickly flatten the battery. Check they follow this instruction.

Station F: An oil burner

1 Ensure that the students keep the oil bottle sealed so the oil and its vapours do not come in contact with the flame.
2 Ensure the students treat the matches sensibly. The matchbox should be closed when they strike the match.

ADVICE FOR THE CLASSROOM

See also the general advice provided on pages 28-29.

Teachers are strongly advised to:

1 Ensure the students have been introduced to the concepts of energy, energy transfers and energy transformations prior to this investigation.
2 Trial the activity prior to the class, to identify problems the students might encounter and to judge the time they need.
3 Decide how to best manage the activity, particularly the size of each student group to avoid the problem of some students becoming spectators only and the time that can be spent at each work station and how this will be managed. Groups of just two or three are highly recommended. If necessary, set up two of each kind of work station to accommodate this.

Setting up:

Have the work stations set up around the room.

Introducing the activity:

1 Elicit from the students what they already know about energy transformations and energy transfers

2 Tell the students they will be performing a 'Round Robin' of fun activities at different workstations. Give them your directions about what groups they will be in, which work station each group will start at, how you will signal the time to move to the next work station, the direction in which they are to move when changing work stations and your expectations of their behaviour.

3 Show the students the different pieces of equipment, and demonstrate any key points about using the equipment.

4 Work through the safety precautions to be taken, eliciting as much as possible from the students.

5 It should be stressed that the students must negotiate the answers to the questions as a group. Emphasise that they will be expected to contribute some of their answers to the class discussion at the end of the session.

During the session:

Be very vigilant during the session.

Keep the groups moving around the workstations according to the timetable you set at the start.

Watch that the students observe all of the agreed-upon procedures and safety precautions. This must include immediately wiping up any drips and spills.

When watching a group, ask questions about what they think is happening, or how the device or process works, and so on.

At the end of the session:

This part of the session is very important because it helps the students clarify ideas in their mind, and helps develop communication skills and skills in analysis and evaluation.

Draw the students together to discuss and compare their findings. They could discuss what they discovered, any new ideas they had for ways of representing the energy transformations, what they found interesting or unexpected, and so on. Ensure each group contributes to the discussion

This part of the session should take about 10 -15 minutes.

EXPECTED RESULTS

Station A: Light sticks

The light sticks should produce a bright light.

Station B: A chemical reaction

Students should observe the following:

- The mixture should rapidly effervesce due to the formation of carbon dioxide gas.)
- The universal indicator should go red when added to the vinegar. As the reaction proceeds it should go orange then yellow. If sufficient bicarb of soda is added, it may go green.
- The temperature of the mixture should rise a little.

Station C: Dissolving some crystals

Students should observe the following:

- The solution should become blue as the crystals dissolve.
- The temperature of the mixture should steadily rise as the crystals dissolve. The net amount by which it rises will depend on the mass of anhydrous copper(II) sulfate that dissolves.

Station D: A chemical cell

Students should obtain a voltage reading.(This may be about 1 V.*)*
They also may have observed that bubbles formed around the copper electrode, if they leave the battery running, instead of testing it very quickly.

Note: *The bubbles are hydrogen gas – see the background information on page 79.*

Station E: Electrolysis

There should be bubbling around the surface of each electrode. This should be more rapid around the negative electrode.

Station F: An oil burner

- *Students should smell the oil quite quickly.*
- *The candle flame should be yellow.*

SUGGESTED SOLUTIONS TO QUESTIONS

Note:

The students may represent the energy transformations in all of these devices as a list as shown in the suggested solutions, a flow chart or some other pictorial device of their own design (which may resemble a Sankey diagram).

Station A: Light sticks

The energy transformation occurring is:

Chemical potential energy→ Light energy

Note:
Some students may start with the chemical potential energy of their food then the kinetic energy of the muscles involved in bending the light stick. (The students should not be expected to include this, but should be acknowledged if they do suggest it.)

Discussion questions:

1 One of the chemicals is sealed in a separate container inside the light stick. Bending the light stick breaks this container so the two chemicals can mix and react.
2 [*Student response*]

Station B: A chemical reaction

The main energy transformation occurring is:

Chemical potential energy → Heat energy

Note:
Some students may include sound energy, if they can hear the bubbling.

Discussion questions:

1 Carbon dioxide
2 The heat energy is transferred to the water and container.
3 [*Student response*]

Station C: Dissolving some crystals

One representation of the energy transformation occurring could be:

Chemical potential energy → Heat energy

Note:
This is difficult, since strictly speaking this is not a chemical reaction. Nevertheless, it takes energy for water molecules to 'pull' the ions apart, as oppositely charged ions are held together by strong electrostatic attraction. As the ions separate in the solution, water molecules form a sheath around them, which process releases energy – more than was required to separate the ions.

Discussion questions:

1 The water molecules in the hydrated copper(II) sulfate are responsible for its blue colour. When they are 'returned', as it were, the copper sulfate has its blue colour restored.
2 The heat energy is transferred to the water and container.
3 [*Student response*]

Station D: A chemical cell

One representation of the energy transformation occurring could be:

Chemical potential energy → Electrical energy

Note:
Some students may consider the production of some heat energy (due to electrical resistance).

An example of an energy transfer is the transfer of electrical energy from one electrode to the other, via the electrical circuit.

Discussion question: [*Student response*]

Station E: Electrolysis

The main energy transformations occurring are:

Chemical potential energy →Electrical energy → Chemical potential energy
(Battery) (Products of reaction)

Discussion questions:

1 An examples of energy transfer is the transfer of electrical energy from the battery to the electrodes , via the electrical circuit.
2 [*Student response*]
3 They contain dangerous chemicals.
4 It can produce large quantities of oxygen gas and hydrogen gas, both of which are very useful.
5 [*Student response*]

Station F: An oil burner

For the candle, the energy transformations could be: Chemical potential energy → Heat energy + Light energy

For the evaporation of the oil, the energy transformations could be: Heat energy →Kinetic energy

Discussion questions:

1 An example of energy transfer is the transfer of heat energy from the candle flame to water and oil in the bowl.
2 If the oil is heated directly it may catch on fire. This ensures the oil is gently heated so it slowly evaporates from the solution.

TOPIC: ENERGY TRANSFORMATIONS AND ENERGY TRANSFERS

STUDENT ACTIVITY SHEET 6: HOW DO HYDROELECTRIC POWER STATIONS WORK? – INFORMATION AND SUGGESTED SOLUTIONS
STUDENT BOOKLET pages 41-42

INFORMATION

The Pelton wheel is among the most efficient types of water turbines. It was invented by Lester Allan Pelton (1829-1908) in the 1870s, and is an impulse machine. That is, it uses the principle of Newton's second law to extract energy from a jet of fluid.

Many variations of impulse turbines existed prior to Pelton's design, but were very inefficient. The water leaving these wheels typically had high speed, and carried away much of the energy. Pelton modified this with a paddle geometry which ensures that when the rim runs at half the speed of the water jet, the water leaves the wheel with very little speed, making it a very efficient turbine.

The image here shows an old Pelton wheel from Walchensee Power Plant, Germany.

Source: http://en.wikipedia.org/wiki/Pelton_wheel
Accessed: 10 February 2010

Using Google and the search words 'Pelton wheel', teachers can find a wealth of information and images of Pelton wheels, including videos, on the world wide web.

SUGGESTED ANSWERS TO QUESTIONS

1 Energy can be thought of as the ability to make something happen. For example, the water stored up in the dam has the ability to run down the pipes and turn the turbines. A force is a pull or a push or a twist. For example, when the moving water reaches the turbines, it will hit the turbine and push the blades, causing them to spin.

2 Kinetic energy is the energy possessed by any object that is moving.

3 The energy transformations occurring in a hydroelectric power station could be represented as:

Gravitational potential energy	→ Kinetic energy	→ Mechanical energy	→ Electrical energy
(water stored in dam)	*(water running down pipes)*	*(spinning turbine)*	*(generator)*

4 The water is still flowing after it hits the turbines, so it must still have kinetic energy.

5 The building of a dam, which involves flooding of the chosen site, and the subsequent control of and reduction in water flow, has a harmful effect on all of the ecosystems along the river. The construction of pipes across the country, and of the power grid into which the power station is connected, as well as the maintenance of these 'corridors', requires the removal of trees and other plants. This damages a lot of land and could be harmful to the ecosystems present.

TOPIC: FUELS

BACKGROUND INFORMATION ON BIODIESEL

Biodiesel is made by reacting a plant oil, such as canola oil, with an alcohol, such as methanol, in the presence of a catalyst. This is an outline of the chemistry of the substances involved in this reaction.

METHANOL

Methanol is the first (simplest) member of the family of organic compounds known as **alcohols**. Its common name is methyl alcohol. Its chemical formula is CH_3OH. A model of a molecule of methanol is shown in Figure 1.

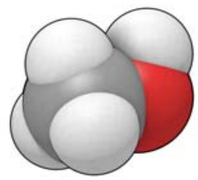


Figure 1This model of the methanol molecule is known as a space-filling model. The grey sphere represents a carbon atom, the white spheres hydrogen atoms, and the red sphere an oxygen atom. Red and white are the colours conventionally used in molecular models to represent atoms of oxygen and hydrogen respectively. Carbon is usually represented with a jet black sphere.

All the members of the alcohol family have an oxygen atom with a hydrogen atom attached to it, like this molecule. This is why their formula ends in **OH**.

Where they differ is in the total number of carbon atoms attached to this OH group, and the way the carbon atoms (and the hydrogen atoms attached to them) are arranged.

OILS AND FATS

All oils and fats produced by living organisms are a mixture of substances that belong to a family of organic compounds known as **triglycerides**. Family members that are solid at room temperature are called **fats**. Family members that are liquid at room temperature are called **oils**. In other words, fats and oils belong to the same chemical family and have the same basic chemical structure. They are simply further classified according to their melting points.

Triglyceride molecules are shaped rather like a letter E. They all have three long fatty acid ‘tails’ that are attached to a ‘backbone’ of glycerol. The reason for the different melting points of fats and oils lies in the shape and lengths of these ‘tails’. (This is shown in Figure 4, page 88.) So what is a fatty acid?

Fatty acids

Fatty acid is the common name of most members of a family of organic acids known as **carboxylic acids**. The active ingredient of vinegar, ethanoic acid (common name acetic acid), is a carboxylic acid, and has the formula CH_3COOH. The acid present in ant stings, methanoic acid (common name formic acid), also is a member of this family, and has the formula HCOOH. (Formulas of organic compounds are usually arranged in this style to show how the atoms are connected together. These are known as **semi-structural formulas**.)

Fatty acids are those members of the carboxylic acid family that have four or more carbon atoms in their molecules. Their name arises from the fact they are oily to handle. ‘Oilyness’ is a property exhibited by substances that have molecules containing one or more chains of carbon and hydrogen atoms. This is why the principal constituent of petrol, octane (Figure 5, page 97), also is oily. Figures 2 and 3, page 88, show models of molecules of two different fatty acids.

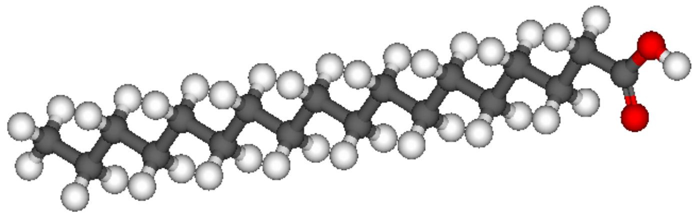


Figure 2 A ball-and-stick model of a typical saturated fatty acid molecule. The overall molecular formula of this molecule is $C_{17}H_{35}COOH$.

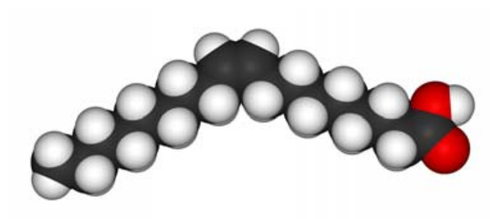


Figure 3 A space-filling model of a molecule of a typical monounsaturated fatty acid. This is oleic acid, which has the overall molecular formula $C_{17}H_{33}COOH$. Oleic acid is given off by dying insects, such as bees. When other bees smell this, they know the bee is dead and remove its body from the hive.
Source: http://upload.wikimedia.org/wikipedia/commons/2/27/Oleic-acid-3D-vdW.png **Accessed:** 25-10-2010

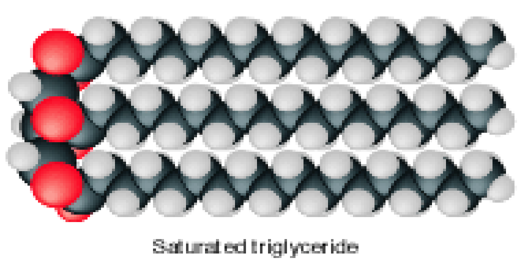
The 'bend' in the molecule in Figure 3 is due to the fact that a carbon-carbon double bond, C=C, is present at this point, which changes the angles between the carbon atoms. The formation of the C=C bond is why the molecule has 2 less H atoms than the molecule in Figure 2.) All unsaturated fatty acids have at least one C=C bond present. As can be seen in the example shown in Figure 2, saturated fatty acids do not have this 'bend'. This is because they have no C=C bonds present.

Like the molecules shown in Figures 2 and 3, all fatty acid molecules have the same little group of atoms on the end, known as the **carboxyl group**. This group of atoms consists of one carbon atom, two oxygen atoms attached to the carbon atom, and a hydrogen atom attached to one of the oxygen atoms, and is written as **COOH** at the end of the formula.

Where the molecules of the different members of the family of fatty acids differ is that they have different sized and shaped 'tails'. The 'tails' are simply chains of carbon atoms with hydrogen atoms attached. 'Tails' can have no bends (as in Figure 2), just one bend (as in Figure 3) or more than one 'bend', depending on whether the fatty acid is saturated, monounsaturated, or polyunsaturated, respectively.

The formation of a triglyceride molecule

A triglyceride molecule is formed when three fatty acid molecules react with a glycerol molecule. (The glycerol molecule is shown in Figure 7, page 91.) The COOH group on the end of each fatty acid molecule reacts with one of the OH groups on the glycerol molecule and form part of the 'backbone'. (A water molecule is eliminated in the process.) The 'tails' of the three fatty acid molecules hang out, as shown in Figure 4.



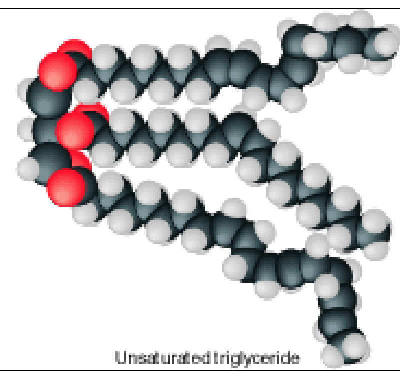


Figure 4
Left: A saturated triglyceride, formed from three saturated fatty acids
Right: A polyunsaturated triglyceride, formed from two polyunsaturated fatty acids and one monounsaturated fatty acid

Source: http://www.odec.ca/projects/2004/thog4n0/public_html/allpicfat.gif **Accessed:** 10 November 2010

Note:
In the process of forming a triglyceride molecule, three water molecules are also produced. This reaction can be simply represented as follows:

3 fatty acid molecules + 1 glycerol molecule → 1 triglyceride molecule + 3 water molecules

Since there are so many different fatty acids, there is a large variety of triglyceride molecules. The only difference between them is in their set of three fatty acid 'tails'. These affect the properties of the triglyceride. Saturated triglycerides have a higher melting point than polyunsaturated ones. As a result, saturated triglycerides are usually solids at room temperature while unsaturated triglycerides are usually liquids at room temperature.

Plant oils are mixtures of different triglyceride molecules. Each contains a certain proportion of saturated, monounsaturated and polyunsaturated triglycerides. Palm oil has a higher proportion of saturated triglycerides than canola oil, which is why it is a soft solid at room temperature whereas canola oil is a liquid. Copha, which is derived from coconuts, has an even greater proportion of saturated triglycerides than palm oil, which is why it is a harder solid than palm oil when compared at the same room temperature.

What is the difference between plant oils and oils derived from crude oil?

Mineral oils

Oils derived from crude oil are commonly termed **mineral oils**. They only contain carbon and hydrogen atoms - they do not contain any oxygen atoms.

Most belong to another family of organic compounds known as **alkanes**. An example of a member of the alkane family is shown in Figure 5.

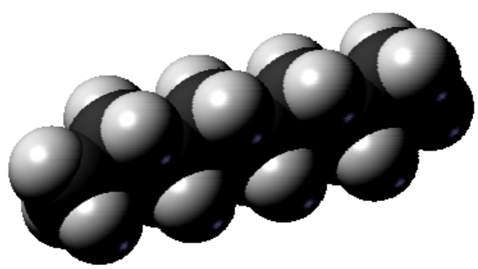


Figure 5 A model of a molecule of octane, one of the constituents of petrol. Its overall molecular formula is C_8H_{18}.

The liquid fuels that are derived from crude oil, such as kerosene, petrol and diesel, are a mixture of different alkanes that have similar-sized molecules. The molecules in petrol are generally a little smaller than those in kerosene, which in turn are a little smaller than those in diesel (now often called petrodiesel). Some special additives are present as well.

In general, the longer (and hence heavier) the alkane molecules in a mixture:
• The harder it is to ignite the fuel
• The more viscous the fuel at a given temperature

Shelf-life

Unlike organic oils and fats, which have a limited shelf life, mineral oils do not go rancid. Organic oils and fats go rancid because oxygen 'attacks' the C=C bonds in the molecules of the unsaturated triglycerides present, forming new compounds that have a bitter taste. Exposure to light and warmer temperatures speeds up this process. Thus the process is slowed down by storing the oils and fats in airtight containers in a dark place, and refrigerating them.

THE CATALYST

The raw materials for the production of biodiesel in the teacher demonstration require the presence of potassium hydroxide, KOH, for the reaction to proceed. This acts as a **catalyst**. That is, it speeds up the reaction and although it is involved in the process, it is not consumed. That is, it is still present at the end of the reaction. (A catalyst alters the way the particles interact. The mechanism of the reaction is quite complex, however, and will not be considered here.)

THE BIODIESEL

In the reaction between methanol and the oil, the methanol molecules react with the triglyceride molecules and with the help of the catalyst, break them up. After the fatty acids are pulled away from the glycerol 'backbone', they form a new kind of organic compound with the methanol known as a **methyl ester.** This is shown schematically in Figure 6.

