

# REACT TO CHEMISTRY

A resource book of ideas for National Science Week 2011



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# MINISTER'S FOREWORD



Science knows no borders of race, gender, age or income. It offers us all the tools to explain the world, and to change it for the better.

The Gillard Labor Government is determined to inspire all young Australians to be part of that great mission. That is why we are proud to support National Science Week, our annual salute to Australian scientists of the past, the present – and the future.

2011 will take the celebration to new heights, with more than 1000 events and 1.6 million participants.

As part of this celebration, it is my pleasure to commend the Australian Science Teachers Association's (ASTA) 2011 National Science Week teacher resource book, *React to Chemistry*.

The United Nations has named 2011 the International Year of Chemistry, commemorating the 100th anniversary of the awarding of the Nobel Prize for Chemistry to Madame Marie Curie.

*React to Chemistry* will help bring this critical subject to life for young Australians, with the help of our teachers and community science advocates. It provides a wonderful range of online resources, classroom and community activities, photographs, diagrams, projects and challenges that will engage children in science.

Australian chemists have a remarkable story to tell. We boast a world-class chemical research sector, working in academia and industry to meet the challenges of the twenty-first century. They are cleaning up our environment, finding new energy sources, and fighting hunger and disease.

In recognition of the important contribution of women, the resource book includes profiles of inspirational young women chemists who work in such diverse fields as mining, wine-making and degradable plastics.

I encourage you to bring their remarkable stories to the young people of Australia, in National Science Week and beyond.

My sincere thanks go to ASTA for another outstanding publication that will open the transformational power of science to a new generation.

**Senator Kim Carr**  
Minister for Innovation, Industry, Science and Research

## PRESIDENT'S MESSAGE

The Australian Science Teachers Association (ASTA) is pleased to bring you *React to Chemistry*, the 2011 resource book for National Science Week. The purpose of the year is to celebrate "the achievements of Chemistry and its contributions to the well-being of humankind" (<http://www.chemistry2011.org/>). 2011 is also the 100th anniversary of Marie Curie receiving the Nobel Prize in Chemistry.

ASTA acknowledges the funding support for this resource from the Australian Government through the Department of Innovation, Industry, Science and Research (DIISR). I would also like to acknowledge the significant contribution of the many people who assisted with the writing, editing and production of this book.

I'd like to thank each of ASTA's eight member Science Teacher Associations, through their National Science Week Representatives, for encouraging schools to be involved in activities during National Science Week.

We are continually revising the book and in 2011, there is a section on community events and activities that are occurring throughout Australia for the International Year of Chemistry. There is also information on how school students can get involved in the Global Water Experiment and contribute their results to a global map. Finally, I'd like to encourage all teachers of science across Australia to use this resource to promote Science, and the role of chemistry, within your local communities.

**Anna Davis - President, ASTA**



# 2011 NATIONAL SCIENCE WEEK RESOURCE BOOK

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Members: \$12.00  
 Non-Members: \$15.00  
 STAs: \$10.00

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2	\$3.80	\$3.80
3-5	\$8.00	\$10.00
>5	POA	POA

A resource book of ideas for National Science Week 2011



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# CONTENTS AND ACKNOWLEDGMENTS

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<b>INTRODUCTION.....</b>	<b>2</b>
<b>SAFETY.....</b>	<b>3</b>
<b>QUESTIONNAIRE .....</b>	<b>4</b>
<b>IYC2011 AUSTRALIA - Community Events and Activities.....</b>	<b>5</b>
<b>EARLY CHILDHOOD - Muds and Suds: the science of cleanliness.....</b>	<b>8</b>
<b>CHAPTER 1 - FOOD CHEMISTRY.....</b>	<b>13</b>
Chocolate.....	14
Milk and Cheese.....	17
Vitamins and Nutrition.....	20
Sausage-ology.....	23
<b>CHAPTER 2 - GREEN CHEMISTRY .....</b>	<b>25</b>
<b>A COLLOID OF AUSTRALIAN CHEMISTS ....</b>	<b>26</b>
<b>CHAPTER 3 - ENVIRONMENTAL CHEMISTRY..</b>	<b>31</b>
Atmospheric Chemistry .....	32
Soil Chemistry .....	34
<b>CHAPTER 4 - LIGHT CHEMISTRY .....</b>	<b>39</b>
Nuclear Chemistry.....	40
Synchrotron Chemistry.....	42
<b>CHAPTER 5 - MATERIALS SCIENCE.....</b>	<b>44</b>
<b>WATER – A CHEMICAL SOLUTION - A Global Experiment for the International Year of Chemistry.....</b>	<b>48</b>
<b>CHEMIST PROFILES.....</b>	<b>53</b>

# INTRODUCTION

2011 is the International Year of Chemistry, sponsored by the United Nations and driven internationally by the International Union of Pure and Applied Chemistry (IUPAC), which is the international body that establishes agreed nomenclature in all fields of chemistry. The IYC 2011 is a world-wide celebration of the achievements of chemistry and its contributions to the well-being of humankind. The Australian Science Teachers Association has chosen to celebrate the IYC 2011 with the publication of *React to Chemistry*, its annual resource book for National Science Week.

The *React to Chemistry* resource book has been designed to provide teachers and community science educators with background information and activities that they can use to increase the knowledge and understanding of the science of chemistry of young Australians.

It is not intended to be an exhaustive resource but rather a springboard of ideas to enable educators, either in schools or in community groups, to select aspects of chemistry that may interest them or their charges.

## HOW THIS BOOK IS STRUCTURED

This booklet has been structured to provide opportunities for teachers and students to develop an understanding of the background science of chemistry and the important, positive role it plays in everyday life, as well as in many of Australia's main industries.

The first section summarises some of the community events and activities that will take place during 2011 to celebrate the International Year of Chemistry, including travelling exhibitions and competitions for all ages.

The next section is designed for Early Childhood classes. However, Early Childhood teachers are encouraged to read through some of the later chapters to find other activities that can be adapted for their students.

The applied chemistry section of the book has been divided into five chapters:

1. Food Chemistry – looking at chocolate, milk and cheese, vitamins and sausages.
2. Green Chemistry – examining a branch of chemistry that aims to find alternative chemicals, conditions and processes to reduce risks to the environment and human health.
3. Environmental Chemistry – looking at the chemical interactions between humans and nature.
4. Light Chemistry – its important application to areas of science including medicine, industry and environment.
5. Materials Science – provided by Bayer MaterialScience.