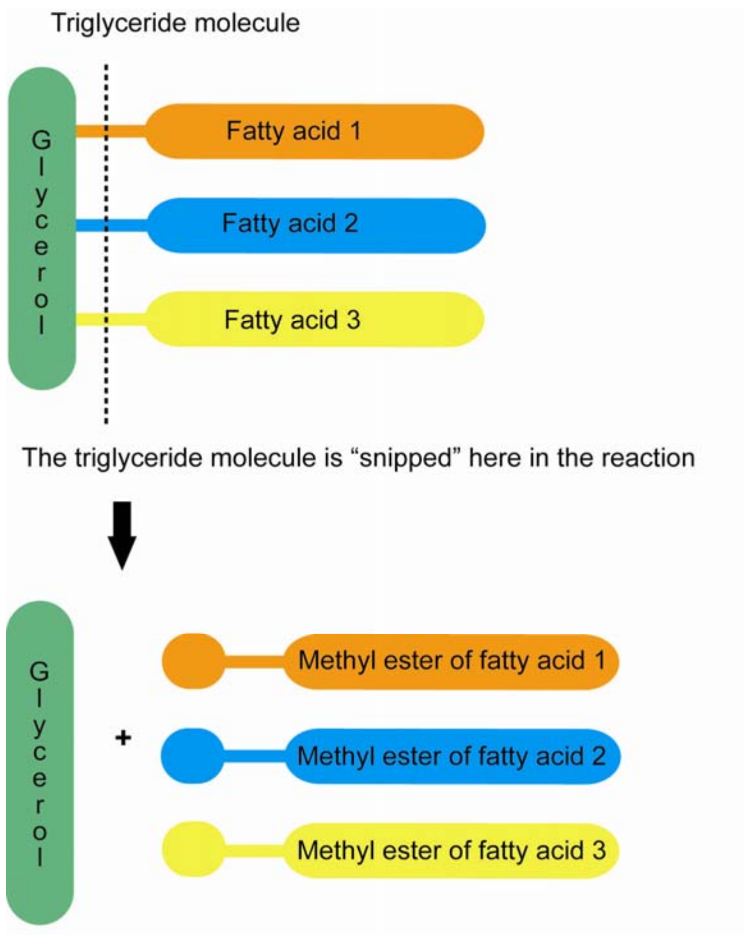


Figure 6

Overall, the reaction can be summarised as follows:

3 methanol molecules + 1 triglyceride molecule → 3 methyl ester molecules + 1 glycerol molecule

A TYPICAL BIODIESEL MOLECULE

Since there were a variety of fatty acid ‘tails’ in the original oil, biodiesel consists of a mixture of different methyl esters. A model of one possible methyl ester molecule, which was formed from a straight fatty acid ‘tail’, is shown in Figure 7.

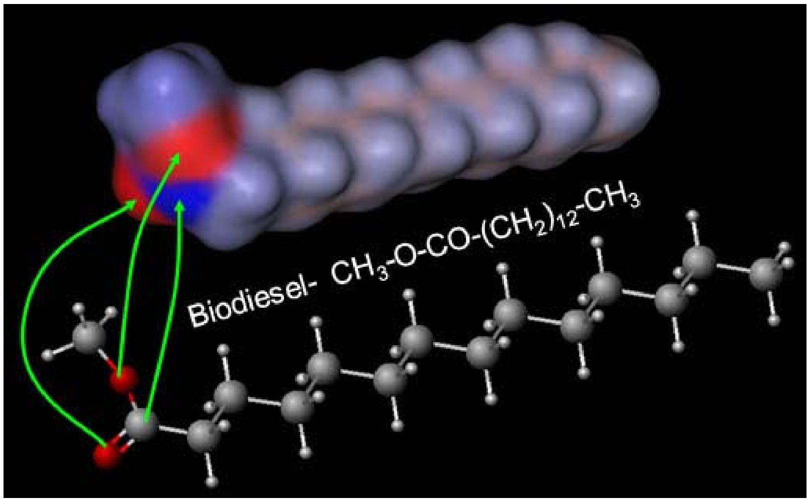


Figure 7 Two different models of a typical biodiesel molecule. The main drawback of these models is that conventional colours have not been used for the carbon atoms and hydrogen atoms. The light blue spheres on the space-filling model and the very small grey spheres in the ball-and-stick model represent hydrogen atoms. All other spheres, except the red spheres, represent carbon atoms. (The red spheres represent oxygen atoms.)
Source: http://www.chemistryland.com/CHM151W/12-Final/BiodieselCharges.jpg **Accessed:** 19-10-2010

Note:
Compare the structure of the biodiesel molecule with that of the fatty acid molecule in Figure 2 on page 96. Allow for the fact that the molecule in Figure 7 is viewed from a different angle, so the part with the oxygen atoms is on the left instead of on the right. The key difference between them is that hydrogen atom attached to the oxygen atom at the end of the fatty acid molecule has been replaced with a carbon atom that has three hydrogen atoms attached to it. (This is known as a methyl group, formula CH_3. The presence of this group that is the reason the compound is classified as methyl ester.)

THE OTHER PRODUCT - GLYCEROL

A model of the other product of the reaction, glycerol, overall molecular formula $C_3H_8O_3$, is shown in Figure 8. If you compare this with Figure 4 on page 88, you can see how this molecule forms the ‘backbone’ of a triglyceride molecule.

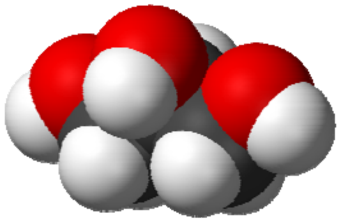


Figure 8 A model of a glycerol molecule. Notice it has three OH groups.

Glycerol and soap-making

Glycerol is not only the by-product of making biodiesel, but also of making soaps. Soaps are produced by adding a base to plant oil. For example, some hand-made soap is made from olive oil and sodium hydroxide. Essential oils and colouring agents are added at the end to give the soap an appealing aroma and appearance.

In good quality soap, the glycerol is not removed. It is blended within the soap, giving the soap its rich creamy lather and moisturising properties. In poorer quality soaps, however, the glycerol is separated from the soap and removed so that it can be sold for use in various other products. Other less expensive substances are then added in its place. If biodiesel were produced on a large scale, however, the production of glycerol would exceed the demand for it.

TOPIC: FUELS

EXTENSION: TEACHER DEMONSTRATION: PRODUCING BIODIESEL

SYNOPSIS

This teacher demonstration is designed to show students how biodiesel can be produced from new vegetable oil or oil that has been used to cook fish and chips. It can be extended to show the effect of temperature on the ability of the biodiesel to flow, a very important property for all liquid fuels.

This can be an excellent introduction to the topic of biofuels.

The demonstration is designed to minimise risk to the students and to the teacher.

Teachers may show students a short video clip of the process as carried out by one biodiesel producer as well as, or in place of, the demonstration. Even if the teacher only shows students the video clip, the information referred to below should be of interest and assistance to the teacher.

Background information on the chemistry of biodiesel, which shows what actually happens in this reaction, and how oils and biodiesel have quite different structures, is shown on pages 87-91. The images in that document will also be made available as a PowerPoint Presentation in the teacher portal of the STELR website.

APPROXIMATE TIME REQUIRED

15-20 minutes for the initial procedure. The students then look at the products again 24 hours or so later, since the reaction is slow.

If the teacher chooses to extend the experiment by testing and comparing the flow characteristics of the biodiesel at two different temperatures, the students need to see the samples again a day or so later.

BACKGROUND INFORMATION FOR THE TEACHER

Producing biodiesel

The procedure used to produce biodiesel depends on whether fresh oil or waste oil (such as waste oil from fish and chip shops) is used as a raw material, and also on the scale on which the biodiesel is to be produced.

If the oil has been used for cooking or other purposes, it is likely to contain solid particles, fatty acids and water. These will affect its conversion to biodiesel. For this reason, when waste oil is converted to biodiesel on a larger scale than in the laboratory, it is filtered, analysed to determine its acid content, and treated prior to converting it to biodiesel.

In this demonstration the raw materials for producing the biodiesel are methanol and a vegetable oil. The teacher may choose to prepare one or more varieties of biodiesel, by selecting one or more of the following vegetable oils.

- New canola oil
- New palm oil
- Oil that has been used for cooking fish and chips (filtered)
- Oil that has been used for cooking fish and chips (unfiltered)

A catalyst, potassium hydroxide, is used to speed up the process. The products are glycerol and biodiesel.

The possible combinations of methanol, oil and catalyst listed above have been found to work well. See the Practical advice and hints as well as the following instructions on how to perform the actual conversion.

The reaction

Oil and methanol do not mix, any more than oil and water. So in this reaction you start with two layers. This is why the mixture has to be shaken vigorously. The two liquids can only react with one another where their surfaces meet. Shaking them into smaller droplets significantly increases the total surface area of each liquid and hence the total area of contact between them.

As the oil is less dense than the methanol-potassium hydroxide mixture, the oil layer is uppermost and occupies the larger volume. After the reaction is complete, you will end up with two or three different layers. The uppermost layer is the biodiesel. The bottom layer mainly contains glycerol and potassium hydroxide.

In between these, there may be a whitish layer. This is just some of the biodiesel mixture that has a higher melting point than the remaining biodiesel and forms a gel (jelly-like soft solid) at room temperature. As this gel has a higher density than the remaining biodiesel mixture but a lower density than the glycerol, it forms a layer between them.

The biodiesel molecules in the gel are the more saturated molecules, as described in the background information on biodiesel (pages 95-99). You can see the same effect if you refrigerate some olive oil in a narrow glass bottle. The more saturated oils in the mixture will form a milky gel at the bottom.

Oil viscosity

The **viscosity** of a liquid is its resistance to flow. A liquid with high viscosity, often described as a viscous liquid, flows with difficulty.

The viscosity of a liquid decreases with increasing temperature. That is, the hotter the liquid, the more readily it flows. This is very evident if you compare the ability of honey to flow when it is very cold and when it is warm.

One of the most important properties of any liquid fuel for vehicles is its ability to flow well to the engine over the range of temperatures to which the vehicle may be exposed. It is no use if the fuel gels and therefore cannot flow to the engine on a cold or freezing day. This is one of the problems that biodiesel poses. Through this activity, if this extension to the preparation of biodiesel is undertaken, students will see how it is affected by cold temperatures.

It is interesting to note that petroleum companies allow for the change of the viscosity of a liquid fuel with temperature. The composition of a liquid fuel is designed to ensure it will have a suitable flow rate to the engine at the temperatures that are likely to be experienced. This is why the composition of petrol sold in the northern parts of Australia, for example, is different to that sold in Tasmania.

Comparing the viscosity of oils

A number of different technologies are available for measuring and comparing the viscosity of different fluids. One simple test that can be used in the laboratory to compare the viscosities of different oils involves a set of tubes that are rather like a spirit level. One commercial variety that uses relatively short tubes known as bubble viscometers is shown in Figure 1.

Figure 1 A set of bubble viscometers containing different oils

The oils are sealed into hollow glass tubes. One air bubble should be present. The tubes should have the same diameter bore and the same length and should be at the same temperature.

After holding them vertically until the air bubble travels to the top, the set of tubes is quickly inverted and placed in a vertical position. (They can all be set into a stand to ensure they are inverted at the same moment.) A stopwatch is started at this point. The time taken for the air bubble to travel from the bottom to the top is then measured. This of course is repeated at least twice and an average time is calculated. It is important that the tubes are not held in the hand, as this will change their temperature.

The greater the viscosity of the oil, the longer it takes the bubble to flow up to the top and the oil to flow down to take its place. From the positions of the bubbles in Figure 1, it can be seen that the oil on the right has the lowest viscosity and the oil on the left has the highest.

In this demonstration, a simpler comparison of the viscosities of the different biodiesels that have been produced can be made using just a teaspoon of each of the samples. The ability of the liquid to flow down from the teaspoon into a beaker or watch glass placed below it will show which liquid flows more easily (just like comparing water, honey and golden syrup).

LIST OF MATERIALS REQUIRED

For the conversion of one oil sample:

- 500 mL vegetable oil*
- 3.5 g solid potassium hydroxide freshly weighed
- 1 L beaker
- 100 mL glass measuring cylinder
- Tight-fitting latex gloves
- 100 mL methanol (methyl alcohol) from new bottle
- 1 L glass separating funnel and stand (or glass jar and lid)
- 500 mL or 1 L glass measuring cylinder
- Plastic funnel for filling separating funnel (see Figure 2 on page 97)
- Tub of safety glasses

For the conversion of palm oil, in addition to the above:

- Additional 1 L beaker
- Metal loop stirrer (as used in calorimeters)
- Large beaker of hot water at 60-65 ºC**

For the optional extension on viscosity, for each biodiesel sample prepared:

- 2 x 100 mL glass jars with lids and labels – one stating ‘refrigerated’
- 250 mL beaker
- 2 x teaspoons
- 2 x small beakers
- 0-100 ºC thermometer
- Access to refrigerator

Note:
*** If filtered fish and chip oil is to be used, this should be supplied pre-filtered. (See section on Practical Hints and Advice.)**
**** Check the temperature is in this range with a thermometer.**
All glassware should be clean and dry.
All the wastes from this demonstration should be poured into residue bottles and disposed of according to the safety protocols for organic liquids.

PRACTICAL ADVICE AND HINTS

Video of preparation

It is worthwhile viewing the video on preparing biodiesel at: http://www.youtube.com/watch?v=9-SaPRccSDE ***Note that the demonstrator in this case should be wearing safety glasses and should vent the reaction mixture. For canola oil, warming the oil may speed up the initial process, but is not necessary. In any case it would be safer to use sit the oil in hot water than to heat it on a hot plate. Also, the temperature is quoted are in degrees Fahrenheit. Despite these drawbacks, it is a very helpful video. The related website for his company is at www.utahbiodieselsupply.com. This has a lot of other useful advice under the title ‘Getting started’.***

PRACTICAL ADVICE AND HINTS continued

The oil

1The disadvantages of using palm oil are that it is difficult to source and it is a soft solid at around 22 ºC, which means its volume can only be measured after it is warmed and melted (see Procedure below). The other oils do not have to be heated. One source of palm oil is suppliers to cosmetic companies.

However, if it is available then it is worth testing because palm oil is widely used to produce biodiesel on a larger scale, which raises issues such as the conversion of arable land and destruction of rainforests in developing countries in order to grow it for this purpose. (It has other applications as well, such as in the cosmetics industry.)

2 Used oil from cooking fish and chips is worth testing, as long as it is not too old or contaminated, since this shows students how a waste product can be used to produce a useful biofuel. If the school tuckshop serves fried foods, it can be sourced from there. It can be used unfiltered and/or filtered. The filtered oil should be filtered through a very fine mesh strainer then through filter paper. A vacuum pump can speed up the filtration process through filter paper.

3 Preparing more than one kind of biodiesel will allow students to see that the rate of the reaction and the appearance of the products depends on which oil is used. Their viscosities can be compared as well.

4 The canola oil and palm oil should be fresh, from newly purchased sealed, containers. This is because vegetable oils go rancid. These reactions produce contaminants that will adversely affect the production of biodiesel.

Methanol

Methanol can be sourced from car supply shops. It is advisable to use a fresh sample from a sealed, recently purchased bottle. It works better than ethanol. The potassium hydroxide readily dissolves in it.

The catalyst

Potassium hydroxide works better than sodium hydroxide. The solid pellets should be kept sealed in their container until the moment it is to be weighed out. It then should be weighed out as rapidly as possible into a sealed 200 mL plastic container just prior to the demonstration. Why is this? When it is exposed to the air, solid potassium hydroxide absorbs carbon dioxide from the air, forming carbonate salts, which will contaminate it.

Moreover, it also absorbs water from the air, so much so that it eventually dissolves in the water. (Solids with this property are described as deliquescent.) Water must not be present for the reaction producing biodiesel. And the reason for the plastic container is that potassium hydroxide is one of the few chemicals that will react with glass.

Note : Sodium hydroxide exhibits all these properties as well.

Viscosity extension

1 If the biodiesel is to be tested in the extension, then the large separating funnel rather than the large glass jar should be used, so that it can be readily separated from the bottom layer.

2 The method suggested for the extension is much quicker than using bubble viscometers. However, if the school had these, they could be used instead.

SAFETY WARNING!

1 Never shake the liquids unless the reaction vessel is sealed. However, ensure you follow the instructions about venting the reaction vessel, so that increased pressure from any vapour build-up is released and the vessel does not shatter.
2 Eyes must be protected when using methanol and potassium hydroxide. See the Material Safety Data Sheets for these substances. It is advisable that the teacher and students wear safety glasses. Note the advice above advice about weighing out the potassium hydroxide.
3 Keep the bottle of methanol sealed except when measuring out some for the demonstration, to help avoid spills of the liquid and exposure to its vapours, which are toxic.
4 While peanut oil also produces a good result, teachers are advised not to use it in case any students have a peanut allergy.
5 ALWAYS ensure the tap of the separating funnel is closed (horizontal) before adding any liquid to it, as shown in Figure 2 on page 97.

RISK MANAGEMENT

View the MSDS for each chemical and also note the above safety warnings.

Although you should view the MSDS supplied by the companies that supply the potassium hydroxide and methanol you use, generic versions for these and for the products of the reaction can be found as follows:

Potassium hydroxide: http://www.miracosta.edu/home/dlr/msds/potassium_hydroxide.pdf

Methanol: http://www.csr.com.au/msds/MSDS/Methanol.pdf

Biodiesel: http://www.reefuel.com/data/msds/reeFUEL_biodiesel_MSDS.pdf

Glycerol (also known as glycerine or glycerin): http://www.sciencelab.com/msds.php?msdsId=9927350

An MSDS should not be required for food oils. But remember they are flammable, which is why heating the oil must be tightly controlled and the container should be resealed immediately after measuring it out. See the advice on performing risk assessments and the sample risk assessment proforma on pages 149-151 of this book.

ADVICE FOR THE CLASSROOM

Teachers are strongly advised to rehearse the demonstration prior to the class, to identify any problems and determine how to overcome them.

During the initial demonstration:

As you perform the demonstration, talk to the students about the reasons behind different aspects of the procedure, including safety precautions. These are discussed in the above practical advice and hints and safety advice.

NOTE: During your presentation, very able students may appreciate being shown the images of the molecular models of methanol, glycerol, biodiesel, and so on, provided in the additional chemistry information document. As stated earlier, these will be provided the as a PowerPoint presentation that can be accessed through the teacher portal of the STELR website.

At the end of the sessions:

Elicit as much as possible from the students as they observe the products and results of the viscosity extension (if performed). In order to gauge, and build up, their level of understanding. Also give them opportunities to ask their own questions.

PROCEDURE

Note: See also the recommended videos of the preparation of biodiesel.

Part A The initial preparation

Step 1 Set up the equipment. If you are using separating funnels, then place them in their stands.

Step 2 If you are using palm oil, then transfer some to a 1 L beaker until it is about two thirds full and sit this in the large beaker of hot water so that it can melt. Reseal the oil container. Add the metal loop stirrer to the oil and stir it occasionally over the next 10 minutes.

Step 3 For each oil tested, measure out 100 mL of methanol and add it to the container of pre-weighed potassium hydroxide pellets, screw the lid back on and start shaking the mixture to dissolve the potassium hydroxide. Immediately re-seal the methanol bottle.

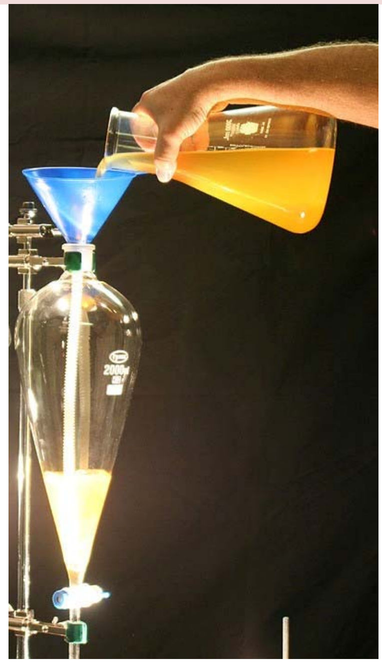
Step 4 Shake each methanol-potassium hydroxide mixture for 1-2 minutes, then hold it still and open the lid for a few seconds to let out any excess vapours so the vapour pressure does not build up. Reseal and shake again. Repeat this shaking and venting procedure twice, then set it aside. The potassium hydroxide should be totally dissolved in the next 5 to 10 minutes. Vent the mixture every 1-2 minutes over this time.

Step 5 By now the palm oil, if this is to be used, should have melted. If not, then replace the hot water and keep stirring until it has melted.

Step 6 Measure out 500 mL of each test oil into separate 1 L beakers.

Part B Performing the reaction

NB: THE FOLLOWING INSTRUCTIONS APPLY TO EACH INDIVIDUAL TEST OIL.



Step 1 By now the potassium hydroxide should be dissolved in the methanol. (It actually reacts with the methanol.) Pour this mixture into the separating funnel using the plastic funnel (after checking the tap is closed!), by the method shown in Figure 2, or pour it into the large glass jar.

Step 2 Carefully pour the oil **i**nto the separating funnel via the plastic funnel, as shown in Figure 2, or into the large glass jar.

Step 3 Seal the container and shake vigorously for 1 minute, then stop shaking, remove the stopper or lid to let out any excess vapours, reseal and shake again. Repeat this shaking and venting procedure twice. Then let the layers settle, and examine them.

Figure 2 Safely pouring oil into a separating funnel.

Notice that the tap is horizontal (closed).

Tight-fitting latex gloves must be worn for this when the liquid being added to the funnel is the methanol-potassium hydroxide mixture.

In this case a retort stand has been used. Notice in this case that the funnel is clamped in two places to hold it securely. (There also are special stands for separating funnels.)

Source:
http://www.chemistryland.com/Biodiesel/SmallScale/PourProductInSepFunnel.jpg
Accessed: 25 October 2010

Part C The next session

Have the students observe, describe and discuss the layers that have formed in the container.

Part D The optional viscosity extension

NB: THE FOLLOWING INSTRUCTIONS APPLY TO EACH INDIVIDUAL SAMPLE OF BIODIESEL

Step 1 Place a 250 mL beaker under the separating funnel. Tap off the bottom layer plus a little of the top layer into the beaker and immediately pour it into a residue bottle then seal the bottle.

Step 2 Next collect the biodiesel into the two labelled glass jars and seal them. Each jar should contain the same amount of biodiesel. Place the one labelled 'refrigerated' into a refrigerator for overnight. Repeat this for the other biodiesel if two different samples were prepared.

Step 3 The next day, remove the sample(s) from the refrigerator and show the students all the samples.

Step 4 Measure the temperature of the two samples as quickly as possible so that the refrigerated sample remains cold for the next step.

Step 5 Take one teaspoon of each sample and hold each teaspoon at the same height above a small clean dry beaker. Then let the oil flow into the beaker from the spoon and compare the flow rates of the samples at the different temperatures.

EXPECTED RESULTS

When the oil and methanol-potassium hydroxide solution are shaken, the mixture will be cloudy. It then will settle.

The palm oil mixture takes much longer to settle.

Figures 3 and 4 show what two of the mixtures should like on the first day, just after they are shaken.

Figures 5-8 show what they should look like after 3 days.

Figure 3 The initial mixture of palm oil, methanol and potassium hydroxide, just after shaking

Figure 4 The initial mixture of filtered fish and chip oil, methanol and potassium hydroxide, just after shaking.

Figure 5 The biodiesel (top layer) produced from fresh canola oil – viewed after 3 days

Figure 6 The biodiesel (top layer) produced from palm oil – viewed after 3 days

Figure 7 The biodiesel (top layer) produced from unfiltered fish and chip oil – viewed after 3 days

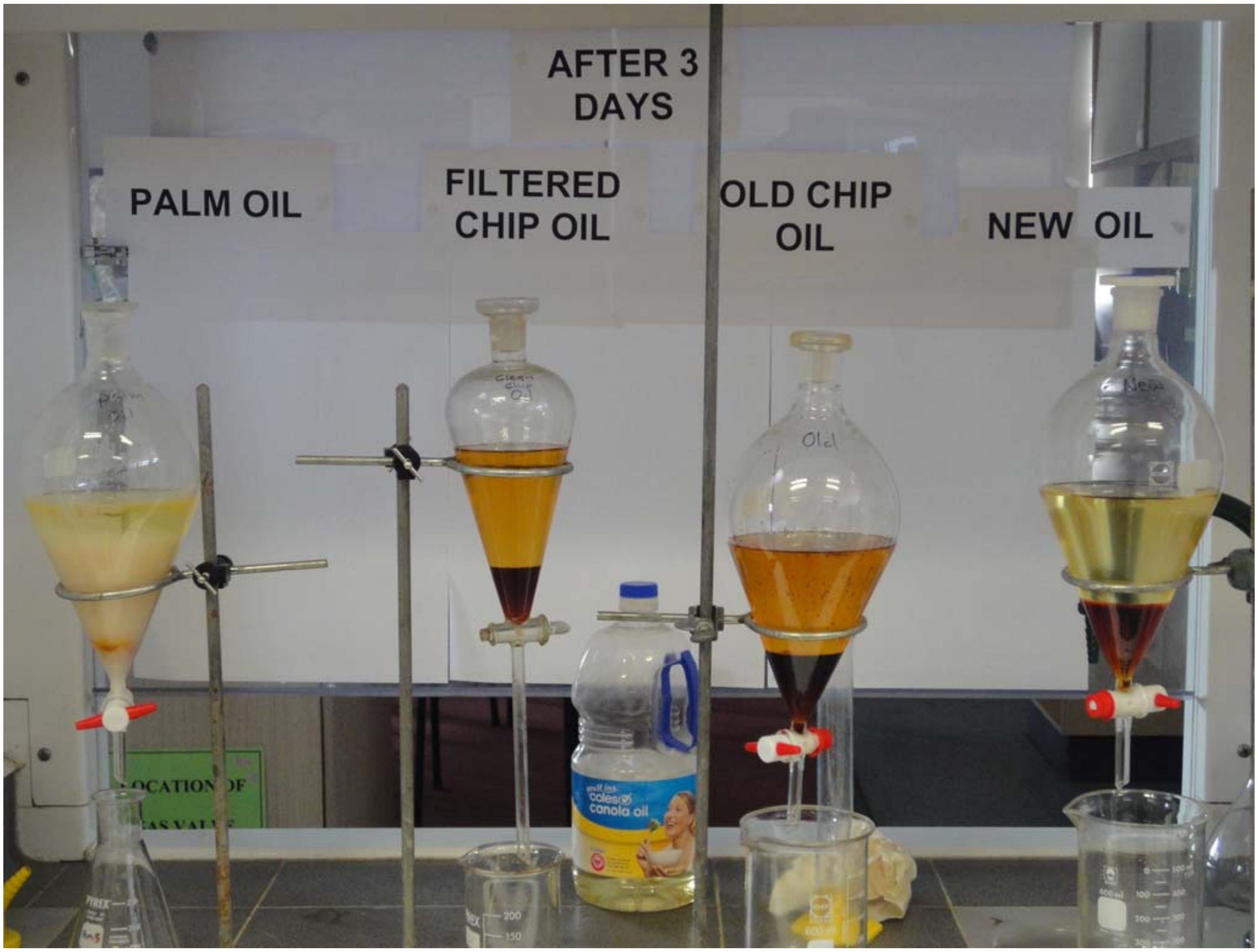


Figure 8 All four biodiesel samples after 3 days. It can be seen that the dbiodiesel produced from palm oil has taken much longer to separate out. It also can be seen that the old chip oil (unfiltered) contains particulate matter.

Part D: The viscosity extension

The flow rate of the biodiesel should be slower when it is colder. It may well form a gel and not flow at all until it is warmer.

ACKNOWLEDGEMENT

The STELR Project Team wishes to acknowledge and thank Mrs Iris Avery, Laboratory Manager, Box Hill Senior Secondary College, for all her invaluable advice and assistance in developing this demonstration, and for providing the images in Figures 3 to 8.

TOPIC: FUELS

ADDITIONAL IDEAS FOR INTRODUCTORY ACTIVITIES ON FUELS

OPTIONAL INTRODUCTORY ACTIVITY 1: TAKING A POSITION

This is a very lively form of debate that requires everyone to be involved.

But don't do this if you have already used this idea for global warming.

Designate different parts of the room for different viewpoints on using coal to generate electricity, and exporting Australia's coal to other countries to generate electricity and for steel-making.

Ask the students to move to the corner that best matches their viewpoint. (They cannot 'sit on the fence'.) Tell them they will need to defend this viewpoint.

Give each group a few minutes to produce a list of arguments and to elect a spokesperson to argue their case. Each spokesperson has two minutes to speak.

After the speakers have finished, have the class analyse their arguments.

• Were these arguments based on reliable evidence?

•Where did their ideas come from?

Then give the students the opportunity to move to another part of the room as a result.

Advice for the classroom

Mining and using coal is a very important issue which can concern many students. It can be a very emotive issue for some, especially if they are very fearful of the contribution of the burning of coal to global warming and to the build-up of other pollutants in the atmosphere, or if the livelihood of their family is tied up in the coal industry. It therefore needs to be handled sensitively. Insist that the students treat those who have other viewpoints with respect.

Do not put students who have problem verbalising their thoughts in an embarrassing position in this activity. Maintain a positive and encouraging atmosphere.

OPTIONAL INTRODUCTORY ACTIVITY 2: WHAT ARE COAL AND CRUDE OIL LIKE?

Set up a display of some different samples of coal and/or crude oil.

In the case of brown coal or black coal, put a label showing how long that mass of coal can run a 60 W light globe, according to the table below. This is drawn from the graph in Figure 2 page 100 of the student booklet, and assumes that 100 % of the energy content stated in that graph is obtained. If the power station is just 30 % efficient, then the mass actually required may be 100/30 times more than the mass stated in this table.

Type of coal	Brown	Black (bituminous)	Black (anthracite)
Electrical energy required to run a 60 W globe for 1 hour	216 kJ	216 kJ	216 kJ
Average number of gram of coal that must be burnt to run a 60 W globe for 1 hour	216 ÷ 25 **= 8.6 g**	216 ÷ 33 **= 6.5 g**	216 ÷29 **= 7.4 g**

TOPIC: FUELS

STUDENT ACTIVITY SHEET 7: WHAT KINDS OF FUELS ARE THERE? – INFORMATION AND SUGGESTED SOLUTIONS

STUDENT BOOKLET pages 44-52

BACKGROUND INFORMATION

Natural gas and the lighter constituents of crude oil are essential raw materials for the production of pharmaceuticals, plastics, synthetic rubber, dyes, solvents, detergents, and so on. The most useful number of carbon atoms per molecule for these purposes is 2. Molecules containing 3 or 4 carbon atoms are also very useful.

The molecules present in crude oil that contain about 20-30 carbon atoms per molecule are separated out and used as tar and bitumen, and paraffin wax for candles.

The problem is that the lighter molecules that are essential for the production of many chemicals are also those that flow, ignite and burn most easily. For this reason they are also are used as a source of energy - for transport, heating and the generation of electricity. How can these competing demands be met?

The composition of crude oil depends on its origin. A lot of crude oil only has a small percentage of the most useful molecules. Even though some of the heavier molecules present can be broken up into smaller, more useful molecules by a process called **cracking**, there clearly needs to be a reduction in the amount of lighter molecules consumed as fuels, especially since there is a limited amount of crude oil available because it is a non-renewable energy resource.

It should be pointed out that the same dilemma applies to bioethanol. It has many other applications besides being consumed as a fuel. These range from boosting the alcohol content of wines and spirits to being the main constituent of various solvents to the manufacture of a range of useful chemicals.

See also the background information on biodiesel and the comparison with mineral oils on pages 87-91 of this book.

SUGGESTED SOLUTIONS TO QUESTIONS

1 *Suggested responses to Table 6, page 52 of the student booklet.*

Table 6

Feature	Fossil fuels	Biofuels
Renewable or non-renewable?	Non-renewable	Renewable
Formed up to millions of years ago, or recently?	Thousands or millions of years ago	Recently
Formed from organisms that are alive now or that once lived, or from non-living materials?	Formed from organisms that lived thousands or millions of years ago	Formed from plants or microalgae or bacteria, etc., that are still living or that have just been harvested
What must be present for them to burn?	Oxygen and a spark	Oxygen and a spark
When they burn, what are the two main substances produced?	Carbon dioxide gas and water (in the form of steam)	Carbon dioxide gas and water (in the form of steam)
Do they produce greenhouse gases when they burn?	Yes	Yes, but there is a lower net production of greenhouse gases
What is one danger that must never be forgotten when processing, storing, transporting and using them?	The danger of an uncontrolled fire or explosion	The danger of an uncontrolled fire or explosion

What are some examples of each kind of fuel?	Natural gas, LPG, kerosene, petrol, diesel (also known as petrodiesel), coal	Biogas, bioethanol, biodiesel
Can any of them be used to generate electricity? Which ones? Is this on a small scale or large scale?	Petrol and diesel are used in small-scale generators. Natural gas is used in large-scale gas-fired power stations. Coal is used in large-scale coal-fired power stations.	Of these, biogas is the one that is mainly used to generate electricity, though only on a small scale.
What are some examples of other ways they can be used?	The constituents of natural gas and petrol can be used to produce pharmaceuticals, plastics, dyes, etc.	Bioethanol is used to produce many useful substances, including solvents.

2 *Student response*

3 *Student response*

TOPIC: FUELS

RUNNING PRACTICAL ACTIVITY 3: PRODUCING BIOETHANOL

STUDENT BOOKLET pages 53-57

SYNOPSIS

This is a class experiment, in which bioethanol is produced from a solution containing sugar and yeast. Some student groups will collect the gas produced during this fermentation process in a balloon, and work out how to measure its approximate volume, which provides them with an interesting challenge. The remaining groups will test the gas produced, either by bubbling it through water to which some universal indicator has been added, or by using the more specific limewater test. The universal indicator solution option, which is the one outlined in the student booklet, is the recommended method. Not only is it safer but also it ties this experiment in with Practical Activity 1.

The experiment is designed so there is minimal risk. The only laboratory chemical involved is just a few drops of universal indicator solution, unless the teacher chooses to use limewater instead.

APPROXIMATE TIME REQUIRED

30-40 minutes for the initial experiment. Some brief observations are required over the next three days, since the reaction is slow. The discussion of the experiment and cleaning and packing away the equipment will each take extra time.

BACKGROUND INFORMATION FOR THE TEACHER

The fermentation reaction

The balanced chemical equation for the fermentation of glucose is:

$$\underset{\text{glucose}}{C_6H_{12}O_6(aq)} \xrightarrow{\text{yeast}} \underset{\text{ethanol}}{2C_2H_5OH(aq)} + 2CO_2(g) + \text{energy}$$

The balanced net chemical equation for the fermentation of table sugar (sucrose) is:

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}(aq)} + H_2O(l) \xrightarrow{\text{yeast}} \underset{\text{ethanol}}{4C_2H_5OH(aq)} + 4CO_2(g) + \text{energy}$$

The energy produced is used by the yeast organisms for movement, reproduction, cellular processes, and so on.

Theoretically, for each gram of table sugar actually reacting, 0.27 L of CO_2 gas should be produced at 22 ºC and normal atmospheric temperature. However, the reaction will be stopped before the collecting balloons burst. This means that only a small proportion of the sugar will have reacted by the time the reaction is stopped.

LIST OF MATERIALS REQUIRED

Per student pair:

- 25 g white sugar (pre-weighed)
- 250 mL conical flask
- 100 mL measuring cylinder
- Glass stirring rod
- 2.5 g powdered yeast (pre-weighed)
- 500 mL beaker (to sit conical flask in)
- Thermometer (or temperature sensor)

Per student pair in Group A:
- Balloon

Per student pair in Group B:
- Delivery tube inserted in one-holed rubber stopper
- Small dropper bottle of universal indicator solution and pH colour chart
- Test tube and test tube rack

Optional – per student pair if limewater is used:
- Small dropper bottle of limewater
- 2 pairs of safety glasses and 2 pairs of tight-fitting latex gloves

SAFETY WARNING!

1 Only substitute limewater for the universal indicator solution if you feel confident that students will use it safely. They must wear goggles and protective gloves if they are to handle limewater solution.

2 Ensure you work through the risk assessment section in the student instruction sheets with the students BEFORE letting them start the experiment.

3 To safely smell the solution after fermentation has taken place, the students should fill their lungs with fresh air and then gently waft some of the vapours from the solution past their nose and take a shallow 'sniff'. Then breathe out. That way they should only get a very small amount of the vapours inside their nasal cavity and none should enter their lungs. Learning this technique is a good lesson for students.

4 It would be wise to conduct this experiment in a well-ventilated room and to store the fermenting solutions in a prep room rather than a classroom.

5 Ensure the students do not attempt to drink the solution!

6 It is far safer to supply the delivery tube already inserted into the rubber stopper, or students may break the glass tube and cut themselves trying to insert it.

PRACTICAL ADVICE AND HINTS

1 It is far more time-efficient to supply the sugar and yeast pre-weighed.

2 The delivery tube must fit tightly into the hole and the rubber stopper must fit tightly into the flask.

3 Use a good quality rubber balloon that is less likely to leak over the time of the experiment. But stop the experiment as soon as the balloons are blown up to a reasonable size, before they burst.

4 Ideally, all student pairs should start and stop the process at the same time, for valid comparisons of their results.

5 One method of measuring the volume of gas in a balloon is to quickly seal the balloon and plunge it just under the surface of water in a large beaker. Mark the level of the water before and after. Then use a large measuring cylinder to determine what volume of water is required to make the water level rise by that height. It is therefore worth having this equipment in readiness, though hidden from the students.

6 The reason for having a warm mixture to start with is that this helps 'kick-start' the fermentation process. Ideally this temperature should be maintained, as this is the best temperature for the yeast organisms to act. However, in most schools it is not practical to maintain this temperature.

RISK MANAGEMENT

Teachers need to actively supervise this activity.

Possible responses to the students' risk assessment activity are shown below.

Student activity sheet: Table 2

The facts	What might be the risks?	What precautions will we take?
1 The equipment, including the thermometer, is made of glass.	The glass could break if mishandled.	Handle the glass with care.
2 Universal indicator solution can stain skin and clothes etc.	The solution could accidentally spill.	Gloves and laboratory coats could be worn whilst handling the solution. Keep the bottle way from where it may be knocked over, and place the lid on the dropper bottle immediately after use, to prevent it spilling.
3 Universal indicator solution and the fermentation mixture are both poisonous.	Some of either solution could accidentally be ingested if anyone gets some on their fingers.	Wash hands thoroughly after handling so that they cannot be ingested. Wipe up any spills immediately.

ADVICE FOR THE CLASSROOM

See also the general advice provided on pages 28-29.

Teachers are strongly advised to:

1 Trial the activity prior to the class, to identify problems the students might encounter and to judge the time they need.
2 Decide how to best manage the activity, particularly how to divide the class, where to store the mixtures over the time required, and at what times the additional observations can be made.

Setting up:

Have a demonstration set of equipment and materials ready to show the students during the introductory discussion.

Introducing the activity:

1 Elicit from the students what they already know about yeast and the fermentation of sugars.
2 Talk about the activity and demonstrate the most important points, including how to safely smell the vapours coming from the solution.
3 Work through the risk assessment and safety precautions to be taken, eliciting as much as possible from the students.

During the sessions:

1 Watch that the students wipe up any drips and spills immediately and that they observe all of the agreed-upon procedures and safety precautions.
2 Have the students place their fermentation mixtures somewhere safe for observing over the next three days.
3 Ensure the students do not prematurely loosen the balloons when taking their observations.
4 Encourage the students to devise a way of measuring the volume of the gas produced.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report their findings. They should discuss what they found interesting or unexpected, problems they encountered, their conclusions and their responses to some or all of the discussion questions. Ensure each group contributes to the discussion.

This part of the session should take about 10 -15 minutes.

EXPECTED RESULTS

Typical results for Part A

As stated in the introduction, for each gram of sugar reacting, theoretically 0.27 L of CO_2 should be produced at 22 ºC and normal atmospheric pressure (1 atmosphere, or 760 mmHg). The students are using 25 g of sugar. However, since the students are just collecting the gas in a normal-sized balloon, the reaction should be stopped before the volume of gas collected even reaches 1 litre.