The next section of the book is dedicated to the IUPAC IYC2011 Global experiment, which is an initiative of the IUPAC Committee on Chemistry Education. It has been developed to appeal to students from middle primary to senior secondary and to community groups. The activities that make up the experiment will help students appreciate the role of chemistry in issues of water quality and purification.

The final section is a selection of biographies of young Australian chemists who explain their passion for chemistry, where they work and what they do.

Where appropriate, websites have been suggested to enable readers to access further information and activities. All websites were deemed appropriate at the time of publication. It cannot be guaranteed that all websites will continue to be available after publication.

## ORGANISATION OF THE CHAPTERS

Each of the chapters are written for F-12 teachers and include the following features:

- an introductory page which provides background information on the subject of the chapter
- a series of topics of varying length, each of which can be used independently of other topics.

Each topic consists of:

1. background information about the header topic. This information contains the background science knowledge and understandings relevant to the topic.
2. teaching and learning activities. Activities are generally provided across four groups:
  - lower primary (Years F-2)
  - primary (Years 3-5)
  - middle school (Years 6-9)
  - upper secondary (Years 10-12)

Not all groups are catered for in every set of teaching activities, so teachers are encouraged to read across all the activities for ideas that are appropriate to, or could be adapted for, their own students' specific talents, interests and levels of conceptual development.

## LINKS TO THE AUSTRALIAN CURRICULUM - SCIENCE

*React to Chemistry* has been developed to have broad links to the Australian Curriculum – Science. Topics covered align with the Chemical Sciences sub-strand of **Science Understanding** across all years F-12, and with many of the sub-strands in both **Science as a Human Endeavour** and **Science Inquiry Skills**. The resource book is not intended to be a comprehensive resource for the chemical sciences sub-strand nor is it a curriculum document. As a result, so some strands are not covered fully allowing teachers to explore other aspects of chemical science.

A detailed table of the relationship between topics covered in *React to Chemistry* and the strands and content descriptions in the Australian Curriculum – Science is available on the ASTA website [www.asta.edu.au/resources/national\\_science\\_week\\_resource](http://www.asta.edu.au/resources/national_science_week_resource)

## SAFETY AWARENESS

All experiments included in *React to Chemistry* have been designed or selected to minimise hazards. However, there is no guarantee that a procedure will not cause injury. Teachers need to be aware of the special considerations surrounding practical activities in the classroom and the requirement for protective clothing and safety glasses for participants. Teachers should test all activities before using them in class and observe the OH&S requirements of their own State or Territory. All necessary safety precautions should be outlined clearly to students prior to the commencement of any activity.

It is essential to include a risk assessment as an integral part of any practical activity or investigation where there is a perceived level of risk.

The following sample template for a **risk assessment** has been included for teachers. This can be adapted for students in upper secondary if they are directed to conduct their own risk assessment. The full size version is available on the ASTA website [www.asta.edu.au/resources/national\\_science\\_week\\_resource](http://www.asta.edu.au/resources/national_science_week_resource)

Where chemicals are concerned, the risk assessment process (and access to Material Safety Data Sheets) applies to those that are 'designated hazardous', either by the manufacturer/ supplier or by National Occupational Health and Safety Commission (<http://safeworkaustralia.gov.au/>) criteria. It is easy to find if a substance is a designated hazardous one. One source of information is the ChemWatch database which is used by the majority of secondary schools.



### RISK ASSESSMENT FOR PRACTICAL ACTIVITIES

Practical Activity – describe the activity planned.

Who would do this activity

Teacher demonstration     Teacher and students     Students (under supervision)

What are the possible Risks?

List the Hazards present in this activity that could pose a risk.  
Give each Risk a Risk Rating (e.g. High, Medium, Low)

1  
2  
3  
4  
5  
6

Hazards to consider:

- Chemical
- Thermal
- Biological
- Sharps
- Electrical
- Radiation
- Other

Control measures: Give details of how these Risks will be managed –

Any Designated Hazardous Substances used?  
Are Material Safety Data Sheets required?

#### Facilities and Services needed to do this activity safely

Services	Personal Protective Equipment (PPE)	Safety Equipment
<ul style="list-style-type: none"> <li>• Running water</li> <li>• Gas supply</li> <li>• Good ventilation</li> <li>• Exhaust ventilation</li> <li>• Other (please specify)</li> </ul>	<ul style="list-style-type: none"> <li>• Apron</li> <li>• Safety glasses</li> <li>• Gloves – Type.....</li> <li>• Other (please specify)</li> </ul>	<ul style="list-style-type: none"> <li>• Fume cupboard</li> <li>• Eyewash/shower</li> <li>• Other (please specify)</li> </ul>
Notes:	Notes:	Notes:

#### Disposal of wastes and cleaning up

Are there any wastes or hazardous materials produced in this investigation? If so, outline how they will be disposed of safely.

Risk Assessment indicates that this activity can be safely carried out

Yes    No

This risk assessment has been carried out by the following:

Teacher's name	Signature	Date
Student's name	Signature	Date

# QUESTIONNAIRE - REACT TO CHEMISTRY

Your name	Year level you teach (please circle)
	K 1 2 3 4 5 6 7 8 9 10 11 12
School's name	Year levels catered for at your school (please circle all that apply)
	K 1 2 3 4 5 6 7 8 9 10 11 12
School's email	
School's mailing address	ASTA member (please tick the appropriate box)
	<input type="checkbox"/> YES (please state which science teachers association)
	<input type="checkbox"/> NO

## FEEDBACK CRITERIA - Please indicate your ratings

1. Overall response to the book	2	1	0	-1	-2	
A valuable resource						Of little value
Well presented						Poorly presented
Information sections were helpful						Not helpful
Supports an inquiry approach to student learning						Does not support an inquiry approach
Applicable beyond National Science Week 2011						Not applicable
2. Resource Book Content	2	1	0	-1	-2	
Good balance of activities – primary to secondary						Too targeted
Includes activities relevant to the class level I teach						Irrelevant to my students
Created student interest						Little interest created
Provided a springboard to other ideas and activities						No scope for creativity
Additional resource links were useful						Not useful
Appropriate methodology						Inappropriate methodology

Have you used the National Science Week resource book in previous years?  Yes  No

Will you/did you use *React to Chemistry* for National Science Week 2011?  Yes  No

Which two features of the book are of the most use to you?