The volume recorded by the students will depend on a number of factors, however. These include:

1 The actual temperature and pressure of the gas at the time the volume is measured.
2 The total time allowed.
3 The rate at which fermentation occurs over the period of the experiment (which will depend on the ambient temperatures over the time and the efficacy of the yeast) and hence the extent to which the reaction takes place.
4 The porosity of the balloon
5 The way in which the students seal the balloon and measure its volume.

When the students sniff the solution, it should have an odour similar to fermenting fruit.

Typical results for Part B

The students should find that the universal indicator turns orange. It may also turn red depending on the indicator used and the amount of CO_2 produced.

Limewater, if used instead, will turn milky then may go clear again.

When the students sniff the solution, it should have an odour similar to fermenting fruit.

SUGGESTED SOLUTIONS TO QUESTIONS

1 *Students who use universal indicator to test for carbon dioxide should comment that their results only really show that an acidic gas was produced. There are other acidic gases besides CO_2.*

2 a Fermentation will stop after a while because the alcohol produced is a waste product and is toxic to yeast organisms. As soon as its concentration builds up to a certain level, the yeast organisms die, after which the fermentation process cannot proceed.
b Like other living organisms, yeast organisms need energy to grow, reproduce, move, and so on.

3 a An average is considered to provide a more reliable value than any individual result.
b This is the temperature at which yeast organisms best carry out fermentation. Higher temperatures will kill them. If the temperature is too low they would be dormant.

TOPIC: FUELS

RUNNING PRACTICAL ACTIVITY 4: DISTILLING AN ETHANOL MIXTURE

STUDENT BOOKLET pages 58-65

SYNOPSIS

This is an excellent follow-up activity to Practical Activity 3. It highlights the fact that most fuels are purified or extracted by a process of fractional distillation.

In this practical activity, students use micro-scale equipment to perform a distillation that models the kind of process that is used to separate ethanol from a fermentation mixture. Even if they perform Practical Activity 3 prior to this experiment, they will not distill the final mixture of ethanol, remaining sugar, yeast and water. The reason is that this would require Quikfit apparatus, which is very expensive, difficult for younger students to assemble, and easily broken.

In this practical activity, students distil what they are told is an ethanol mixture, but which in fact is methylated spirits to which a vegetable dye has been added. The methylated spirits, which is colourless, is separated from the dye; it therefore is obvious that a separation has occurred.

The reasons for not telling them what the ethanol mixture actually consists of are as follows.

1 The notion of extracting some ethanol from a mixture containing ethanol by distillation ties in better with the fermentation activity.

2 Many students may become confused if they are told they are using methylated spirits for heating as well as distilling it.

This activity also provides an opportunity for students to experience the use of methylated spirits as a fuel.

The experiment is designed so there is minimal risk. The only chemicals students handle are very small volumes of methylated spirits and silicone oil. The heat source they use is about the same size as a small birthday candle!

APPROXIMATE TIME REQUIRED

40 minutes

BACKGROUND INFORMATION FOR THE TEACHER

The micro-scale equipment

Micro-scale equipment has many advantages over the normal scale of equipment. Advantages include:

- Students really enjoy using it; it therefore encourages them to be actively involved in the activity rather than spectators.
- Only minute amounts of chemicals are used and waste produced. This models sustainable practice and also reduces risk.
- Spills are less likely because the equipment is set in trays.
- The students' repertoire of practical skills is increased.
- This is great preparation for students who will enter fields such as medical testing, which also works on a very small scale.
- Although there is an initial investment to purchase the equipment, it is much more cost-effective, because it is less breakable, and the cost of chemicals and waste removal and treatment is significantly reduced.
- A dedicated science laboratory is not required.

This is why this equipment is increasingly used by universities and correspondence schools for external students, and schools that do not have science laboratories. [The only Australian supplier of this equipment is Westlab. See www.westlab.com.au]

Methylated spirits

Known as 'denatured alcohol' in some countries, methylated spirits is mainly a mixture of two alcohols – methanol (CH_3OH) and ethanol (CH_3CH_2OH). Both alcohols are toxic, in fact, but ingestion of even a small amount of methanol can lead to blindness. So it is added to deter people from drinking methylated spirits. Some bitter tasting compounds are also added for the same reason. Another purpose of the additives is to make it difficult for consumers to distil the liquid to obtain pure ethanol. This is achieved by selecting additives that have boiling points that are very close to that of ethanol. In this distillation, these constituents will not be separated from one another.

LIST OF MATERIALS REQUIRED

For each student pair or group:

- Combo-Still set
- Microburner containing methylated spirits
- Box of matches
- Small spatula
- Unlabelled bottle containing 3-4 mL methylated spirits coloured with food dye
- Small Petri dish
- Small jar of micro boiling chips (boiling stones)
- Paper towel

In addition you need:

- Tub containing 1 pair safety glasses per student
- Box containing 1 pair tight-fitting plastic gloves per student
- Bottle of methylated spirits from a supermarket, for display. (Students are asked questions about this.)
- Waste bin for used paper towels

PRACTICAL ADVICE AND HINTS

The 'boiling stones'

1 It is advisable to give students just a small spatula-full of the 'boiling stones' supplied in a small jar, rather than the packet that comes with the Combo-Still kit.

2 Do NOT substitute 'normal' porcelain boiling chips used with Quikfit apparatus for these 'boiling stones'; they are not suitable for a micro-scale distillation!

3 If the equipment is used several times in succession, it is best to change the boiling stones frequently. Otherwise their pores will clog and they will not be able to fulfill their very important function.

The silicone oil

The silicone oil can be kept in the glass bottle. A lid is provided to seal it. Once heated, do not put it back into the supply vessel. It can be used for 8-10 distillations, however, after which it should be changed.

The food dye

Queen green food colouring works well. It is very evident that this has been removed from the methylated spirits in the distillation. This is the dye shown in the photographs in the student instructions.

The Combo-Still

1 If the equipment is only used for this distillation experiment, then the condenser and collecting vessels will not need to be washed out, as the substance recommended for cleaning them is methylated spirits and that is all they have been exposed to. However, leave them to dry out before packing them away.

2 Remove from the kit the items that students will not use, prior to giving them to the students.

3 The student instructions have been written with the assumption that teachers will supply the condenser with the glass beads already added. The condenser should have some plastic wrap over the end or a tiny 'plug' inserted to prevent the glass beads from spilling out. These will need to be removed, of course, when the equipment is set up. This will expedite the experiment considerably and help avoid the problem of 'lost' beads rolling over the benches and floors. If teachers are concerned about this problem, they can try not using them at all.

The microburners

1 In the student instructions it also is assumed that teachers will supply the microburners already set up. This again will save time and avoid spills. Use a dropper to add the (undyed) methylated spirits until the container is about 2/3 full. Ensure this is only done when it is cold. It is not safe to pour methylated spirits whilst there is a flame or hot equipment nearby.

2 Figure 1 on the next page shows a microburner that has been set up. Note how the wick is threaded through the 'pipe' in the lid. Only a short section (about 1 cm) is exposed at the top for the flame; most is coiled within the methylated spirits. By the end of the distillation, there will be very little methylated spirits left.

Figure 1 The microburner

RISK MANAGEMENT

Teachers need to actively supervise this activity.

Note:
1There is a link to a MSDS for methylated spirits in the student edition of this experiment.
A suitable link for the MSDS of silicone oil is: http://www.eutechinst.com/msds/Updated_MSDS/silicon_oil_rev0.pdf
2 See the advice about performing risk assessments and the sample risk assessment proforma on pages 149-151 of this book.

SAFETY WARNING!

Ensure the students are very careful when inserting the thermometer into the 'hole' in the Combo-Still Head. Show the students how to hold it near the bulb as they slide the bulb in. This will avoid accidental breaking of the thermometer, which could cause students to receive cuts from broken glass.

Possible responses to the students' risk assessment activity are shown below. Try to elicit as many responses as possible, as students will be more likely to be careful if they have thought about this for themselves. But also ensure they feel confident enough to 'have a go'.

Student activity sheet: Table 1

The facts	What might be the risks?	What precautions will we take?
1 All the liquids in this experiment are flammable.	If any of the liquids spill and there is a flame close by, it could cause a small fire.	Avoid spills - handle the equipment carefully and put lids back on bottles as soon as possible. To prevent a fire, any spilt liquid should immediately be wiped up with dry paper towel and the paper towel removed from the area.
2 When using the microburner, once the end of the wick has burnt, the flame from burning methylated spirits is hard to see, as shown in Figure 2.	Someone could put their hand near the flame without realising it is there, and be burnt.	Do not put hands close to the burner until after it has been blown out and then cooled.
3 The liquids being heated will expand.	If the bottles are too full, the liquids will not have enough room to expand. Since the silicone oil is sealed in, its expansion could cause the glass bottle to break. Then someone could be cut and burnt.	Do not fill the bottles to a higher level than the instructions say.

4 Heated glass can get very hot.	Anyone who touches it when hot would get burnt.	Do not touch the equipment until it has had time to cool down.
5 The ethanol mixture and the methylated spirits in the microburner both will sting eyes and any cuts and abrasions on the skin. They also can irritate even unbroken skin.	If any spills occur, people could get it in cuts or accidentally rub it into their eyes.	Gloves and goggles could be worn whilst assembling or dismantling the equipment. Wipe up any spills immediately, using dry paper towels.
6 All the liquids being used are poisonous.	If any is accidentally ingested, it could sting the mouth and so on, and also cause someone to be ill.	Avoid getting any in the mouth. Wash hands with soap and water after handling it.
7 If thermometers are not very carefully handled, they can break, producing very sharp pieces of glass.	The glass thermometer could break when inserting it, and someone could get badly cut.	Follow instructions about handling the thermometer very carefully.
8 Latex gloves will melt onto skin if they are heated by a flame or a very hot object.	If someone leaves their gloves on whilst lighting the burner and handling the hot equipment, they could receive a bad burn.	Do not wear gloves whilst lighting the microburner or during the heating and cooling phases.

ADVICE FOR THE CLASSROOM

See also the general advice provided on pages 28-29.

Teachers are strongly advised to try the activity prior to the class, to identify problems students might encounter and to judge the time they need.

Setting up:

Have a demonstration set of equipment ready to show the students during the introductory discussion. You may wish to set up a set of Quikfit apparatus for a distillation as well, to show the students the apparatus that many chemists would use in the laboratory.

Introducing the activity:

1 Elicit from the students what they already know about distillation. Ask them if they know what a 'still' is.
2 Talk about the micro-scale equipment and demonstrate the most important points about how to set it up. This includes working through the risk assessment with the students, eliciting as much as possible from them.

During the session:

1 Watch that the students wipe up drips and spills immediately and that they follow all the agreed safety precautions.
2 Watch that the students observe the liquid dripping from the condenser very carefully. They need to change the collection wells before they overflow.
3 If the coloured liquid is boiling too vigorously, help the students raise the vessels so the flame is not as close.
4 Ensure the students stop the distillation once about half the coloured liquid has boiled away, by blowing out the flame. (The liquid will continue to boil for a short while after this due to the heat energy stored in the oil.)
5 If they are to dismantle the equipment themselves, advise the students to remove the microburner before unscrewing the bottles, or oil will drip down onto the burner. They should place paper towel under the bottles to catch the drips.
6 Ensure the students put the lids on the two glass bottles straightaway, once the equipment is cool and they are dismantling it.

At the end of the session:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report their findings. They should discuss what they found interesting or unexpected, problems they encountered, and their answers to some or all of the discussion questions. Ensure each group contributes to the discussion.

This part of the session should take about 10 minutes.

EXPECTED RESULTS

1 The flame for methylated spirits is almost invisible. See Figure 1. Little smoke is produced. (If the wick has waxed ends, it will burn brightly and produce smoke whilst the wax is burning.)
2 Small numbers of tiny bubbles will rise up in the silicone oil once it is heats up. (The boiling chips help control this.) This process should be steady throughout the distillation.
3 After another couple of minutes, the coloured liquid should start to boil quite vigorously, though in a controlled way. (The boiling stones help control this.)
4 In about another minute, a clear liquid will rise up into the condenser, then eventually trickle down into the collection wells. The temperature is likely to be around 72 ºC.

SUGGESTED SOLUTIONS TO QUESTIONS

1 *Student response.*

2 a The ethanol gas would be flammable, so it must be prevented from leaking out near the flame, which could cause a fire.
b The boiling stones are added to control the boiling, so the liquids do not get large bubbles in them. Large bubbles could make the coloured ethanol mixture 'whoosh' up into the condenser.
c If the level of the coloured ethanol solution was too high in the bottle, it could boil up into the condenser. If the level of the silicone liquid is too high, when it expands it could cause the bottle to break.

3 a This controls the boiling better and also makes it less likely that the ethanol mixture catches on fire.
b The beads provide more surface for the vapours to cool on, and help slow their passage down the condenser, which again gives the vapours more chance to cool and condense.
c The ethanol boils at a lower temperature than the rest of the mixture, so turns into a gas first.

4 If the colorless liquid were water, not ethanol, the gas would be steam, which would have the same temperature as boiling water, which is 100 ºC. The temperature of the gas coming over was only 72 ºC (*student result should be stated here*), so it was not simply water.

5 It is light, it flows easily to the wick, it burns with quite clean flame (that is, there is little smoke), and the flame is easy to put out. (Its flame can be extinguished by water, unlike an oil fire.)

6 a *The warnings and first aid advice on one brand (Recochem) sold in Australia and New Zealand read as follows. They are very clearly laid out.*

CAUTION
Keep out of reach of children
Flammable (symbol for Flammable Liquid 3 also shown)
Do not swallow
. . .
Use undiluted as a fuel for burners. For safe use when filling ensure burner has no flame and has cooled down before re-filling.
…
First aid: For advice, contact a Poisons Information Centre (contact numbers supplied) or a doctor. If swallowed, do NOT induce vomiting.

Most would consider these warnings and the first aid advice sufficient for the general public.

b Yes it does have a child safety cap. This is a good idea, since it can harm children if they swallow it or get it in their eyes.

Find out!
Other uses of methylated spirits include solvent, cleaner, disinfectant for small wounds, drying up pimples and cold sores, wick cleaner for kerosene lamps, and preserving biological specimens (less expensive than the preservative usually used).

TOPIC: FUELS

STUDENT ACTIVITY SHEET 8: FAMILIES OF CHEMICAL REACTIONS – INFORMATION AND SUGGESTED SOLUTIONS

STUDENT BOOKLET pages 66-72

BACKGROUND INFORMATION

Is a reaction happening, or not?

Teachers need to alert students to the fact that some signs of change do not necessarily mean that a chemical reaction is occurring. When a liquid boils, bubbles are seen. When some solids sublime and when some liquids evaporate, an odour will be noticed, because their particles are now dispersed through the air and can enter your nasal cavity. These changes of state are not chemical changes. When some solids dissolve in a liquid solvent, they simply break up into smaller particles that are dispersed through the solvent without reacting with it. When the solvent is evaporated, they are recovered. Such cases are often described as physical changes.

How chemists classify reactions

In general chemists are mostly concerned with classifying reactions in terms of the reactants and products involved, and the mechanism by which the reactions occur. Whether the reaction is exothermic or endothermic is more significant in terms of the conditions under which the reaction needs to be performed, and the purpose of the reaction.

For example, if the purpose of the reaction is to supply heat energy or electrical energy, then a suitable reaction is selected for this purpose. Factors such as the energy released per given amount of reactants, cost, accessibility, safety and environmental impact, will all be taken into account in this selection process.

But if the purpose of the reaction is to produce a new material, then the amounts of reactants and the reaction conditions, including temperature, are selected to ensure the reaction produces the required amount of product at the desired rate. The temperature selected will partly be determined the amount of energy produced or released in the reaction, per given amount of reactants.

Note that there are many more classes of reaction than have been outlined to the students. Others include:
- Precipitation reactions
- Polymerisation reactions
- Esterification reactions
- Corrosion reactions
- Decomposition reactions

All reactions can be classified in more than one way. For example, corrosion reactions are another subset of redox reactions. Polymerisation reactions can be further classified as an addition polymerisation reaction or a condensation polymerisation reaction, depending on their mechanism.

What really happens in acid-base and redox reactions?

Acid-base reactions involve the transfer of protons (H^+ ions) from the acid to the base.

Redox reactions involve the transfer of electrons from the reductant to the oxidant

Visualising the classes of reaction

Figure 1 on the next page may be a useful flow chart for showing the information in the student booklet in a more visual way. However, it is just one way in which the information may be represented. The teacher may choose to extend this chart to include other classes of reaction with which the students are familiar. Figure 2 shows more basic information in the form of a Venn diagram. This does not refer to redox reactions.

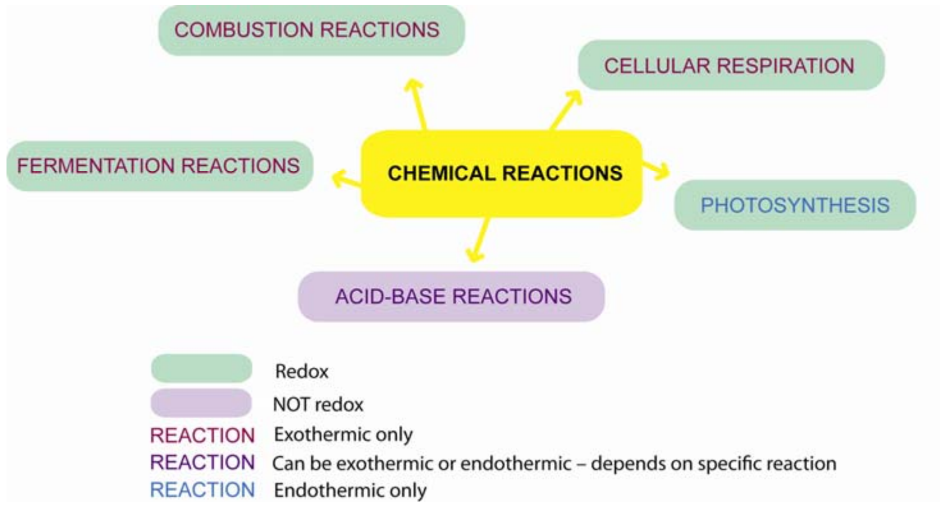


Figure 1 One representation of the classes of chemical reactions outlined in the STELR Chemistry Program, with a key

SUGGESTED SOLUTIONS TO QUESTIONS PAGES 69-70

1 a Energy transformation is the changing of one form of energy into another, whereas energy transfer is the moving of a particular form of energy from one place to another.

b Exothermic reactions are ones in which energy is 'produced', as result of the transformation of chemical potential energy into another form of energy, such as heat energy. In this case the temperature of the substances present will go up. Endothermic reactions are ones for which energy is required. These involve the transformation of a form of energy (such as heat energy) into chemical potential energy. In this case the temperature of the substances present will go down, or else the reaction will not occur unless sufficient energy is supplied to the reactants (such as heat energy, light energy or electrical energy).

c A chemical reaction involves the production of new chemical substances, while a change of state involves changing from a liquid to a gas, etc. No new substances are produced in this case.

2 a Exothermic

b Chemical potential energy → Heat energy

c The transfer of heat energy from the chemicals to the outside layer of the heat pack, to the skier's hands.

d Alternative II

e It spreads the heat energy out more evenly so the pack does not get too hot in one spot and burn the skier.

SUGGESTED SOLUTIONS TO QUESTIONS PAGES 71-72

1 Figure 2 shows one possible solution.

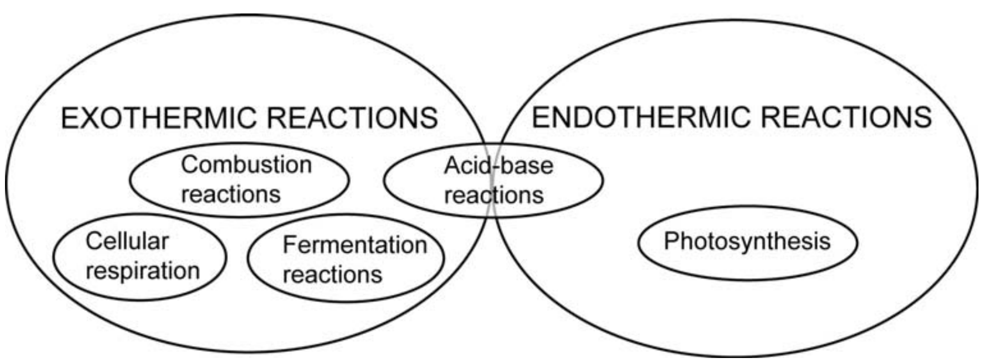


Figure 2 One possible Venn diagram

2

Reaction	Exothermic or endothermic?	Acid-base, combustion, or fermentation?
In peaches rotting on the ground, in the presence of yeast: **sugar → alcohol + carbon dioxide**	Exothermic	Fermentation
In spirit stoves used for camping: **alcohol + oxygen → carbon dioxide + water**	Exothermic	Combustion
Dissolving a sea shell in lemon juice. It is observed that the temperature of the mixture rises slightly. **calcium carbonate + citric acid → calcium citrate + carbon dioxide + water**	Exothermic	Acid-base
When biogas is burnt to generate electricity: **methane + oxygen → carbon dioxide + water**	Exothermic	Combustion
Photosynthesis, in the presence of light and chlorophyll: **carbon dioxide + water → glucose + oxygen**	Endothermic	None of these. They are redox reactions.

3 a Alternative II
b Electrical energy → Chemical potential energy
c Endothermic
d Oxidation- reduction reaction
e From the worded equation shown in Question 3 a, carbon dioxide is produced in the reaction in which the aluminium is obtained from its ore. If the large amount of electricity required is generated by the combustion of a fuel such as natural gas or coal, then further carbon dioxide is produced. Since the production of aluminium is on a large scale, this industry is a major contributor to the problem of global warming.

4 a $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$
REACTANT **PRODUCTS**

b Gas
c Aqueous (dissolved in water)
d To show that in chemical reactions, the atoms are only rearranged. It is only with these relative numbers that the total number of oxygen atoms we start with equals the total number of oxygen atoms we finish with. The same is true for the total numbers of hydrogen atoms and carbon atoms present.
e This equation tells us that for every molecule of glucose reacting, 2 molecules of ethanol and 2 molecules of the greenhouse gas carbon dioxide are produced.

Challenge questions

5 For a chemical reaction to occur, the particles of the reactants have to collide with each other. In a solid the particles cannot move from place to place, so two solids cannot react with each other.

6 If the substance has simply dissolved, it should be able to be recovered by evaporating away the liquid. If there has been a chemical reaction, this should be able to be detected. For example, if it is an acid-base reaction then an indicator should show this has occurred.

TOPIC: THE CONSERVATION OF ENERGY, AND ENERGY EFFICIENCY

IDEAS FOR INTRODUCTORY ACTIVITIES ON THE CONSERVATION OF ENERGY AND ENERGY EFFICIENCY

SYNOPSIS

These two alternative teacher demonstrations show different examples of 'wasted' energy. They are intended to be a good discussion starter before launching into the relevant mathematics of energy efficiency.

The follow-up activity – an excursion to a power station - is an excellent way to reinforce these concepts, if it is at all possible.

ADVICE

Rather than converging too quickly to the key science ideas, whichever demonstration you select, treat it as principally one in which ideas from the students are expressed, shared and discussed. But by the end of the discussion, students should have at least begun to develop a common understanding of the conservation of energy and 'wasted' energy.

Either activity will enable the teacher to identify whether any students still have alternative conceptions about what happens to energy as it undergoes transformations and to help the students gain a clearer understanding of the concepts involved.

Flow charts are a very useful way to trace the series of energy transformations that might occur. These can be annotated to show where energy might be 'wasted'.

Through these discussions and their subsequent practical work it is important that students realise that:

1 One key factor in determining the viability or suitability of energy resources is their energy efficiency.

2 No energy transformation is 100 % efficient.

OPTIONAL INTRODUCTORY ACTIVITY 1: GENERATING AN ELECTRIC CURRENT

Set up the STELR hand-cranked generator connected to the lamp on the STELR testing station.

Ask the students whether they think all of the energy invested in turning the handle is transformed by the lamp into light. If not, where in the series of energy transformations occurring is the energy 'lost' (wasted)? Can energy just disappear? What happens to the 'wasted' energy?

Lead the discussion to other inefficient energy transformations, such as those that occur in car engines.

You need

• STELR hand-cranked generator
• STELR testing station
• Connecting wires

Discussion

In the arm used to crank the wheel, not all of the available chemical potential energy is transformed into the kinetic energy of the muscles; some is 'wasted' as heat energy. Some of the kinetic energy transferred to the wheel is transformed into heat energy instead of electrical energy, due to the internal resistance of the wires. In the lamp, most of the electrical energy is transformed into heat energy instead of light energy.

In most car engines, less than 30 % of the chemical potential energy of the fuel is transformed into the car's movement. For example, much of the heat energy produced during the combustion of the fuel is transferred to the surroundings, including the car engine; not all is used to expand the gases that push the pistons.

OPTIONAL INTRODUCTORY ACTIVITY 2: BOILING WATER

Heat an electric kettle of water, and/or boil water in a beaker over a Bunsen burner.

In the case of the kettle, ask the students to identify where some of the original supplied energy might be wasted. (They can trace these energy transformations right back to the power station.)

In the case of the Bunsen burner, ask the students to identify where some of the energy supplied by burning the gas in oxygen might be 'wasted' – that is, not used to heat the water

You can also invite suggestions on how this energy wastage can be reduced.

You need

- Electric kettle – **preferably metal**; *and/or*

- Bunsen burner, beaker half-filled with water, tripod, gauze mat, heat mat, matches,

Discussion

For the kettle, some of the heat energy supplied by the heating element is transferred to the metal of the kettle and to the surroundings instead of being used to heat the water. (If the kettle is made of plastic, then the heat loss will be less since it is a poor conductor of heat .) This heat energy comes from the energy transformation that occurs in the heating element inside the kettle: Electrical energy → Heat energy.

If you trace back to the source of this electrical energy, then about 10 % of the electrical energy supplied by the power station is 'lost' during transmission, because it is transformed into heat energy due to the resistance of the wires. The further the school from the power station, the greater the percentage loss. (It may reach approximately 12-15%.) Then there are all the ways in which the energy is 'wasted' at the power station itself, which will depend on the kind of power station it is.

For the Bunsen burner, when the gas burns, not all of its chemical potential energy is transformed into heat energy. Some is transformed into light energy and some into sound energy. Like the kettle, only some of the heat energy produced is transferred to the water; the remainder is transferred to the materials involved, such as the glass of the beaker, and the metal Bunsen burner barrel, gauze mat and tripod, and also to the surrounding air.

FOLLOW-UP ACTIVITY

If you have not already done so, consider arranging an excursion to the power station that supplies the area. Find out where in the process energy is wasted and what strategies are used to improve energy efficiency.

TOPIC: THE CONSERVATION OF ENERGY, AND ENERGY EFFICIENCY

STUDENT ACTIVITY SHEET 9: THE CONSERVATION OF ENERGY: USEFUL ENERGY AND 'WASTED' ENERGY–SUGGESTED SOLUTIONS
STUDENT BOOKLET pages 74-77

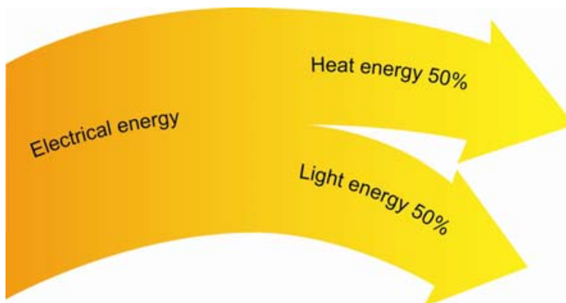
1 a water + carbon dioxide + energy → glucose + oxygen

b 4 %

c No, because only 4 % of the light energy from the Sun is transformed into chemical potential energy. Almost all the light energy is 'wasted' as heat energy.

d [*Student response*] *One thing that they could reasonably suggest might happen is that the plants could grow far more rapidly because they could produce more glucose for the same amount of light energy available. This could also cause carbon dioxide levels in the atmosphere to become much lower and oxygen levels much higher than they are now.*

2



A Sankey diagram that represents the energy transformations in a LED

3 241 000 ÷ 365 = 660 MJ per day

4 a Only 30 % of the available chemical potential energy of the fuel ends up in the form of mechanical energy. The rest is 'wasted'.

b Not all of the chemical potential energy of the fuel would be transformed into heat energy. Some of the available chemical potential energy would have been transformed into light energy and some into sound energy when the fuel burns. In addition, a lot of the heat energy produced in the combustion would be transferred to the parts of the motor, instead of being used to heat the gases.

5 a (5600 – 1800) MJ = 3800 MJ

b $\frac{3800}{5600} \times \frac{100}{1} = 67.86\ \%$

TOPIC: THE CONSERVATION OF ENERGY, AND ENERGY EFFICIENCY

RUNNING PRACTICAL ACTIVITY 5: WHICH FUEL PRODUCES THE MOST ENERGY?

STUDENT BOOKLET pages 78-82

SYNOPSIS

In this activity a spirit burner and a can of water are used to measure the heat energy produced when methylated spirits, ethanol or other fuel burns. By measuring the temperature rise of the water, and mass of fuel consumed, and performing a simple substitution into a formula, an approximate value of the heat energy per gram of fuel can be obtained.

This is a very relevant and meaningful introduction to the concepts of measuring energy, 'wasted' energy and the importance of measuring and comparing the heat energy delivered by different fuels.

The experiment is designed so there is less risk than using a gas barbecue, for example. However, it requires a very sturdy burner made of thick, heat-proof glass, as shown in Figure 3 page 79 of the student book. The burner should have a screw top to help prevent spillage.

- **If this is to be replaced with a teacher demonstration of burning a fuel and measuring its heat content, then the teacher can simply use methylated spirits as the fuel and just perform one set of measurements.**
- **If it is to be used as a class experiment, then the teacher should first demonstrate how to perform the experiment using methylated spirits or ethanol as the fuel, so the class can discuss all the relevant safety precautions and all important steps are clear, especially for students with language difficulties. The teacher's results are then included in the class results collected by the students.**

APPROXIMATE TIME REQUIRED

40 minutes (The actual combustion only takes a few minutes.)

BACKGROUND INFORMATION FOR THE TEACHER

Units of measurement for the heat of combustion of fuels

Some data books state the heat energy obtained from the combustion of different fuels in kJ/mol (kilojoules per mole). This is known as the molar heat of combustion. Others provide the data in different units, such as kJ/g (kilojoules per gram).

The mole is only relevant to chemists, as it is related to the number of molecules of fuel consumed. Moreover, it only is applicable if the fuel is a pure substance, such as pure ethanol. Most fuels used for heating or in the transport industry, however, are actually mixtures of different substances. In these cases this unit cannot be used.

The heat energy per gram (or other mass unit, such as kg) is much more relevant to the everyday use of fuels than the mole. Consider fuels used for transport. Apart from the fact that fuels used for this purpose are mixtures, the total mass of fuel required for a given energy output is very important. The total mass of any given fuel needed for travelling a particular distance depends on the total mass of the vehicle (or aircraft, etc.). The fuel itself contributes to that total mass.

In this experiment, to make it simpler for students of this age, the heat energy will be calculated in joules per gram, since this is their first exposure to the joule. They will be introduced to kilojoules and megajoules and other energy units later in the program.

A more accurate way of measuring heat energy

The drawback of measuring the heat energy produced in the combustion reaction by the method used in this experiment is that a significant amount of the heat energy is 'lost'- that is, it does not heat the water; instead it heats the surrounding air, the tin can, thermometer, stirrer, and so on. This means that the real heat energy produced by each fuel will be much higher than the values obtained by the students.

A more accurate method used to determine the heat of combustion of solid and liquid fuels is the 'bomb calorimeter'. A schematic diagram of a bomb calorimeter is shown in Figure 1 below.

In this case the loss of heat energy to the air is prevented, because the combustion takes place in a sealed chamber right in the middle of the water.

Moreover, the transfer of heat energy to the metal container in which combustion occurs (the 'bomb'), the thermometer, and so on, is allowed for. A value is obtained for how much heat energy is needed to raise the temperature of the whole system by 1 ºC, using a process of accurately known energy change. This is called the calibration factor of the calorimeter and is unique for each instrument.

Interestingly, this device is also used to determine the energy obtained from foods, in the same way. This is how the energy content of foods, as shown on their labels, is determined.

The main drawback of these instruments is that they have been known to blow up on occasions. The danger is in the delivery of pure oxygen into a chamber where ignition takes place by means of an electric spark. This is why they are never an option for schools.

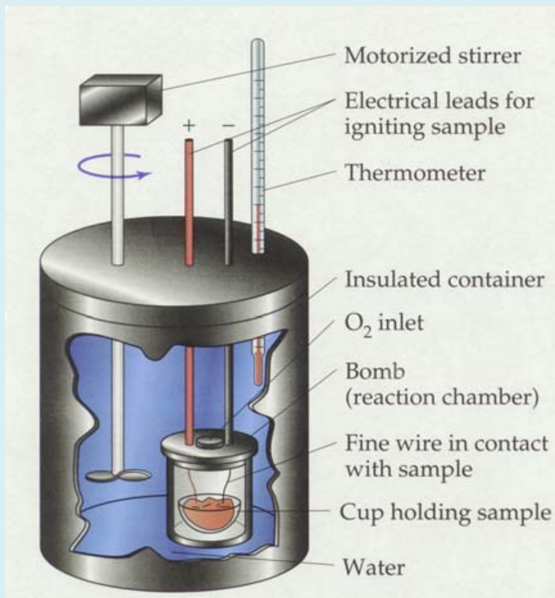


Figure 1 Inside a bomb calorimeter
Source: http://chemistry.umeche.maine.edu/~amar/fall2007/bomb.jpg **Accessed:** 9 November 2010

LIST OF MATERIALS REQUIRED

Per student group:

- Spirit burner containing methylated spirits, ethanol or canola oil
- Tin can
- Thermometer or temperature sensor
- Retort stand with 2 bossheads and 2 clamps
- 100 mL measuring cylinder
- Metal loop stirrer
- Heat-proof mat
- Box matches

Note:
Do not try the prepared biodiesel. See Practical Advice and Hints page 120.

For the class:
A number of electronic balances that measure masses up to 500 g to 2 decimal places.

For the methylated spirits demonstration:
The above equipment, with the spirit burner almost filled with methylated spirits.

For the optional additional demonstrations (page 120):
Ice water and/or a Trangia stove, or similar.

PRACTICAL ADVICE AND HINTS

Burning the fuels

1 It is advisable to perform a demonstration using methylated spirits or ethanol, and give the students a slower burning fuel such as canola oil, although in the case of canola oil the wick will need to be protruding from the burnet at least 3 cm or it will keep going out before a temperature rise of about 10 ºC is achieved.

2 It was found that the prepared biodiesel does not work. The wick burnt completely then fell off. It was concluded that the biodiesel does not flow sufficiently up the wick to maintain a steady flame.

3 Have the flame very close to the can. A good result was obtained when the top of the wick was 3 cm from the can.

4 When ventilating the room, do not have such a strong flow of air that the flames are either blown out or moved sideways, which would make them more difficult to control and hence not as safe. (This is why portable stoves, such as the Trangia stove outlined below, come with wind shields.)

The teacher demonstration

1 In the demonstration, take all the required measurements to model how this is done. The students then can include this result with theirs in their report.

2 Depending on the class, you may wish to relate the true story of one 15-year-old student who, along with her younger sister and father, died in a caravan in about 2001. Her father lit a small kerosene heater to keep them warm over a cold night. Since the caravan was sealed, fresh air could not circulate into the space. The resulting build-up of carbon dioxide, as well as carbon monoxide from the incomplete combustion of the fuel, was too toxic for them to survive. So they went to sleep and never woke up. There are many other cases of this kind of tragedy. Use this example to explain why no fuel should be burnt unless there is adequate ventilation.

Optional additional demonstrations

1 You may wish to add to the demonstration, once all measurements are complete, by replacing the warm water in the tin can with ice water. Raise the tin can a bit higher over the flame. Just let it burn long enough for students to see a few droplets of water collecting under the can. This is because on the water vapour produced in the combustion condenses on the cold surface. This stops, of course, as soon as the can starts to warm up. Students with gas stoves at home may notice the same effect if they put a saucepan of cold water over the flame.

2 If the school has an extensive outdoor education program, this department may have lightweight portable stoves that use methylated spirits as the fuel rather than bottled gas or gas in a small pressure pack. Examples of these spirit stoves are the widely used pressed aluminiumTrangia stove, which is made in Sweden and can be obtained from outlets like Aussie Disposals, or a similar stove that can be purchased through Kathmandu stores. (Trangia stoves may also be viewed on the internet.) If the teacher has access to any example, it would be well worth showing the students one in action.

RISK MANAGEMENT

Students do need to be trained in how to burn fuels safely, as they no doubt will do so in the future.

However, if this is used as a student activity then teachers need to be totally vigilant in supervising this activity. For some classes it would be advisable to restrict this to a demonstration.

Note:
It is important to remember that the composition of methylated spirits varies from country to country. A material safety data sheet for methylated spirits available in Australia can be found at:
www.acsrotech.com.au/msds/ACS_Rotech_MSDS_Methylated_Spirits.pdf

Safety warning!

1 Ensure the students are very careful with the thermometer or temperature probe, to avoid breaking them. Students should not stir the water with them. The light metal loop stirrer is included for that purpose.

2 Keep any bottle of methylated spirits, or other alcohol-based fuel, sealed and preferably out of the room, as these fuels vaporise easily and their vapours are highly flammable. (The same is true of fuels such as kerosene.)

3 Have the room well-ventilated during the combustion, to avoid breathing in any toxic vapours or smoke. But ensure that there is no strong draught that would cause the flames to burn sideways or blow out.

4 Collect the used burners from the students. Do not allow them to fill or empty the burners. The used fuels should be disposed of according the appropriate protocols for organic wastes.

Possible responses to the students' risk assessment activity are shown below. Try to elicit as many responses as possible, as students will be more likely to be careful if they have thought about this for themselves. But also ensure they feel confident enough to 'have a go'.

Student activity sheet: Table 2

The facts	What might be the risks?	What precautions will we take?
1 The fuel is a flammable liquid.	If the liquid fuel spills and goes near a flame, it could catch on fire.	Be careful not to knock over any spirit burners. Keep any bottles of fuel sealed and well away from the flames.
2 The flame will be hot, which will make the tin can hot as well.	If skin or hair or clothes get too close, they could get burnt. Touching the tin can could cause a burn.	Tie hair back, do not have loose sleeves, do not wear latex gloves and do not touch the apparatus until it has cooled.

ADVICE FOR THE CLASSROOM

See also the general advice provided on pages 28-29.

Teachers are strongly advised to try the activity prior to the class, to identify problems students might encounter and to judge the time they need.

Setting up:

Have the demonstration materials ready to show the students during the introductory discussion.

Introducing the activity:

1 Elicit from the students what they already know about the energy produced in a combustion reaction of a fuel, and what are the main products. Find out if any have used spirit burners and for what purposes.
2 Demonstrate how to perform the experiment, taking all measurements and stressing the most important points about the procedure. This includes working through the risk assessment with the students, eliciting as much as possible from them. Involve the students as much as possible in the demonstration and recording of measurements.
3 You may also consider the other quick, optional additional demonstrations and relating the story outlined in the section on Practical Advice and Hints.