1 \_\_\_\_\_ 2 \_\_\_\_\_

Which two features of the book are of the least use to you?

1 \_\_\_\_\_ 2 \_\_\_\_\_

Are there any changes you would suggest?

Would you prefer future editions of the resource book:

to continue in printed format  to change to a digital book  be in both printed and digital format

National Science Week 2012 will be held 11-19 August. Please give suggestions for topics for future editions of the resource book.

FAX/POST this questionnaire to ASTA by 2 September 2011 to

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International Year of  
**CHEMISTRY**  
2011

# IYC2011 AUSTRALIA

## - COMMUNITY EVENTS AND ACTIVITIES

**Throughout 2011, key events will promote IYC and chemistry in modern Australia. These events offer opportunities for public participation at the local, regional, national and international level.**

So often, the influence of chemistry on our daily lives is overlooked. IYC 2011 events and activities emphasise that chemistry is a creative science essential for sustainability and improvements to our way of life.

Events and activities will explore how chemical research is critical for solving our most vexing global problems involving food, water, health, energy and transportation.

IYC 2011 Australia also encourages other organisations and individuals to run events to celebrate the IYC and importance of chemistry in everyday life. The international IYC2011 website is [www.chemistry2011.org](http://www.chemistry2011.org). This website lists international events, ideas and activities.

Listed below are some of the major events that will take place during IYC 2011 Australia. More information on each of these and a full calendar of events can be found at [www.iyc2011.org.au](http://www.iyc2011.org.au). You can also keep up to date on twitter (IYC2011Aus) or Facebook (IYC2011 Australia) and to participate in discussions and see what chemistry is happening in Australia.

### TRAVELLING EXHIBITIONS

Thanks to support from the Department of Innovation, Industry, Science and Research, four travelling chemistry exhibitions will be rolled-out across each state in 2011. The exhibitions will be displayed at public libraries throughout the country demonstrating the fundamental importance of chemistry in everyday life.

#### **Eat, drink and chemistry**

When it comes to food and drink chemists are multi-cultural scientists. Agriculture, using the land to raise

crops and animals; aquaculture, fish farming; and viticulture, growing grapes and making wine, are a few of the 'cultures' where chemistry is at work.

Growing populations, affluence and appetites place pressures on all parts of the food chain. Chemists' efforts go, in part, to improving ways to desalinate, purify or treat water for drinking. Chemists assist with providing sustainable supplies of feed and preventing diseases in aquaculture to improve seafood. They work to increase calcium and minerals in milk products, and to add value to Australian grain products they also develop crops as sustainable sources of specific nutrients. They are also developing sensors to detect the molecules in wines that will help wine makers improve their wines and adjust styles to suit different palates in overseas markets.

'Eat, Drink and Chemistry' showcases projects chemists are involved in to increase and secure the supply of food, reduce dietary health problems and maintain our environment.

Some of the topics covered by this exhibition include:

- **Chemistry's catch of the day** – a few ways that chemistry is helping Australian aquaculture.
- **Water features** – chemical technology working toward securing Australia's water supply.
- **A smell ahead** – how a nose of the future will help winegrowers and others.
- **Food packaging that takes itself away** – a new plastic food packaging material that readily biodegrades.

Locations (from May 2011): WA – South Perth Library, 2 May – 2 June

#### **Nature's chemical diversity**

The natural world is a tapestry of known, new and yet to be discovered chemicals. The smallest living things, microbes, land and sea plants, sea animals and minerals from the ground are sources of new families of compounds with useful properties. Nature was the original

source of materials and medicines for our ancestors. Around 150 years ago chemists started to isolate, identify and make the pure active ingredients to create the first modern medicines, as well as other products.

Our use of the elements and compounds in minerals has also evolved over time and the demand on easily accessible and rich ore bodies is ever increasing. Chemists are responding with new techniques to recover mineral assets more effectively and efficiently with less environmental impacts and by developing synthetic replacement materials.

The value on biological diversity, which supports all living systems including us, has gone up. Biodiversity brings chemical diversity and opportunities for health and wealth. Whether animal, mineral or vegetable it's all a matter of chemistry.

'Nature's Chemical Diversity' highlights the way that chemists have used nature's diversity to identify treatments for diseases, substances that are light yet immensely strong and materials that efficiently transmit electricity and communication signals for broadband and other uses.

Some of the topics covered by this exhibition include:

- **Seaweed's biologically active extracts** – chemicals extracted from seaweed have a surprisingly wide range of uses.
- **Bubbles float the goods** – bubbles provide an energy efficient way for miners to separate valuable minerals from unwanted materials.
- **Jellyfish light up medical research** – a protein from a jellyfish enables researchers to view details inside cells.
- **Venomous path to painkillers** – molecules from animal venoms are leading to new medical treatments.

Locations (from May 2011): QLD – Gladstone Regional Library Fraser Coast, 19 April – 19 June

## Chemistry and the nucleus

The story starts with the sea of invisible natural radiation around and within us and includes a scattering of islands of human-made sources of radiation. The course your lifestyle sets affects your exposure to both natural and other radiation sources.

You interact with radiation directly or indirectly in many ways. To see inside your body doctors often make use of properties of the core of atoms, their nucleus. Numerous medical treatments also use beams of radiation or radiopharmaceuticals to kill cancer cells and other diseases. We use the energy released by unstable, radioactive elements distributed throughout the Earth's crust and its deeper mantle to get heat from the Earth. Particles and radiation from atomic nuclei penetrate matter to enable us to analyse the very small and complex nature of things and allow us to improve foods and make useful new chemicals. We also have means of isolating unwanted radioactive materials from our environment.

Human-made radioactive sources and their chemistry are relatively new to the nuclear family story. While now used in many ways we need care with introduced radiation to ensure we do not encounter excessive exposures.

'Chemistry and the nucleus' looks at the ultimate nuclear family and how their half-lives are part of your lives.

Some of the topics covered by this exhibition include:

- **Revealing the inner you** – nuclear medicine uses radiation to diagnose and treat a wide range of illnesses.
- **Send in the neutrons** – neutrons offer unique and versatile ways to study materials.
- **A date with a radioactive clock** – 'How old is this?' is often a critically important question. The radioactivity in materials can be used as a clock to find the answer.
- **OPAL** – a gem of Australian science – Australia has one of the worlds most versatile and efficient nuclear research reactors.

Locations (from May 2011); NSW – Singleton Public Library, 14 April – 23 May; Wallsend District Library, 23 May – 1 July

## Healthy chemistry

Being healthy is a matter of good chemistry. A myriad of simple and complex chemicals interact and react within your body constantly. To remain in balance you need food, water and oxygen from air to replenish the chemicals your body transforms, uses and then loses in everyday life.

A large part of staying well involves having clean water, good sanitation and a good diet but even the fittest of us can become unwell. Infections, genetic disorders, allergic reactions and impacts from your lifestyle, such as smoking, can make your body's natural balance go awry. Illnesses can be difficult to diagnose or treat.

Chemists look for subtle chemical signals in the body, called biomarkers, which indicate the risk or progression of a disease, or are clues for developing treatments. Once a biomarker is identified drugs can be designed and made from existing or new compounds to treat specific illnesses and disorders and have fewer side effects. Australian biodiversity plays a role as some new drugs and products are discovered from studying substances in our marine and terrestrial plants, algae, invertebrates and microbes.

New science and technology bring answers as well as questions. Nanotechnology uses properties of very small particles for diverse applications including products that

go on or in us such as cosmetics, drugs and food. While nanoparticles offer enhanced performance it is difficult to test some products for potential health effects. Chemists in the new field of nanotoxicology are seeking fast and reliable means of testing the safety of this new technology.

The 'Healthy Chemistry' exhibition looks at the role of chemistry in health and will help demonstrate the ways chemistry and technology are interacting to find answers to some of medicine's biggest questions.

Some of the topics covered by this exhibition include:

- **Butterfly inspires a treatment** – development of the cancer medication Alimta®.
- **A cancer cure that's just for you** – personalised medicine is based on your genetic makeup; for instance the breast cancer treatment Herceptin®.
- **Can robots cure cancer?** – how robotic drug screening speeds up development of personalised cancer treatments.
- **Better nano-safe than mega-sorry** – the new study of nanotoxicology assesses safety of new nanoparticle products.

Locations (from May 2011); VIC – The Age Library, Broadmeadows, 20 April – 18 May; Ballarat Library, 18 May – 15 June



Image: stock.xchng

## THE ART OF CHEMISTRY – THE PERIODIC TABLE ON SHOW

In an exciting project that uses art to describe the most fundamental and important document used by chemists, Australian artists have joined with chemists to produce a unique interpretation of each element of the 2010 IUPAC Periodic Table. Chemists have prepared information on each element including its discovery, history, how it exists in nature and its modern day uses. This information was distributed to Australian artists who are preparing individual prints of each element interpreting this information. All prints will be brought together at the end of the project to form a full Periodic Table. The project will result in a multi-disciplinary educational resource that brings art, history and modern science together, all linked by the elements. The final Periodic Table will be made available for touring, photographed for posters, and become a unique web resource.

Tour dates and venues are yet to be confirmed. Keep up to date by visiting the Australian IYC2011 website [www.IYC2011.org.au](http://www.IYC2011.org.au)

## NATIONAL TOUR

The IYC 2011 Australia National Tour will bring up to four internationally renowned chemists from different backgrounds to Australia to tour as part of the celebration.

Speaking at events throughout the country, the tour guests will include chemists who are involved in current chemistry research or application, as well as those who help cross the divide between science and the everyday.

Keep up to date by visiting the Australian IYC2011 website [www.IYC2011.org.au](http://www.IYC2011.org.au)

## COMPETITIONS

### Australian National Chemistry Quiz (Years 7-12)

The annual Australian National Chemistry Quiz will be held on July 28, 2011.

Run since 1984, the Australian National Chemistry Quiz is a unique chemical education activity that has become a truly international event with quiz papers translated into seven different languages. The Quiz aims to promote the study of chemistry in schools by providing an experience to students that is stimulating and

enjoyable as well as a resource to teachers. The 2010 Quiz attracted 115,012 entries from Years 7-12, representing 1,459 schools throughout the country and 14 neighbouring countries.

The 2011 Quiz has been endorsed by IUPAC as an International unifying event during the International Year of Chemistry. Run in four divisions: Junior Years 7-8, Junior Years 9-10, Senior Year 11 and Senior Year 12, the Quiz papers contain novel and interesting questions that cover the diverse application of chemistry to life.

Supervised by teachers within each participating school, the Quiz consists of 30 multiple-choice questions and runs for approximately one hour. An analysis of school results, reports, certificates and plaques are sent to participating schools after the event.

For further information see the Australian National Chemistry Quiz website, [www.ancq.com](http://www.ancq.com).

### Titration Stakes Competition (Years 7-12)

The Titration Stakes Competition is a quantitative analytical competition open to junior and senior high school students across Australia.

The competitions operate at a number of school and university venues throughout the country. Students compete in teams of three and, in ninety minutes, must complete a set of acid-base titrations to determine the unknown concentration of a weak acid. The team's score will depend on the accuracy of the work of its members. The best scoring teams are then invited to participate in the National Competition later in the year.

The competition allows students to learn and practise one of the most fundamental analytical techniques used in chemistry and chemical related sciences. It also develops numeracy and scientific skills.

For more information, contact your RACI State Branch or National Office.

### Crystal Growing Competition (Years 1-10)

Have your students ever tried to grow crystals? Here is an opportunity for your students to take part in a science-based competition. Students can participate as individuals or with a classmate. The competition is open to primary (Yrs 1-6) and secondary (Yrs 7-10) school students with prizes awarded for lower primary, upper primary and secondary age groups.

All students participating will receive certificates and the winners receive prizes.

Using a saturated solution of Alum, crystals are grown over a period of 2-5 weeks so it is important to begin your experiments early allowing time for your crystals to develop. With simple kitchen items students can grow their first seed crystal and then (with time and patience) watch it grow. Alum (potassium aluminium sulphate) will be supplied to all schools upon registration by the RACI (Tasmanian Branch) and can be posted safely.