During the session:

Watch that the students follow all the agreed safety precautions.

At the end of the session:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report and record and compare the different values they obtained. They should discuss what they found interesting or unexpected, problems they encountered, and their answers to some or all of the discussion questions. Ensure each group contributes to the discussion.

This part of the session should take about 10 minutes.

EXPECTED RESULTS

Following are the results from one trial school.

Fuel: Methylated spirits

Mass of water heated (g)	Initial temperature of water (ºC)	Final temperature of water (ºC)	Mass of spirit burner + methylated spirits before it is burnt (g)	Mass of spirit burner + methylated spirits after it is burnt (g)	Mass of methylated spirits burnt (g)
200	23	35	174.646	173.538	1.108

Calculation:

$$E = \frac{4.2 \times 200 \times (T_2 - T_1)}{m}$$

where: E = heat energy produced per gram of fuel (J/g)
T_2 = 35 ºC
T_1 = 23 ºC
m = 1.108 g

$$= \frac{4.2 \times 200 \times (35 - 23)}{1.108}$$

$$= \frac{4.2 \times 200 \times 12}{1.108}$$

= 9 100 J/g (correct to 2 significant figures)

Fuel: Canola oil (40 mL)

Mass of water heated (g)	Initial temperature of water (ºC)	Final temperature of water (ºC)	Mass of spirit burner + canola oil before it is burnt (g)	Mass of spirit burner + canola oil after it is burnt (g)	Mass of canola oil burnt (g)
200	25	35	218.080	217.593	0.487

Calculation:

$$E = \frac{4.2 \times 200 \times (T_2 - T_1)}{m}$$

where: E = heat energy produced per gram of fuel (J/g)
T_2 = 35 ºC
T_1 = 25 ºC
m = 0.487 g

$$= \frac{4.2 \times 200 \times (35 - 25)}{0.28}$$

$$= \frac{4.2 \times 200 \times 10}{0.487}$$

= 17 000 J/g (correct to 2 significant figures)

Note: The spirit burner used in this trial was supplied by STELR and weighed 185.252 g.

The following table shows some typical results obtained using a bomb calorimeter:

Fuel	Ethanol	Paraffin oil	Kerosene	Petrodiesel
Heat of combustion (J/g)	29 700	46 000	46 200	44 800
Heat of combustion (kJ/g)	29.7	46.0	46.2	44.8

Note:
Bottles of canola oil and other food oils should show their energy content, which will be an average obtained using a bomb calorimeter. Check the units used before comparing them with the above values.

SUGGESTED SOLUTIONS TO QUESTIONS

1 a *Sources of error include*
- It is assumed that all the heat energy is used to heat the water. However, a lot of the heat energy of the flame heated the surroundings, including the tin can, instead of the water.
- It is assumed that the mass measured completely burnt; however, some of the fuel may have been lost by evaporation, especially after the flame was blown out.
- There may have been errors in reading the scale of the thermometer, and its scale may be inaccurate (where a thermometer was used).
- The water may not have heated up evenly, in which case the temperature reading would be unreliable.
- The scale of the electronic balance may be inaccurate.

b One strategy could be to insulate the heating system as much as possible while letting air flow. An insulated ‘shield’ could be placed around the burner, with an open top.

2a It is always considered to be more accurate to take several results and average them, than to take a single result. The average is more likely to be closer to the true result.

b This is to ensure that the temperature of the water is the same throughout. Otherwise the temperature of a hotter or colder part could be taken, which would lead to an inaccurate result.

c The tin can may be hotter than the water. This allows time for heat energy to be transferred to the water so that the water and tin can are at the same temperature.

3 Other factors can include how easily it burns, how it flows, and how clean its flame is. It would be undesirable to have a fuel that produces a lot of smoke or that is hard to ignite, for example.

4 a *This depends on the students' results.*

b As a fossil fuel, kerosene is non-renewable and hence limited resource. Another disadvantage is that it would be expensive, whereas if people produce biofuels from local animal and plant wastes and so on, they have a renewable form of energy and also reduce the amount of waste going to landfill, which will be much more affordable and keeps the limited financial resources within the community.

ACKNOWLEDGEMENT

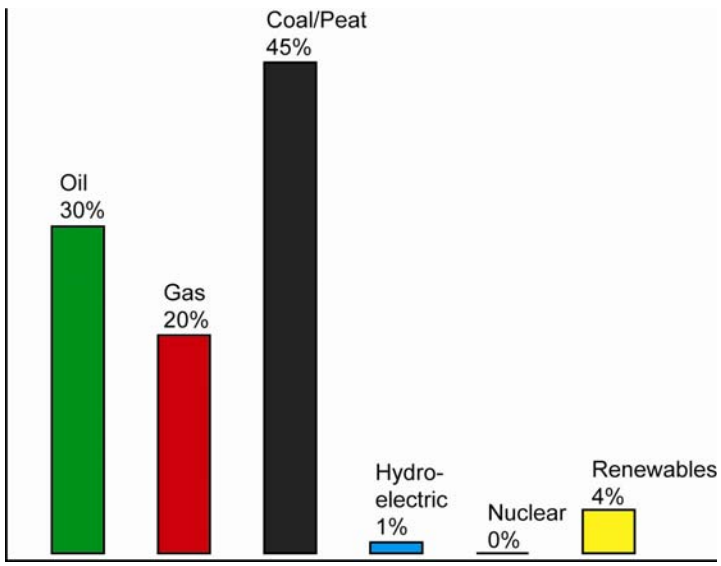
The STELR Project Team wishes to acknowledge and thank Mrs Iris Avery, Laboratory Manager, Box Hill Senior Secondary College, for all her invaluable assistance in trialling this experiment and for providing helpful advice and the sample experimental data.

TOPIC: THE CONSERVATION OF ENERGY, AND ENERGY EFFICIENCY

STUDENT ACTIVITY SHEET 10: COAL-FIRED POWER STATIONS –THE INSIDE STORY- SUGGESTED SOLUTIONS
STUDENT BOOKLET pages 83-88

SUGGESTED SOLUTIONS TO DISCUSSION QUESTIONS PAGES 83-84

A sample graph is shown below.



A graph of the contribution of different energy resources in supplying Australia's energy demands in 2008

1 Oil

2 Coal/peat

3 (38 + 23 + 26)% = 87%

4 (30 + 20 + 45)% = 95%

5 (6 + 1)5%= 7%

6 (1 + 4)% = 5%

7 One very big difference is the use of nuclear power across the world to supply 6% of the world's energy needs, while Australia does not have any nuclear power stations. The other is Australia's much greater use of coal and peat compared with the rest of the world.

8 [*Student response. Given there is only 4 years difference in the years studied, students are likely to consider it a reasonable comparison.*]

9 [*Student response]*

10 [*Student response. Given the problems with the Japanese nuclear reactor at Fukushima caused by the giant tsunami, students are likely to express concern about the use of nuclear power stations. Many will also be concerned about the high dependence on fossil fuels, given that they contribute significantly to global warming.*]

11 [*Student response*]

SUGGESTED SOLUTIONS TO QUESTIONS PAGE 86

1 The Sun

2 Chemical potential energy → Heat energy

3 Possible responses include:

- A lot of the heat energy produced by burning the coal in the furnace will be dissipated, mainly through the hot gases leaving via the chimneys, but also through heating up the walls of the furnace and heat transfer from the hot walls to the surrounding air.

- A lot of the heat energy produced by burning the coal in the furnace will be used up evaporating the water out of the coal, since it has a high moisture content.

- When the coal burns, some of the chemical potential energy of the reactants is converted to light energy and sound energy

- A lot of the heat energy carried by the superheated steam in the pipes will be wasted heating up the pipes and being transferred via the hot pipes to the surrounding air. (Note: See the information about the replacement of metal pipes with ceramic pipes in one recently-built coal-fired power station, which has increased the energy efficiency to a significant extent.)

- Not all of the kinetic energy carried by the superheated steam will be transformed into mechanical energy when it hits the turbine; the steam will still have a lot of kinetic energy as it moves past the turbine. (Note: This is the main reason for the low efficiency.)

- Each spinning turbine, turbine shaft and generator will lose energy in the form of heat energy.

4 A hydroelectric power station should be much more energy efficient than a coal-fired power station, as there are fewer energy transformations involved, and since cold water is used, comparatively little heat energy will be produced and wasted.

5 Advantages include:

- The coal can be continuously mined and fed into the furnaces via conveyor belts, instead of having to be transported to the power station by truck, which would consume a lot of fuel and produce even more greenhouse gases and other pollutants.

- Having the power station located a long distance away from large population centres reduces the health risks to consumers.

The main disadvantage is that the electrical energy produced needs to be transmitted long distances to most consumers, which means:

- A lot of agricultural land is needed for all the power lines.

- Many people think all the power lines and pylons spoil the landscape.

- There is a greater risk of bush fires caused by high voltage power lines.

- There is a greater risk of accidental electrocution.

- Many people are concerned about the possible health effects of electromagnetic radiation around high voltage power lines; the longer the lines are, the greater the number of people exposed to this radiation.

- There is a loss of power along the power lines. The longer they are, the greater the loss.

6 It is an exothermic, combustion reaction. (*It also is a redox reaction, but students should not be expected to know this.)*

SUGGESTED SOLUTIONS TO DISCUSSION QUESTIONS PAGE 88

1 a 30%

b There are a lot of energy transformations involved; there is a large loss of heat energy

2 Carbon dioxide and steam

3 a Oxides (oxygen compounds) of nitrogen and sulfur

b Coal contains nitrogen and sulfur compounds, which react with the air when coal of burned.

c Two of:

- They are toxic to many species, including humans and plants
- They can cause asthmatics to have an asthma attack
- They can cause acid rain and acid snow, which can kill plants and animals and damage entire ecosystems, and ‘eat away’ metal structures, statues and buildings.

d The amount of these gases emitted is controlled and monitored by the EPA.

4 CO_2, H_2O, NO_2, SO_2 and SO_3 are all greenhouse gases as their molecules are made up of three or more atoms.

5 So the waste gases don’t build up near the ground, where they could affect the health of the workers and members of the local community.

TOPIC: HOW SCIENTISTS WORK

IDEAS FOR INTRODUCTORY ACTIVITIES ON HOW SCIENTISTS WORK

SYNOPSIS

The teacher may wish to introduce this topic by having the students discuss the big ideas on page 89 of the student book.

The teacher may also wish to use one of the brief introductory activities below, in which they critically evaluate experimental set-ups that contravene the principles of good design.

ADVICE ON INTRODUCING HOW SCIENTISTS WORK

If arrangements have been made for the students to meet a scientist, the teacher could ask the scientist to talk briefly in simple terms about how they ensure their results are valid. What variables do they consider and how do they control them, what kind of results and how many results do they take, do they use graphs, etc.? Who checks their results? Do they require permission to conduct their experiments - and why or why not?

OPTIONAL INTRODUCTORY ACTIVITY 1: WHAT CAUSES NAILS TO RUST?

Activity outline

Show the students two containers– one a test tube that is open to the air, containing a nail just covered with water; the other a sealed glass jar containing a different-shaped nail covered to the top of the jar with oil. Tell the students this is what one person suggested they would set up to find out if water causes nails to rust.

Divide the class into pairs, then give each pair a sheet of paper. Ask them to decide if the person has designed a fair test, and if not, brainstorm what the problems are with this design and what they would do to improve it.

Then bring all the pairs together to compare and discuss their answers. Their responses could be put up on the walls for all to see. Use this is an opportunity to introduce or reinforce terms such as variables, hypotheses, and so on.

Time required

Approx 20 -25 minutes

Materials

- Test tube that is open to the air, containing an iron nail just covered with water and sitting in test tube rack
- Sealed glass jar containing a different-shaped iron nail covered to the top of the jar with paraffin oil.
- Sheet of paper and poster pen (one per pair)
- Masking tape (optional)

Discussion

If these are the only two samples being tested, then no conclusion would be valid because:

- There should only be one difference between the two cases, in order to test the effect of one variable at a time. Here there are different containers, iron nails of a different shape and size (and possibly different composition), and different exposure to air.
- You cannot draw a valid conclusion from only two pieces of data.

To improve the design you would need to compare:

- A large number of samples
- Samples that have a difference in only one variable at a time
- Containers with iron nails in pure water that has had all air removed from it, with containers with iron nails in pure water that has not had air removed from it

OPTIONAL INTRODUCTORY ACTIVITY 2: WHAT IS THE EFFECT OF TEMPERATURE ON PLANT GROWTH?

Activity outline

Show the students two different-sized pots made of different materials containing different soil, different amounts of moisture (one wet, one dry), and a different plant – different size as well as different species, one with a hot lamp shining on it and one without a lamp. Tell the students this is what one person suggested they would do to find out if warmer temperatures harm or improve plant growth.

Divide the class into pairs, then give each pair a sheet of paper. Ask them to decide if the person has designed a fair test, and if not, brainstorm what the problems are with this design and what they would do to improve it.

Then bring all the pairs together to compare and discuss their answers. Their responses could be put up on the walls for all to see. Use this is an opportunity to introduce or reinforce terms such as variables, hypotheses, and so on.

Time required

Approx 20 -25 minutes

Materials

- Large plastic pot containing dry sandy soil and a large indoor plant species
- Small terra cotta pot containing wet mulch and a small outdoor plant species
- Halogen lamp
- Sheet of paper and poster pen (one per pair)
- Masking tape (optional)

Discussion

If these are the only two samples being tested, then no conclusion would be valid because:

- There should only be one difference between the two cases, in order to test the effect of one variable at a time. Here there are different containers that have a different size and thickness and material, different soil composition, different amount of moisture, different exposure to both heat and light
- You cannot draw a valid conclusion from only two pieces of data.

To improve the design you would need to compare:

- A large number of samples
- Samples that have a difference in only one variable at a time
- Identical plants in identical conditions (including the amount of light), with the only difference between then being their temperature. (This could be achieved by sitting the pots in water or other material held at various constant temperatures. Hot lamps would introduce an additional variable – and that is the amount of light shining on the plant)

TOPIC: HOW SCIENTISTS WORK

STUDENT ACTIVITY SHEET 11: HOW DO SCIENTISTS WORK? - SUGGESTED SOLUTIONS
STUDENT BOOKLET pages 90-94

ADVICE

Of all the topics, the principles behind how scientists work are best learned through examples and hands-on experience. Teachers are strongly advised to consider using one of the introductory activities for this topic (pages 127-128) and to run Practical Activity 6 and/or 7using the investigation planner, to give the students the opportunity to put the principles into practice.

SUGGESTED SOLUTIONS TO DISCUSSION QUESTIONS

1 a A variable is a factor that may affect the outcome of an experiment.

b A fair test is one in which only one variable is being tested. That is, there is only one factor different in all the samples.

2 a A hypothesis is a proposed explanation for something, whereas a scientific hypothesis is a proposed explanation for something that can be tested by experiment.

b A scientific theory is based on much more evidence that has been taken over a much longer time than a scientific hypothesis.

3 a They need evidence to see if the hypothesis is correct or needs to be revised.

b They need to know what factors could affect the results so they can design fair tests.

c They need to be sure what effect that variable has.

d The average of a large number of measurements is more likely to be closer to the true result than any individual measurement, which means any conclusions drawn will be more reliable.

e Each instrument has its own inbuilt error. If they keep changing the instrument they are unlikely to get consistent results.

f Scientists must evaluate their results and judge how reliable they are. This process must include identifying sources of error that were operating when they conducted the experiment.

g Their results and conclusions cannot be relied upon if they have been dishonest.

4 a It is better to start with all that is known and build on that. Otherwise a lot of time and money is wasted.

b It is dishonest to imply other people's work is your own.

5 People who read the journals need to be able to completely rely on the truth of the articles that are published, as this can affect what actions they take, such as what research they then undertake.

6 Scientists should not be allowed to conduct any tests they like, as they might harm people or other living things, or cause social or environmental problems.

7 They might be working in the metals industry, as there is a furnace behind them and they are wearing hard hats and testing a lot of samples.

TOPIC: HOW SCIENTISTS WORK

STUDENT ACTIVITY SHEET 12: INVESTIGATION PLANNER - ADVICE
STUDENT BOOKLET pages 95-96

ADVICE

As stated on the previous page, of all the topics, the principles behind how scientists work are best learned through examples and hands-on experience.

Teachers are strongly advised to copy the investigation planner for students for the two guided student-designed experiments (Practical Activity 6 and Practical Activity 7) onto A3 sheets of paper, so they can work together in their small groups on planning what they will do. They need sufficient room to enter their group decisions.

It also is important that the students are given sufficient time to plant their investigations and to discuss their plans with the teacher.

It can be useful to allow students to make mistakes and learn from them. They should not be over-directed. There is very little risk involved in the experiments in this program.

It is useful for students to keep a record in a log book of what they tried, what problems they encountered, and so on, when conducting the experiments they design.

TOPIC: HOW SCIENTISTS WORK

RUNNING PRACTICAL ACTIVITY 6: LEMON POWER

STUDENT BOOKLET pages 97-98

SYNOPSIS

In this guided student-designed investigation, different small groups of students explore the relationship between the distance between the electrodes of the lemon cell and the voltage it delivers. Some may choose to explore another question such as:

- What is the effect of how deep the electrodes are inserted on the voltage?
- How does the voltage delivered by the cell change over time?

(It needs to be a question that will lead to a set of data points and a graph.)

This fun class experiment. Many students will be astonished that a lemon or an orange or potato can act as a chemical cell. It provides the students with an opportunity to build on and reinforce their understanding of the principles of good experimental design. It also is an excellent preparation for Practical Activity 7 and any other student-designed experiments they may perform in the future.

APPROXIMATE TIME REQUIRED

50 -60 minutes

BACKGROUND INFORMATION FOR THE TEACHER

How a lemon cell works

Not only can metals conduct electricity, but also they are able to give away electrons to other substances. This is because the outermost electrons in their atoms – those that make up the surface of the atoms - are relatively loosely bound to the atoms. In a sample of the metal these electrons move around between all the metal atoms and so are generally referred to as **delocalised electrons**, since they are not confined to one locality.

The delocalised electrons enable metals to conduct heat and electricity. The delocalised electrons present on the surface of the metal also reflect light very well, which is why freshly polished samples of metals are so shiny.

But in the presence of an **oxidant** (a substance that takes up electrons), most metals will donate these delocalised electrons to the oxidant. When they donate electrons to an oxidant, metals are acting as **reductants**.

However, some metals have a stronger ability give away electrons than others. This is why the lemon cell works. Zinc metal has a much stronger ability to give away electrons than copper metal. For this reason zinc is described as a stronger reductant than copper. So in this cell (or, more strictly speaking, in this galvanic cell), when it is connected into a complete circuit, electrons leave the zinc metal electrode and travel around the wires to the copper electrode.

When they travel down the copper electrode, the electrons are accepted by the acid present in the lemon that is in contact with the copper surface. The acid reacts with the electrons and produces hydrogen gas. Tiny bubbles of the gas form on the surface of the copper then migrate away. The circuit is completed as ions (electrically charged particles) in the lemon juice carry the current back to the zinc electrode.

The worded equation for the net chemical reaction is: zinc + citric acid → zinc citrate + hydrogen

In this battery, the zinc acts as the negative electrode and the copper acts as the positive electrode.

The reaction occurring at the negative electrode (also termed the anode) is: $Zn(aq) \rightarrow Zn^{2+}(aq) + 2e^-$

The reaction occurring at the positive electrode (also termed the cathode) is: $2H^+(aq) + 2e^- \rightarrow H_2(g)$

Note: These are called **half-equations**, and show what really happens at each electrode and how the electrons are involved.