### Royal Australian Chemical Institute (RACI) contact details

National Office: (03) 9328 2033

NSW & ACT Branches: (02) 9663 4960  
email: [raci-nsw@raci.org.au](mailto:raci-nsw@raci.org.au)

Qld Branch (07) 3420 4223  
email: [qld-raci@raci.org.au](mailto:qld-raci@raci.org.au)

WA Branch 0403 022 968  
email: [ben.fletcher@raci.org.au](mailto:ben.fletcher@raci.org.au)

Other Branches contact National Office in the first instance.





# EARLY CHILDHOOD

## - MUDS AND SUDS: THE SCIENCE OF CLEANLINESS

This special early childhood section of *React to Chemistry* presents a wide range of ideas and activities within the general theme of *The science of cleanliness*. Based on the Joy Crowley book *Mrs Wishy-washy*, these ideas and activities have been developed in a logical order. Read the entire section, and choose those that best suit your class and context in order to develop an appropriate series of meaningful learning experiences. Accepting that early childhood education is delivered in an integrated manner, many of the ideas show links with the various areas of science and learning areas other than science. Scientific explanations of certain concepts are presented in boxes throughout.

### AIMS

*The science of cleanliness* aims to promote in children a greater sense of responsibility in maintaining their own health through developing an understanding of how and why both animals and humans wash themselves, the differences between being dirty and clean, and how soap works.

### Sam and Jane Wishy Washy

Read the book *Mrs Wishy-washy*. Why did Mrs Wishy-washy wash the animals? How did Mrs Wishy-washy wash the animals? What equipment did she use? What clothing did she wear? Why did she wear those clothes?



Develop a procedure for washing animals based upon the story. Support this with a storyboard of what went into the tub (animals, water, soap, scrubbing brush). For example, 'The \_\_\_\_\_ is in the tub.' Select children to mime this procedure and perform the story for the class.

Act out the story with children dressed up as Mrs Wishy-washy and the animals. Use an old brown sheet as the mud, and encourage the children to roll in the mud.

Alternatively, use plastic toy animals, small plastic tubs, scrubbing brushes, water and soap to retell the story. Photograph the experience so children can develop their own story book called 'Jane Wishy Washy' or 'Sam Wishy Washy'.



Use plastic toy animals, small plastic tubs, scrubbing brushes, water and soap to retell the story.

### Dog wash

How could we wash a dog? Children brainstorm the procedure and what equipment would be needed. Using modelled procedural writing, develop the process of how to wash a dog. Arrange for either a mobile dog wash to visit, or ask a parent to bring a very placid dog to demonstrate the procedure at school. Take photos of the sequence of events, showing the dog before, during and after the wash.

Display photographs in the correct order so a story wall can be made and a sequence demonstrated. Have children draw a diagram to illustrate the sequence of how the dog was washed. Write one or two sentences to describe the pictures. Invite an RSPCA Education Officer to discuss pet care and responsibility.

### How do animals stay clean?

Investigate with the children how different animals stay clean. Use childrens' prior knowledge, books, the Internet and a variety of pictures to obtain information. Set up a picture and word wall showing how different animals clean themselves. For example, birds preen themselves and have baths – some even have dust baths! Many animals lick themselves, some rub up against a tree or have a mud bath, some big animals allow small birds to sit on their back and peck insects off their body, and big fish allow smaller fish to clean out their mouths. Emphasise the verbs used in cleaning language, such as *rub, sit, peck, roll, preen* and *lick*. Invite children to individually select one animal and role play how it cleans itself. The rest of the class have to guess which animal they are and how they are cleaning. To assist this role play, have picture cards that illustrate a variety of animals and how they clean themselves.

### How do I get dirty?

Find out how much the children know about their own personal hygiene. Children need to feel comfortable about getting dirty and knowing they can easily be cleaned. Brainstorm with them ways to get dirty. See how many different ideas the children can come up with: spilling food, getting sweaty, or painting. Using one example, such as playing in the sand pit, list the possibilities such as getting sand in hair, on hands, under fingernails, in clothes or shoes.

Develop a class list of all the parts of their body that get dirty, and how they get dirty. Children can draw a picture of themselves getting dirty. Turn the picture into a collage by adding real dirt to the picture. A short sentence can then be added to the picture by child or adult, about how they got dirty. Children then share their drawings and story with the class, describing which parts of their body are dirty and how they got dirty.

### The Science: What is dirt?

Dirt can be defined as any material that is unwanted and needs to be removed to make something clean. It can come from soil, foods, machines or almost anywhere. Water soluble dirt, like salt and sugar, are easily removed with water alone and are often not thought of as dirt. Dirt from soil (like clay and mud) and dirt from foods and machines (oils and greases) are removed by soap and water.

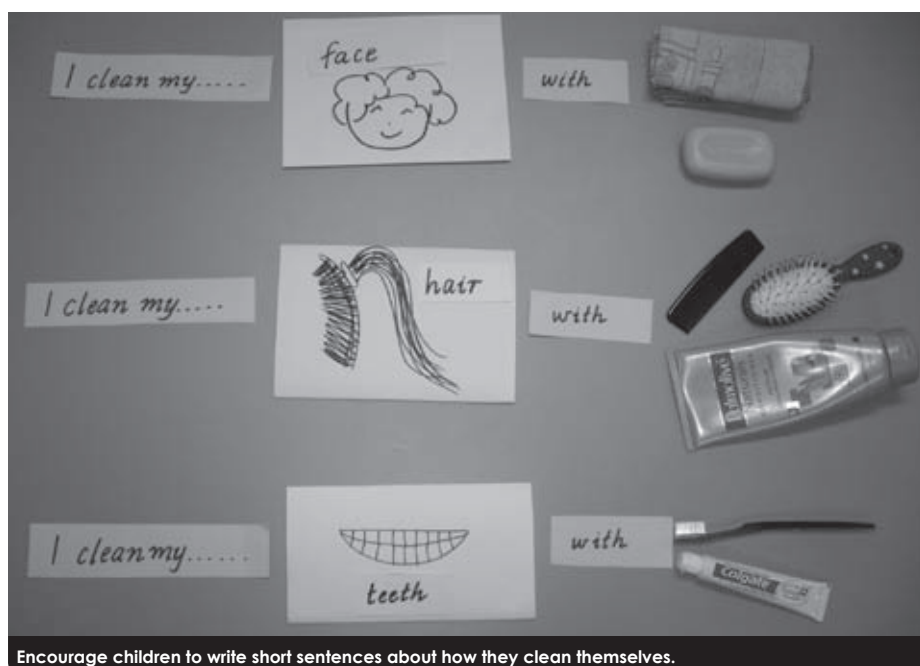


### How do I get clean?

Brainstorm with the children how they get clean? Different parts of their body require different cleaning. Develop a matching chart of all the parts of their body, how they are cleaned and the product used to clean that part.

Develop a body cleaning collage where the children draw a picture of self and glue on cut-out pictures from magazines or catalogues, small pieces of flannel, soap, or photos of bubbles to demonstrate cleanliness.

Using repetitious language, encourage children to write short sentences about how they clean themselves. For example, 'I clean my ... with....' Allow the children to share their drawings and sentences with others, describing and dramatising how they clean themselves.



Encourage children to write short sentences about how they clean themselves.

### The Science: What is soap and how is it made?

Soaps are cleaning agents made from the reaction of fats or oils with an alkali (or strong base). Soaps (and detergents) contain surfactants (surface active ingredients). These surfactants interact with water and the water insoluble dirt particles, allowing the dirt to be taken up into the water and removed from the object being cleaned.

The variation among different soaps (other than the added perfumes, dyes and emollients) is due to the different fatty acids used in their preparation. If the soap is to be used in saltwater or other 'hard' water, it will produce a better lather if made with a high percentage of coconut oil. Palm oil soaps give small, long-lasting bubbles and are very mild to the skin. As soap makers must formulate each soap base with a different blend of fatty acid, soap making is as much an art as it is a science.

### It's in the bag!

Develop the getting dirty and getting clean concept with a 'Getting dirty - Getting clean' home bag. The bag contains a copy of Mrs Wishy-washy along with associated toys and a diary for records. At home, the child chooses which toys to play with and ensures that at least one gets dirty so that it can be cleaned. With assistance from an adult, the child adds their own experience to the diary as they describe the toy they

chose, how it got dirty and how the toy was cleaned. If they wish, they can photograph the toy at home or add a drawing to the book. In addition, the story could be told to the rest of the class when 'the bag' is returned to school.

### Why must I be clean?

With children make a list of reasons why they need to stay clean. Introduce the notion of personal hygiene and why it is important for them to be responsible for their own cleanliness. In particular, discuss why, when and how the children should wash their hands? Develop a cleanliness chart using their contributions to complete these sentences: 'We wash our hands before we ...', 'We wash our hands after we ...', 'When we wash our hands we ...'. Demonstrate the correct way to wash and dry hands, and then have each child show how they wash and dry their hands. Emphasise the importance of washing hands before we eat and after going to the toilet.

### Painted handshake

Discuss germs and how they make us sick. Show magnified pictures of germs; discuss their purpose and how they can be harmful. Perform a painted handshake where the child paints a hand using a water soluble coloured paint. This child then shakes hands with another classmate, who shakes hands with another and so on. Observe how the paint is transferred from one hand to the other in this process. This activity illustrates how germs can be transferred from one person to another, and highlights the importance of washing hands correctly.



Observe how the paint is transferred from one hand to the other.



## Messing about with mud

Brainstorm children's prior experiences with mud to find out what they know about mud? What is mud? Where have you seen mud before? What is the composition of mud? Who or what uses mud? Why did the animals in Mrs Wishy-washy roll in the mud?

Allow children to explore mud or potter's clay. Remind children to wash hands afterwards, use gloves if required, and use an apron to protect their clothes. What does the mud look like, feel like, smell like, and sound like? How is mud similar and different to dry soil? Record 'mud words' on a Mud Word Wall.

### The Science: What is mud?

Mud is a mixture of soil and water. There are many different types of soils: clay, loam and sand are just some of them. Soil found in the garden has many different things in it: minerals, rock particles, and organic matter (broken down leaves, twigs, and insects).

#### Safety

If you wish the children to use soil in class you will need to make sure that it is 'clean' soil. This can be achieved by sifting the soil, or purchasing clean soil from a nursery. Soil from your back yard will not be clean. The best soil to use would be one with a high clay content, as this has a very muddy, smooth and sticky texture when wet, allowing a lot of descriptive language to develop. Alternatively use potter's clay.

## Useful mud

What animals, other than those in the story, like to be covered in mud? Why do pigs like rolling in mud? Would pigs be happy without mud? Research pig farms where pigs play in straw or recycled shredded paper instead of dirt. Why would farmers use straw?

Conduct class research to find different ways that humans use mud. Show pictures of mud brick houses and fences from around the world. Mud bricks are not uncommon and there may be an example of a mud-brick building near your school for a class visit.

Clay is like mud and is used to build, to sculpt and to make pottery. Visit a potter, or ask one to come to class and show the children the craft. Provide clay for each child, divide the class into three and have each group make 'a herd of

cows' 'a flock of ducks' or 'a drift of pigs' from the story. Notice how the clay dries out, changes colour and cracks over time.

## Mousse mud

Now use something very different to represent mud. Chocolate mousse makes a great substitute and this can be made using one of many recipes available on the web or use a commercial brand. What does the chocolate mousse look like, feel like, smell like, and sound like? Add these descriptive words to the Mud Word Wall.

Compare descriptions of the two types of mud: real mud and mousse mud. Using hoops and word cards, create a Venn diagram to record how the mud and chocolate mousse are similar and different to each other.

## History of cleanliness

Find out how people used to keep clean in the past when cleaning products were not readily available. What did people use before soap was invented? How did they wash their clothes? Take the class to a

history museum to view clothes and equipment that was used a long time ago. Look at how a cleaning object, such as the washing machine, has changed over time. Introduce children to washboards. Invite grandparents who may have stories to share about washing in the past. Research how other cultures do the washing? Compare pictures of 'stone washing', using a copper and stick, or using a Laundromat with the methods they currently use at home. Perhaps someone has an old washing machine that children could take apart, or old wringers that could be set up and tested in class.

## The cleaning process

Mrs Wishy-washy cleaned the dirty animals by placing them in a tub and using soap, water and a scrubbing brush. Using brainstorm, find out how much the children know about cleaning dirty clothes. What do they know about the actual process of washing clothes, as opposed to just stating "we use a washing machine"?