Orange batteries and apple cells

The three equations written for the lemon cell apply to an 'orange battery' as well.

The last two equations also apply to an 'apple cell'. The net equation is similar, but the main acid present is a different acid.

Potato cells

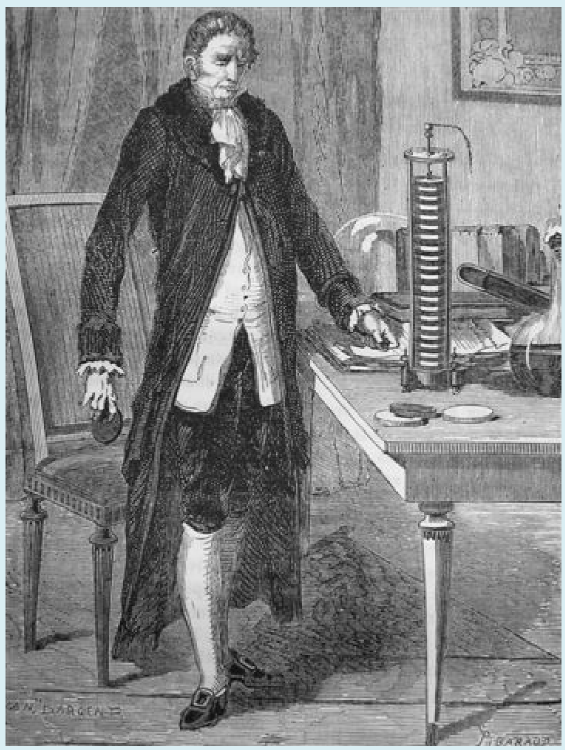
In the case of a potato cell, the high concentration of mineral salts enables the potato to conduct the current between the electrodes very well. The water present acts as the oxidant.

The reaction occurring at the negative electrode (anode) is: $Zn(aq) \rightarrow Zn^{2+}(aq) + 2e^-$

The reaction occurring at the positive electrode (cathode) is: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

The worded equation for the net chemical reaction is: zinc + water → zinc hydroxide + hydrogen

Volta's Pile



Source: http://www.ampere.cnrs.fr/parcourspedagogique/agora/IMG/jpg/Volta_Pile.red-2.jpg **Accessed:** 5 May, 2011

The potato cell works on the same principle as one of the earliest batteries that was able to deliver a significant voltage – which was known as **Volta's Pile**. One version of this battery was a tower of alternating copper and zinc discs. (Other versions used a different pair of metals.) Between the discs were pieces of fabric soaked in salt solution. Volta apparently delighted in using it to give people an electric shock. The tower delivered around 12 volts! There are many worthwhile discussions of this battery on the internet.

The problem with the battery was that the hydrogen gas produced built up between the metal discs, stopping the current from flowing. To get the battery going again, it had to be taken apart to release the gas then reassembled. Potato batteries work because they contain a high concentration of mineral salts. In their case the salts greatly increase the conductivity of the water, and the water acts as the oxidant

Note: Volta's Pile is classified as a battery as it has many cells connected in series. (Each cell consists of one pair of electrodes, and the salt solution.)

LIST OF MATERIALS REQUIRED

Per student pair:

- Large lemon (or orange or apple or washed potato)
- Piece of emery paper
- Piece of paper towel
- STELR multimeter
- Graph paper and copy of the Investigation planner
- Copper electrode and zinc electrode (narrow)
- Wooden board
- Narrow-bladed vegetable knife
- STELR testing station (optional)
- Large plastic beaker for used food
- 2 x leads with banana plug one end and alligator clip at the other end (one red, one black if possible)
- Metal ruler or other device for measuring the distance between the electrodes, or their depth

SAFETY WARNING: Ensure that no electrodes have sharp edges!

PRACTICAL ADVICE AND HINTS

1 It can be difficult to insert the electrodes. It may be easier for the students to pierce the skin with a vegetable knife at the different distances that will be tested, before starting.

2 The electrodes need to be inserted into the lemon in a vertical position, as otherwise the distance between them will vary with depth and so cannot be accurately measured. (It is best to elicit this idea from the students.)

3 The students need to devise a way to control the depth of the electrodes, so this is held constant. They may suggest putting a little mark on the electrodes, such as a scratch, to show how far they are to be pushed in.

4 It is probably best to start with the electrodes as far apart as possible, then to reduce the distance between them by, say, 1 cm at a time. Aim for at least 4 sets of readings.

5 If the depth is being tested rather than the distance apart, then it is best to have the electrodes about 2 cm apart, but allow the students to decide this.

6 The emery paper should be used to clean the electrodes <u>just before</u> the experiment starts, to remove any corrosion products. This should be done over the wooden board, so that benches are not scratched. The electrodes then should be wiped with paper towel to remove any powder.

7 The multimeters should be set as voltmeters at 20 V, which is the setting that will be used throughout the STELR program. The voltage delivered will be of the order of 1 V. If no reading is obtained, check the connections and if the voltmeter still does not work, then check if its battery is flat.

8 The students may like to test if the lemon battery can light up the LED or lamp on the testing station, or make the buzzer work. But it must be borne in mind that the LED and buzzer will only work if the current flows in a particular direction. So before any conclusions are drawn, the leads should be reversed if they don't appear to work.

9 It is worth giving the students the opportunity to discover that if two copper electrodes are used or two zinc electrodes, no voltage is delivered. It is crucial that there are two different metals.

RISK MANAGEMENT

Possible responses to the students' risk assessment activity are shown below.

What might be the risks?	What precautions will we take?
Hands can be scratched or cut when cleaning the electrodes with emery paper, or when using the knife.	Handle them carefully. If necessary, wear tight-fitting latex gloves whilst handling them.
The multimeters are sensitive digital instruments and may get damaged.	Place the multimeters well away from the edge of the bench, and ensure they do not get any lemon juice on them.
Lemon juice is acidic and can sting eyes or cuts or open sores on the skin.	Take care when handling the lemon not to rub fingers in eyes. Wear latex gloves if the hand has any cuts or open sores on it.

ADVICE FOR THE CLASSROOM

See also the general advice provided on pages 28-29.

Teachers are strongly advised to:

1 Trial the activity prior to the class, to decide whether you will use lemons and/or other foods, identify problems the students might encounter and to judge the time they need.
2 Decide how to best manage the activity, particularly how to divide the class, whether any groups will be allowed to investigate other questions, whether different groups will test different foods then compare results, and how much time the students should be given for their preliminary planning.

Setting up:

Have a demonstration set of equipment ready to perform a simple demonstration during the introductory discussion.

Introducing the activity:

1 Elicit from the students what they already know about how scientists go about their experiments, variables, fair testing, and taking accurate measurements and also what they know about batteries and voltage.
2 Show them how to use the STELR multimeter in its voltmeter mode and also show them a lemon cell action. Ask them how they could apply the principles of good experimental design to answer the inquiry question, or give them the opportunity to pose a different question. (See the synopsis on page 131 for alternative questions.) Distribute the investigation planners.
3 If they are to investigate the effect of the distance between the electrodes, discuss how they might accurately measure the distance, avoiding parallax error.
4 Elicit from the students what kinds of graph would be suitable for displaying their results, and why they need to take repeat measurements and take averages.
5 Assign the pairs to their groups.
6 State your expectations of their behavior and the time limits they will work under, including the time allowed for completing as much of their investigation planner as they can before submitting it for approval, and how they are to clean up afterwards.

During the session:

1 Ensure the groups do follow the planning procedures before starting their experiment.
2 When watching a group, ask questions about what they are predicting and observing, how they might explain their results, what might be the sources of error and why the experiment is designed in this way.
3 Watch that the students observe all of the agreed-upon procedures and safety precautions, and are obtaining results in a timely manner. Ensure they rinse the electrodes and knife with water at the end and put their food in the waste container.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report their findings. They should discuss what they found interesting or unexpected, problems they encountered, their conclusions and their responses to some or all of the discussion questions. Ensure each group contributes to the discussion.

This part of the session should take about 10 -15 minutes.

EXPECTED RESULTS

The voltages obtained will be of the order of 1 V, but will depend on the food used and the size and shape of the electrodes and how well they have been cleaned. The students may find that the voltage either increases slightly or else varies very little with distance, in which case the graph may be virtually horizontal. It is important they can understand how to interpret a graph like this, should this occur.

If depth is tested, students are likely to find the voltage increases with depth, although not by a large factor.

If variation over time is tested, if studied over enough time, students may find the voltage decreases with time.

SUGGESTED SOLUTIONS TO DISCUSSION QUESTIONS

1-4 [*Student responses will depend on the results*]

TOPIC: HOW SCIENTISTS WORK

STUDENT ACTIVITY SHEET 13: HOW DO SCIENTISTS USE GRAPHS? – SUGGESTED SOLUTIONS
STUDENT BOOKLET pages 99-107

SUGGESTED SOLUTIONS TO QUESTIONS PAGE 99-100

1 a Sugar cane

b It will reduce the amount of carbon dioxide emitted by 90 %.

2 Sugar cane, since it makes a far bigger difference to the amount of carbon dioxide produced than do corn or wheat.

3 [*Student response - students might suggest that the graph might be easier to read if it is presented as a column graph with a vertical scale.*]

SUGGESTED SOLUTIONS TO QUESTIONS PAGE 101

1 Peat has the highest moisture content.

2 Burning 1 kg of black coal will produce more ash than burning 1 kg brown coal.

3 Bituminous coal is the most energy-rich form of black coal.

4 a 25 kJ b 34 kJ

5 For the first five fuels on the graph, the higher the fixed carbon content, the greater the amount of energy obtained by burning 1 kg. However, if this relationship were always true, the natural graphite should have the highest energy content of all, which it does not.

6 Given that rank increases from left to right, it appears that the rank is related to the fixed carbon content. However, this is not fully clear with anthracite.

7 The content of these fuels would vary from place to place and even from sample to sample in one location.

8 [*Student response*]

SUGGESTED SOLUTIONS TO QUESTIONS PAGES 103-104

1 *Student response. The ozone would be mostly produced by the action of sunlight on car emissions. The denser the traffic, the greater the amount of emissions produced per minute. This graph could be explained by changes in traffic density, from low early in the morning to a maximum at peak hour. It may be the delay in obtaining the highest ozone reading would be due to waiting on more intense sunlight to be available to act on the emissions, and the time taken for these reactions to occur.*

2 a Approx. 4.6 g *(from drawing a vertical line up to the graph at 20 seconds, then a horizontal line from that point across to the vertical axis)*

b It shows no more CO_2 is being produced, so the reaction must have stopped. This would be because one of the reactants has run out.

c The mass of CO_2 produced is the dependent variable, because the amount of CO_2 produced depends on how long the reaction has been going.

3 a *The students should draw a curve through the points.*

b Approx. 0.52 or 0.53 V *(from extrapolating the curve and using the process outlined in the suggested solution to question 2 a.)*

c There is a limit to the voltage it can produce, no matter how intense the light.

3 d Advantages of this style of graph include the time saved and convenience of having a computer draw the graph for you. Disadvantages include the fact that the horizontal scale is not clearly defined, which means the value of the voltage at a given light intensity cannot be accurately determined, and the fact that you have to guess where the line or curve of best fit is, which again means you cannot be sure of any values.

SUGGESTED SOLUTIONS TO QUESTIONS PAGES 105-106

1 It lets you see at a glance whether the patterns or trends in the mean maximum temperature are the same for the mean minimum temperature, which is useful to know.

2 The vertical scale for the mean maximum temperature goes from 24 to 30, while the vertical scale for the mean minimum temperature goes from 13 to 19. This allows for the fact that minimum temperatures are lower than maximum ones, and would reduce the space taken up by the graph. (It would otherwise have to go from 13 to 30, and would be more than twice as high.)

3 It shows the falls and rises in mean temperatures over each successive year.

4 The trend lines show that despite the falls and rises year-by-year, there is a definite increase over the time studied.

5 a Mean maximum: Approx. 27.8 ºC
Mean minimum: Approx. 14.5ºC *(The right-hand scale must be used for this value.)*

b It is hard to determine where 1950 is along the horizontal axis, due to the lack of bolder or longer markings to show each decade. The lack of a detailed graph grid also means that the temperatures can only be estimated.

SUGGESTED SOLUTIONS TO QUESTIONS PAGE 107

1 80 ºC *(using the plotted point rather than the curve)*

2 By approx. 8 ºC *(using the plotted points rather than the curve)*

3 It should be dotted in because measurements were only taken for 10 minutes, so this is just assuming the trend continues.

4 The graph should start at the same point (100 ºC) but drop less steeply so that by the end of 10 minutes the temperature will be higher than 62 ºC. This is because polystyrene is a good heat insulator, and so the heat energy of the water will dissipate into the environment more slowly.

TOPIC: HOW SCIENTISTS WORK

RUNNING PRACTICAL ACTIVITY 7: WHAT CONDITIONS MAKE A CHEMICAL CELL DELIVER THE BIGGEST VOLTAGE?

STUDENT BOOKLET pages 108-110

SYNOPSIS

This is a guided student-designed experiment in which different groups of students trial the effect of different variables on the voltage delivered by the chemical cell, then compare their findings.

Factors they might trial include:
- The distance between the electrodes
- The depth of the electrodes
- The metals in the electrodes
- The width of electrodes (when in the form of metal foil)
- The time over which the cell is running

(Testing the effect of salt concentration is not recommended since this requires the preparation of several salt solutions of different concentration, and students are given too much of a guideline for this, as it is posed as one of the discussion questions.)

At the end of the activity, through class discussion they pool their findings and suggest the ideal cell design. This is then set up by the teacher to test if it does produce the greatest possible voltage.

This provides the students with an opportunity to:
- Build on and reinforce their understanding of the concepts of chemical cells and voltage
- Learn about and practise the principles of good experimental design, including multiple trials in data collection.

APPROXIMATE TIME REQUIRED

60 minutes

BACKGROUND INFORMATION FOR THE TEACHER

See the background information on chemical cells on pages 79 and 131-132 of this book.

Testing different combinations of metals

Should the students test different metals, the metals they may be able to test include: zinc (Zn), iron (Fe), aluminium (Al), tin (Sn), copper (Cu) and nickel (Ni).

In this case, the order of these metals in terms of their strength as a reductant is: Al > Zn > Fe > Ni > Sn > Cu

This means that:

1 The greatest voltage will be delivered by a combination of aluminium and copper.

2 For any pair of metals, the stronger reductant (the one furthest to the left of this list) will always be the negative electrode.

The drawback of aluminium is that aluminium reacts very rapidly with oxygen in the air and forms an invisible protective coating of aluminium oxide, making it appear unreactive. Unless it is sanded then immediately inserted into the solution, it will give misleading results. Even then, the voltage of any battery in which an aluminium electrode is used will rapidly drop off as the surface of the aluminium reacts with oxygen dissolved in the solution.

LIST OF MATERIALS REQUIRED

Per student pair:

- Piece of emery paper
- Piece of paper towel
- Retort stand
- 100 mL measuring cylinder
- Plastic tray
- Wooden board
- 100 mL beaker
- 2 x bossheads and clamps
- STELR multimeter
- 2 x safety glasses and latex gloves
- 2 x leads with banana plug one end and alligator clip at the other end (one red, one black if possible)
- Graph paper and copy of the Investigation planner

Groups testing different electrodes:

- 1 L of salt solution (10 g per litre)
- Identical sized and shaped electrodes made of aluminium, iron (steel), zinc, copper, nickel and tin

Groups testing different electrode widths:

- 80 mL of salt solution (20 g per litre)
- Strips of zinc foil pre-cut to different widths, such as 1 cm, 2 cm, 3 cm, 4 cm, 5 cm and 6 cm
- Strips of copper foil of the same thickness and widths as the strips of zinc foil

Other groups:

- 80 mL of salt solution (20 g per litre)
- Two identical sized and shaped electrodes –one copper, the other zinc
- Metal ruler or other device for measuring the distance between the electrodes, or their depth in the solution

SAFETY WARNING: Ensure that no electrodes have sharp edges!

PRACTICAL ADVICE AND HINTS

1 The electrodes need to be long enough to be able to dip into the solution to a reasonable depth.

2 The electrodes need to be inserted into the solution in a vertical position, as otherwise the distance between them will vary with depth and so cannot be accurately measured. (It is best to elicit this idea from the students.) For this reason is it best to set up a retort stand and clamp each of the electrodes into position. A different clamp should be used for each electrode.

3 The students need to devise a way to control the depth of the electrodes, where this needs to be held constant. They may suggest putting a little mark on the electrodes, such as a scratch, to show how far they should go.

4 The emery paper should be used to clean the electrodes <u>just before</u> the experiment starts, to remove any corrosion products. This should be done over the wooden board, so that benches are not scratched. The electrodes then should be wiped with paper towel to remove any powder.

5 The multimeters should be set as voltmeters at 20 V. The voltage delivered will be of the order of 1-1.5 V. If a reading is not obtained, check the connections and if the voltmeter still does not work, then check if its battery is flat.

6 It is worth giving the students the opportunity to discover (if they have not already done so) that if the two electrodes are made from the same metal, no voltage is delivered. It is crucial that there are two different metals.

7 It is best to have the beaker on a plastic tray to help avoid spills.

8 For testing the electrode materials, students could keep one constant (the copper electrode would be best) and just change the other one.

RISK MANAGEMENT

Possible responses to the students' risk assessment activity are shown below.

Note: The only time students may require safety glasses and protective gloves is when they are sanding the electrodes.
***See the earlier warning about ensuring the electrodes do not have sharp edges.**

What might be the risks?	What precautions will we take?
Hands can be scratched or cut when cleaning the electrodes with emery paper.	Handle them carefully. If necessary, wear tight-fitting latex gloves whilst handling them.
The multimeters are sensitive digital instruments and may get damaged.	Place the multimeters well away from the edge of the bench, and from the beaker, and ensure they do not get any salt solution on them.

ADVICE FOR THE CLASSROOM

See also the general advice provided on pages 28-29.

Teachers are strongly advised to:

1 Trial the activity prior to the class, to identify problems the students might encounter and to judge the time they need.
2 Decide how to best manage the activity, particularly how to divide the class, what variables can be investigated by the class, how much time the students should be given for their preliminary planning, and how the 'ideal' battery can be set up at the end, using the findings of all the groups.

Setting up:

Have a demonstration set of equipment ready to perform a simple demonstration during the introductory discussion.

Introducing the activity:

1 If they have not been very recently asked, elicit from the students what they already know about how scientists go about their experiments, variables, fair testing, and taking accurate measurements and also what they know about cells and voltage.
2 Show them how to use the STELR multimeter in its voltmeter mode (if they need this reminder), and how to clamp the electrodes in place. Also show them the cell in action. (They should have seen this at one of the work stations in Practical Activity 2, but may have forgotten. In any case, on that occasion the electrodes were not clamped into position.)
3 Have a brainstorming session to elicit from the students what are some of the variables that might affect the voltage delivered by the chemical cell. Then, if necessary, state any restrictions on the variables they will be able to test in the session. Then tell them their results will be pooled to construct the 'ideal' chemical cell that can deliver the greatest possible voltage.
4 Assign the pairs to their groups.
5 Distribute the investigation planners and ask the students to decide what variable they wish to test and to start planning their investigation.
6 State your expectations of their behavior and the time limits they will work under, including the time allowed for completing as much of their investigation planner as they can before submitting it for approval, and how they are to clean up afterwards.

During the session:

1 Ensure the groups do follow the planning procedures before starting their experiment.
2 When watching a group, ask questions about how they are making their measurements, what they are predicting and observing, how they might explain their results, what might be the sources of error and why the experiment is designed in this way.
3 Elicit from the students what kinds of graph would be suitable for displaying their results, and why they need to take repeat measurements and take averages.
4 Watch that the students observe all of the agreed-upon procedures and safety precautions and are obtaining results in a timely manner, and ensure they clean up as instructed in the end.

At the end of the activity:

This part of the session is very important because it will help the students clarify ideas and develop communication skills.

Draw the students together to report and compare their findings and hence what battery design might deliver the biggest voltage of all. Then try this out! Does it give a greater voltage than any of the batteries they tested?

This part of the session should take about 10 -15 minutes.

EXPECTED RESULTS

In general, the voltages will be of the order of 1-1.5 volts. They will depend on the particular electrodes used, but in general the voltage should increase with:
• Decreasing distance between electrodes (probably the smallest effect)
• Increasing depth of electrodes
• Increasing width of electrodes

The voltage will certainly be greater if the electrodes are very freshly cleaned than if they are old and corroded..

See the background information on page 137 for the likely effect of changing the metal electrodes. The choice of electrode is significant.

NOTE: In the case of using different electrodes, the most suitable graphical representation is a column graph. Each column would represent a different pair of electrodes. The vertical column could them show a scale for voltage.

SUGGESTED SOLUTIONS TO DISCUSSION QUESTIONS

1-2 [*Student responses will depend on the class results and the experience*]

3 a This seems to be a fair test as all the other factors were kept the same (the choice of electrodes, the positions of the electrodes, the volumes of solutions).

b The dependent variable would be the voltage. The salt concentration is being controlled so it has different known values, so it is the independent variable. The experiment is designed to see if the voltage is affected by the salt concentration.

c As the salt is dissolved in water, you cannot be sure if the water has an effect of its own. This will show that.

d It is helpful for graphing purposes to increase the salt concentration by the same amount each time. The choice of 5 g/L means there is a reasonable increase.

4-5 [*Student responses will depend on the class results and the experience*]

SUPPORT

DOCUMENTS

FOR

TEACHERS

INCLUDING:

ASSESSMENT ADVICE AND PROFORMA

WEBSITES AND EXCURSIONS

RISK ASSESSMENT ADVICE AND PROFORMA

ASSESSMENT OF STUDENTS

ASSESSMENT ADVICE

The assessment modes selected by the teacher will depend on the requirements of the school and of the state or territory in which the school is located.

It is important that the students are informed at the outset how they will be assessed in the STELR Chemistry Program. They should be provided with a written statement of the assessment tasks and requirements and a copy of any assessment rubrics or other assessment charts that will be used for particular tasks, before they perform the tasks, so they have a clear understanding of what is expected.

At the same time, it is important that this program is not assessment-driven. Its overarching goal is to inspire, encourage and enable the students to study science subjects at the senior level and to consider careers in science and engineering. The students' enjoyment on the program and hence their attitudes toward science will be diminished if their overriding concern is whether each aspect is to be assessed and if they believe that what they do only matters if it is to be assessed.

Following is a sample assessment rubric for science inquiry skills. Its format and wording will need to be modified according to the school and state requirements. Teachers may wish to copy and paste it onto a blank word document, then change it to landscape orientation.

ASSESSMENT RUBRIC - SCIENCE INQUIRY SKILLS

STUDENT NAME: ____ CLASS: __________

Science inquiry skill	Undeveloped	Developing	Proficient	Exemplary
Designing an experiment	The student can: • Develop a testable hypothesis with assistance. • Show little understanding of the variables operating • With assistance can design simple fair tests and select equipment suited to the purpose.	The student can: • Develop a testable hypothesis with assistance. • Identify some variables with assistance, and • Design simple fair tests and select equipment suited to the purpose.	The student can: • Develop a testable hypothesis. • Identify a number of variables and, with assistance, design an experimental investigation a procedure in which these are tested one at a time and repeat trials are conducted. • Select equipment suited to the purpose. • Suggest some ways to reduce risk in the investigation.	The student can: • Develop a testable hypothesis based on prior observations and/or secondary sources. • Design an experimental investigation, including using repeat trials and replicates, independently identifying and controlling variables and selecting equipment suited to the purpose. • Suggest a number of ways to reduce risk in the investigation that show insight into the specific risks involved.
Collection of data	The student can: • With assistance, collect data in a consistent and ethical manner, including using ICT where possible. • Use equipment and materials safely, with assistance and advice.	The student can: • With assistance, collect data in a consistent and ethical manner, including using ICT where possible. • Use a wide range of equipment and materials safely.	The student can: • Collect data in a consistent and ethical manner, including using ICT where possible. • Use a wide range of equipment and materials safely and show consideration of the safety of others.	The student can: • Collect data in a consistent, efficient and ethical manner, including using ICT where possible. • Use a wide range of equipment and materials safely and manage the working environment for the safety of self and others.
Recording and processing data	The student can: • Record some data in provided tables with accuracy. • With assistance, construct graphs with reasonable accuracy.	The student can: • Record data in provided tables accurately. • With assistance, construct graphs with accuracy. • Use simple statistical tools to process and analyse data, with assistance.	The student can: • Select and design tables and graphs for the recording and analysis of **some** data. • Record data in provided tables accurately. • Construct graphs with accuracy. • Use simple statistical tools to process and analyse data with accuracy.	The student can: • Select and design tables and graphs for the recording and analysis of data. • Record data efficiently and accurately. • Construct graphs with accuracy • Use simple statistical tools to process and analyse data with accuracy.
Analysis and evaluation of data	The student can: • Draw conclusions from observations, evidence and data, and relate this to hypotheses, with assistance. • With assistance, identify sources of error in the investigation method.	The student can: • Draw conclusions from observations, evidence and data, and relate this to hypotheses and scientific concepts, with assistance. • With assistance, Identify sources of error in the investigation method.	The student can: • Draw conclusions from observations, evidence and data, and relate this to hypotheses and scientific concepts. • Identify sources of error in the investigation method and suggest specific improvements that would reduce error.	The student can: • Draw conclusions or explain interactions from observations, evidence and data, and relate this to hypotheses and scientific concepts. • Identify sources of error in the investigation method and suggest specific improvements that would reduce error. •Critique reports of investigations noting any flaws in design or inconsistencies of data.

Communication of findings	The student can: • With assistance, communicate findings using scientific language and meaningful representations and make evidence-based arguments.	The student can: • Communicate findings using scientific language with a fair degree of accuracy and using some meaningful representations. • With assistance, make evidence-based arguments.	The student can: • Communicate findings using scientific language with a good degree of accuracy and fluency, and using meaningful representations. • Make evidence-based arguments.	The student can: • Communicate findings using scientific language with a high degree of fluency and accuracy, and using meaningful representations and make evidence-based arguments.

Overall evaluation with comment/evidence:

Teacher's signature: ____

Date: ______________________________

WEBSITES AND EXCURSIONS

WEBSITES FOR TEACHERS

Topic	Website	Comment
Global warming	http://www.cmar.csiro.au/e-print/open/holper_2001b.html	This 6 page long information sheet provides an excellent overview of global warming, the greenhouse effect, greenhouse gases, etc. It provides data and graphs that show the build-up of greenhouse gases in the atmosphere, and likely consequences. Written in June 2001, it was reviewed in 2008 and still is a very useful resource.
	http://www.science.org.au/nova/016/016key.htm	This is part of the website of the Australian Academy of Science. It provides an excellent overview of global warming in language suited to teachers and students, ideas for lessons, related sites, and other useful resources.
	http://www.nasa.gov/multimedia/podcasting/GlobalTemperature09.html	This is a podcast from NASA. It features a recently released new analysis by climate scientists at NASA's Goddard Institute for Space Studies (GISS) of global average temperatures that show 2009 was tied as the second warmest year ever recorded.
	http://www.teacherscop15.dk/themes/sea-level/index.html	This is an excellent teacher resource. It includes valuable information about sea-level rising in particular, lesson ideas, ideas for experiments and demonstrations on sea-level rising, and many links to other valuable sites that include interactive animations from NASA.
	http://www.csiro.au/multimedia/Climate-Adaptation-Video.html	This is an approx 4-minute video produced by the CSIRO's Climate Adaptation National Research Flagship. It is an excellent documentary about how we can adapt to climate change in Australia.
	http://www.csiro.au/org/ClimateAdaptationFlagship.html	This describes the work of the CSIRO Climate Adaptation National Research Flagship, and provides links to many excellent resources.
	http://www.csiro.au/science/Climate-Change.html	This is the starting page to the CSIRO resource on this issue. It contains an excellent video about how climate change is threatening the Southern Ocean, which lasts almost 8 minutes. It also provides links to further information and other resources.
	http://www.csiro.au/science/Managing-Species-Ecosystems.html	This is an interesting outline of the likely impact of climate change on Australia's ecosystems, with further worthwhile links provided.
	http://www.csiro.au/science/SustainableCitiesAndCoasts.html	This is an overview of the likely impact of climate change on urban and coastal communities and the research CSIRO is undertaking to help the communities solve these challenges.
	http://www.nasa.gov/home/hqnews/2011/mar/HQ_11-090_Amazon_Forest.html	This is a fascinating news bulletin from NASA about the effect of drought on the greenness of tress in the Amazon forest, which could cause loss of trees and hence contribute to global warming
	http://www.csiro.au/multimedia/Methane-Clathrate.html	This is a fascinating podcast about the problem of methane locked away in permafrost and in the ocean floors. Global warming can cause this ice-like material to be released as a methane gas, which is a far more potent greenhouse gas than carbon dioxide.
	http://www.nasa.gov/multimedia/imagegallery/image_feature_1549.html	This is an exceptional image of the Earth from NASA, showing snow cover in November 2009. The text accompanying the image is very informative.
	http://data.giss.nasa.gov/gistemp/	This is a fascinating site that provides recent data on the surface temperatures across the world collected by NASA over the past few years. It includes very useful graphs and animations.
	http://www.sciencedaily.com/releases/2009/0	This is a very interesting media release about the significant but largely unknown role played by diatoms in fixing carbon in

	3/090317125217.htm	the oceans and how this may change with increasing ocean temperature. The media release has links to related articles. This news source also has tabs for 'Earth and Climate', and 'Matter and Energy', and a search engine for other specific topics.
	http://www.ucsusa.org/global_warming/science/global-warming-faq.html	This website of the Union of Concerned Scientists from the US provides answers to some frequently asked questions on the science of global warming, and is worth looking at.
	http://www.ipcc.ch/	The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organisation and the United Nations Environment Program. The IPCC issued its first set of reports on the science of climate change, likely impacts and response strategies in 1990. The latest report (Fourth) was in 2007 and can be found at this site. The site also has other valuable information.
	http://www.climatechange.gov.au/publications/#renewable	This is part of the website of the Australian Government's Department of Climate Change. It shows many valuable resources that are available.
	http://www.nasa.gov/home/hqnews/2011/jan/HQ_11-014_Warmest_Year.html	This NASA news bulletin reports on 2010 as the warmest year on record, with other interesting data and links.
	http://www.bom.gov.au/info/GreenhouseEffectAndClimateChange.pdf	This is a very comprehensive and useful 78 page booklet on the greenhouse effect and climate change produced by the Australian Government Bureau of Meteorology.
Ozone layer and atmospheric pollutants	http://macuv.gsfc.nasa.gov/	This very useful NASA website provides 'the results and ongoing data studies for the study of ozone and other gases, aerosols, radiances, and ultraviolet radiation, and what has been learned about atmospheric pollution and air quality from the international science missions making these measurements.'
Range of energy resources	theconversation.edu.au	Launched in March 2011, The Conversation is an independent source of information, analysis and commentary from the university and research sector. The site is in development and feedback is welcome.
	http://serc.carleton.edu/NAGTWorkshops/energy/visuals.html	This is an excellent website that provides videos of a range of different energy resources. In particular there is a very interesting video of a German experiment in which solar panels have been installed everywhere possible near Munich, including along the length of the highway, to maximize its potential contribution to their energy needs.
	http://www.infinitepower.org/lessonplans.htm.	This part of the website of the Texas State Energy Conservation Office provides lesson plans, worksheets and other useful resources for teachers. It caters for students of different age groups.
	http://www.energymatters.com.au	This is a large energy company that provides a lot of very useful information about renewable energy options in the various parts of its website.
Geothermal power stations	http://www.ga.gov.au/image_cache/GA10663.pdf	This is a very helpful article accompanied by clear diagrams about how this energy resource works, where it is established in Australia, and its possible future development in Australia.
Biofuels	http://www.sciencedaily.com/releases/2009/06/090622165830.htm	This is a very interesting media release about the possible harvesting oil from diatoms, with the aid of solar panels. They are thought to have greater potential than oil seeds. The media release has links to related articles. This news source also has tabs for 'Earth and Climate', and 'Matter and Energy', and a search engine for other specific topics.
Solar ponds	http://en.wikipedia.org/wiki/Solar_pond	This provides fascinating information about another way to use the energy of the Sun, using salt ponds.

NOTE:

1 Other websites are listed in some activity ideas and some of the other support material in this Teacher Resource.

2 Some of these websites are suitable for students. Websites for students are listed on the STELR website.

3 The teacher also is advised to access the digital curriculum resources provided by Education Services Australia. The access pathway to their learning objects, videos and other resources depends on the State or territory. In some states and the territories it is: www.scootle.edu.au. Other states have their own education access portals. Use the advanced search in your education authority's portal by using key words such as global warming. For example, they have available an excellent video: R11443 'Climate change: coral reefs on the edge'. This is a 26 minute video about coral bleaching, and ocean acidification.

4 Subscription to COSMOS magazine and membership of the Australian Institute of Energy, which publishes a very helpful and informative periodical and organizes many worthwhile seminars and conference, are also very worthwhile.

WEBSITES AND EXCURSIONS

POSSIBLE EXCURSIONS

Place	Website	Comment
CSIRO Energy Centre, NSW	http://www.det.csiro.au/energycentre/	The CSIRO Energy Centre is located in Newcastle, NSW. The building models an ecologically sustainable design. The website shows a video of the centre, information and contact details.
Display of sustainable technologies in NSW	http://www.futureworld.org.au/	This display centre exhibits technologies for a sustainable world. Located in Warrawong, NSW, the display includes wind energy, a solar display, a model of the Solar Sailor powered ferry with a computer simulation, and the 'What is a watt?' activity in which students can pedal a bike and learn how much energy appliances use and how much greenhouse gases they produce.
Snowy Hydroelectric Scheme display centre in NSW	http://www.snowyhydro.com.au	An information and education centre that offers educational programs and interactive displays on hydroelectric power is run by Snowy Hydro Limited in Cooma, NSW. Click on 'Education program' for details.
Renewable energy display centres in WA	http://www.energy.wa.gov.au/3/3550/64/demonstration_sites.pm	This website of the Office of Energy, Government of WA, lists a range of renewable energy display centres that are available for school excursions. Contact details are provided.
Renewable energy displays in Adelaide	http://www.southaustralia.com/adelaide-green-city.aspx	This website of the Government of SA lists a range of events, tours, resources, etc. that are part of its Green City Initiative.
Large-scale solar display in Alice Springs	http://www.desertknowledge.com.au	This solar technology demonstration display centre exhibits include solar concentration dishes that use the latest waterless cooling systems and large scale tracking arrays. Click on the Desert knowledge solar centre tab. You can see an interactive map of the sire by clicking on 'Live system Info'.
Energy park in Melbourne	http://www.ceres.org.au	This organisation has a large site in Brunswick which includes an energy park. A variety of activities is provided for students, who can also view other sustainable practices in action. Incursions also are available (see Table 3).
Coal-fired power stations in Victoria	http://www.powerworks.com.au	This organisation offers a variety of educational programs on electricity, energy and in particular the mining of coal and coal-fired power stations at its display centre in Morwell. A tour of a mine and a large coal-fired power station can be included in the program.
Renewable energy sites in Queensland	http://www.cleanenergy.qld.gov.au	The Department of Clean Energy of the Government of Queensland operates this site which provides information about a range of locations for geothermal power stations and other renewable energy resources in Queensland.

PERFORMING RISK ASSESSMENTS

ADVICE ON PERFORMING RISK ASSESSMENTS

The student experiments in the STELR Chemistry Program have been designed to pose as little risk as possible. Since the chemistry experiments generally involve food items and gentle cleaning agents, teachers do not need to have specialised in chemistry to perform the chemistry experiments in the student book.

Teachers will notice that in almost every experiment, students are asked to perform a risk assessment of their own, by completing a table. Teachers are strongly advised to provide students with the opportunity to complete this before a class discussion, so that they learn to think through possible risks and problems and how they can be avoided. This active involvement of students will help them 'own' their risk management and should help make them far more aware of possible consequences of their actions, and hence more careful and responsible.

Teachers are strongly advised to trial experiments themselves prior to performing them with students. Teachers need to know the finer points of the experiments, which knowledge can only be gained by performing the experiment at first-hand. This will enable them to identify possible risks, as well as to determine how to best manage the class for that activity. This is far preferable to having laboratory staff perform it in their stead.

Following is a risk assessment proforma, which teachers may feel find useful. However, in some locations there may be a standard proforma that must be used. In many locations it is mandatory that the teacher performs the risk assessment, not a member of the laboratory staff. This makes eminent sense, since there will be different levels of risk with different groups of students performing the same experiment. The teacher knows the students and can therefore judge the risk for each class and how best to manage the class.

In some of the chemistry experiments, teachers have been provided with links to relevant generic Material Safety Data Sheets (MSDS). However, teachers should be aware of the health and safety regulations in their State or Territory and follow these requirements. For example, one requirement might be that the MSDS used should have been obtained from the supplier of the chemical used in the school; the generic MSDS should only be used where the supplier is unknown or has ceased trading.

SAMPLE RISK ASSESSMENT PROFORMA

A risk assessment must be performed by completing this form before conducting an experiment in which materials that are classified as hazardous or dangerous are used or produced.

TITLE OF EXPERIMENT					
YEAR LEVEL		DATE OF RISK ASSESSMENT		NAME OF TEACHER CONDUCTING THE RISK ASSESSMENT	

HAZARDOUS OR DANGEROUS SUBSTANCES THAT ARE USED OR PRODUCED IN THIS EXPERIMENT

HAZARDOUS OR DANGEROUS SUBSTANCE	FORM (solid, liquid, gas/vapour, dust, dissolved in solution) and CONCENTRATION (if dissolved in solution)	DATE STATED ON MSDS

If necessary, attach an additional sheet.

HAZARD INFORMATION

Classify every substance in the above list into one or more of the following categories.

Toxic	Carcinogenic	Corrosive	Genetic damage or birth defects	Harmful	Irritant	Sensitiser	Other

ROUTES OF ENTRY

State the possible routes of entry of all the substances listed, by listing them in one or more of the following categories.

Ingestion	Skin/ membrane absorption	Inhalation

ORGANS AFFECTED

State the possible organs affected by the substances listed, by listing them in one or more of the following categories.

RESPIRATORY SYSTEM	DIGESTIVE SYSTEM	NERVOUS SYSTEM	EYES	LIVER	KIDNEYS	SKIN	OTHER

CONTROL MEASURES REQUIRED

Tick appropriate boxes. In the case of protective gloves and protective clothes, also state the type required.

Use fume cupboard		Wear protective gloves	
Use exhaust ventilation		Type of protective gloves required	
Use full face shield		Wear protective clothes	
Use safety glasses		Type of protective clothes required	

DISPOSAL OF WASTES REQUIRED

CONCLUSION ABOUT RISKS

DECLARATION

I have read and understand the risk assessment and acknowledge the controls that must be taken when handling the above-named materials and undertaking the experiment.

Signed: **Assessor:** ______________________________ **Date:** __________

Teacher: ______________________________ **Date:** __________

Teacher: ______________________________ **Date:** __________

Teacher: ______________________________ **Date:** __________

Teacher: ______________________________ **Date:** __________

Teacher: ______________________________ **Date:** __________