Discuss with children the importance of the soap, water and agitation to help get dirty clothes clean. Ask children what they think 'agitation'

### The Science: Why do pigs like mud so much?

Rather than being dirty animals, pigs are very clean animals. The reason some people think they are dirty is due to the fact pigs like to roll in the mud. However, pigs tend to roll in mud in the hot summer months to help them cool off. Pigs cannot sweat to cool down, like humans can. Therefore, pigs are extremely sensitive to heat. They can suffer from sunburn and heat stroke, just like humans. Wading in water and rolling in mud assists pigs from becoming over heated, and also helps control parasites.



Why do pigs like mud so much?



means (mixing soap, water and dirt). Agitation helps break dirt particles into smaller pieces so the soap can loosen and carry dirt away from the clothes. Refer back to Mrs *Wishy-washy* and how soap, water, a scrubbing brush and agitation (rubbing and scrubbing) were used in order to remove the mud from the animals.

### **The Science: How does soap remove dirt?**

Soap works by making oil mix with water, so that the water can wash off the oil, taking with it the dirt and bacteria. In order for oil to mix with water, some means must be found to make the oil (or dirt particles) more like the water particles. This is the task of the soap molecules.

Soaps are large molecules that look like tadpoles, and consist of two basic parts: the head and the tail. The tail of the molecule is structurally very similar to oil and thus is soluble in oil. The tail of the soap molecule is nonpolar (does not have a charge), and does not like water. Hence, it is called hydrophobic or 'water fearing'. The head of the tadpole has a charge (and is called polar), making it extremely soluble in water. The head of the soap molecule is called hydrophilic or 'water loving'. These water fearing and water loving properties of soaps are essential to how soap works.

When we wash with a solution of soap and water, we rub and scrub (or agitate) to break up the oil into small droplets. The soap molecules dissolve their tail (oil-like end) into these droplets, leaving their charged ends sticking out into the surrounding water. The soap molecules form a kind of shell around the oil droplet. This small sphere, with a captured oil drop in the centre, is called a micelle. The soap camouflages the oil droplet, making its exterior attractive to water. The micelle (disguised with its oil and dirt) is then easily washed away.

Soaps increase the compatibility between water and dirt (oil and grease) by being able to partly dissolve in oils and partly dissolve in water, thereby linking the two dissimilar materials together.

### **Investigating cleaning a stain**

Conduct a simple but fair investigation with the class to find out if agitation or no agitation is the best way to remove a stain from a piece of material. Equipment to perform this investigation includes two tubs, water, small strips of material all the same size, a suitable stain (such as tomato sauce or mud), cold-water laundry detergent, teaspoon, 'agitate' and 'no agitate' labels, newspaper, and white paper.

Place the strips of material onto the newspaper. Put a small amount of tomato sauce onto the centre of each strip of material, and rub in with the back of the teaspoon. To obtain better results, leave the stain for 24 hours before continuing the investigation.

Add the same amount of cold water and laundry detergent to each of the two tubs. Stir in the detergent with the teaspoon, making sure that each tub is stirred the same amount of time. Set up the labels beside the tubs. Place the plain white paper

nearby, labelling one as 'agitate' and the other as 'no agitate'. Keep one strip of stained material so that the original stain can be compared to the washed strips. For the 'no agitate' tub, have a child push one strip of material under the water and leave it there. At the same time, have another child dip a strip of material in and out of the 'agitate' tub. Perhaps have the children count to 20 as the 'agitate' child keeps dipping the strip of material.

The children remove their strips of material at the same time and place on the appropriate labelled white paper. Have pairs of children repeat this procedure until the whole class has cleaned a strip of material. As a whole class compare the agitated and non-agitated strips to the original stain. Which method of cleaning a stain (agitation or no agitation) produced the cleanest strips of material? When performing this investigation, note the amount of stain (tomato sauce) that has come off the material into the water as another form of comparison.



Investigating cleaning a stain

Further investigations could be based on the following questions: Does warm or cold water work best for cleaning a stain? What type of stain is hardest to remove from material? Is detergent better than no detergent for removing a stain?

### Dramatise the story

Invite parents to class to celebrate the children's learning. Children and parents could attend dressed as a character from the *Mrs Wishy-washy* story. Dramatise the story of

*Mrs Wishy-washy* for the audience. Depending on ability, a child could narrate the story while others play the characters.

### Investigating with parents

While parents are visiting, children take them on a tour of the Mud Word Wall, demonstrate how agitation works, and read them the books made about clean and dirty. Have various investigations set up for the parents to perform, with the children explaining the procedure and the

results. The day could include clay painting, mud mousse prints, and removing a stain.

### USEFUL WEBSITES

Mrs Wishy-washy. Contains some excellent information for literacy ideas with the story, and many excellent links.

<http://www.thevirtualvine.com/mrswishywashy.html>

RSPCA. Education unit  
<http://www.rspcawa.asn.au/education/education.html>

Mobile dog washing. Click on 'Hydrobath' to see pictures of a dog bath.  
<http://www.dogwashing.com.au/>

How to make soap, and related soap making information  
[www.soapmakingfun.com](http://www.soapmakingfun.com)

The Soap and Detergent Association - Hygiene and children's news  
[www.sdahq.org/sdakids/index.cfm](http://www.sdahq.org/sdakids/index.cfm)

History of washing. A comprehensive and easy to read history covering soaps, baths, laundry, water supply and plumbing, and fabrics from prehistory to present day.  
[http://www.scienceinthebox.com/en\\_UK/pdf/history-of-washing.pdf](http://www.scienceinthebox.com/en_UK/pdf/history-of-washing.pdf)

Mr Mud's Website. Facts and information about making mud bricks  
<http://www.mrmud.com.au/mudbrick.htm>

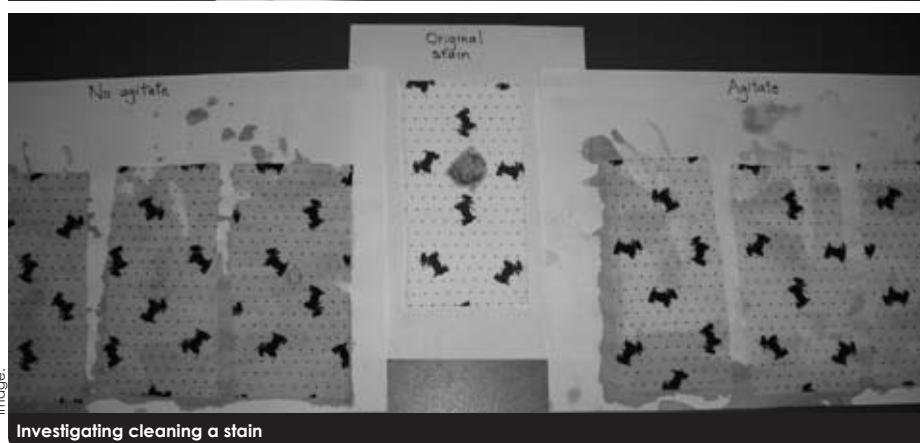
Teaching Heart's Dental Health. Activities, rhymes and books relating to dental hygiene. <http://www.teachingheart.net/teeth.html>

The Bubblesphere. Contains some great information about bubbles, including answers to many common questions <http://www.bubbles.org>

### ACKNOWLEDGEMENTS

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### The Science: Why are some stains hard to remove from clothes?

The ease of removal of dirt from clothes (or any other thing) depends on how strongly the dirt is bound to the clothes. Some dirt is just physically entangled in the fibres of the clothes (like sand or clay) and can often be removed by beating the clothes with water (minimal soap is required). Other forms of dirt interact with the surface of the fibres and may even react with the fibre. These are harder to remove and require soaps or detergents to remove them. For a soap to remove dirt from fabric, the soap and dirt must interact better with each other than the dirt and fabric interact with each other. It is a bit like a tug of war between the soap and the fabric.

# CHAPTER 1 - FOOD CHEMISTRY

**We all need food. Throughout the ages, food has been available in many different forms – all with varying textures, flavours, colours and nutritional value. The range of food products has never been so vast as we have available today. Food is now processed and packaged and sent all over the world! Food Chemistry is essential for providing freshness, quality, developing new foods, ensuring availability and satisfying consumer and government requirements.**

Food chemistry is the study of chemical processes and interactions of all biological and non-biological components of foods. Foods such as meat, dairy products, fruit and vegetables are all made of various chemicals. In addition to water, which can make up as much as 95%, the main groups of chemicals that make up food are:

- **Carbohydrates** – Carbohydrates (also known as saccharides or sugars), are organic compounds consisting of carbon, hydrogen and oxygen with a hydrogen:oxygen atom ratio of 2:1, and make up 80% of all food intake for human consumption. Carbohydrates can be small monosaccharides, such as glucose and fructose; disaccharides, such as sucrose or table sugar; or polysaccharides such as starch (found in many grains). Other important polysaccharides found in foods include agar, pectin, alginate, xanthan and carageenan.
- **Lipids** – This is a broad group of naturally occurring molecules which includes fats, waxes, sterols, glycerides and phospholipids. The main biological functions of

lipids include energy storage, as structural components of cell membranes, and as important signalling molecules. Cholesterol is a lipid which, in excess, can lead to serious health problems. Humans and other mammals have a dietary requirement for certain essential fatty acids such as omega-6 and omega-3 fatty acids because they cannot be produced in the body from simple compounds.

- **Proteins** – These very complex macromolecules compose over 50% of the dry weight of an average living cell. They play a fundamental role in the structure and function of cells. For instance, haemoglobin is the iron-containing protein in red blood cells that transports oxygen from the lungs to the rest of the body. Proteins are essential for growth and survival. They are also involved in tests to determine food allergies.
- **Vitamins** – These are nutrients (chemicals that an organism needs to grow) required in small amounts for essential metabolic reactions in the body. Two well-known vitamins are Vitamin C and Vitamin E. Appropriate amounts of vitamins in your diet can prevent diseases (scurvy, a disease resulting from a deficiency of Vitamin C was common among sailors and pirates when the supply of fruit and vegetables ran out on long voyages). However, too much can produce nausea, vomiting and even death!
- **Minerals** – These are normally inorganic compounds that supply elements that are necessary for life. These elements are usually metal ions such as potassium, calcium and magnesium (which are bulk elements), through to trace elements that can be hazardous if consumed in excessive amounts, such as copper, iron and zinc. Usually a Reference Daily Intake (RDI) is suggested for minerals to maintain health. Minerals are found in many foods, but can also be taken in dietary supplements.

- **Enzymes** – These are the body's catalysts used to convert one chemical into another, for example amylase is an enzyme in saliva that breaks down carbohydrates into their component sugars such as glucose. Catalysts allow difficult reactions to occur easily over and over again because they, themselves, do not break down.

Processed foods also contain flavours and colours. These are mainly for sensory analysis purposes, i.e. looks or smell. Colours can be natural, such as caramel, or synthetic such as the colour in some breakfast cereals. Food additives are also found in processed foods. These are compounds that are added to preserve flavours or improve taste or appearance. For example, vinegar is a food additive for pickling.

The food industry is regulated with maximum intake limits determined for metal and other contaminants and acceptable limits of microbial contaminants. In Australia this is controlled by Food Standards Australia New Zealand ([www.foodstandards.gov.au](http://www.foodstandards.gov.au)).

Food chemists investigate the chemical, microbiological, physical and sensory nature of food, and apply their knowledge in the development, processing, preserving, packaging, distributing and storing of foodstuffs. They also develop new ingredients, such as sugar replacements, and new processes, such as in dairy or brewing industries.

NUTRITION INFORMATION		
Servings per package:	22g	
Serving size:	10g	
	Average Quantity per Serving	Average Quantity per 100g
Energy	310kJ	3100kJ
Protein	0.1g	0.6g
Fat, total	8.3g	83.2g
- saturated	5.5g	54.7g
Carbohydrate	0.1g	0.7g
- sugars	0.1g	0.7g
Sodium	1mg	9mg

Example nutrition panel.



# CHOCOLATE

Chocolate has become one of the world's most loved flavours. Whether it be sweetened or unsweetened; dark, milk or white, chocolate is an extremely popular food that is sold throughout the world. Chocolate can be made into a variety of products, such as: chocolate bars, blocks, coins, frogs, eggs, hearts and it's used to flavour drinks, cakes, biscuits, muffins... So, why does chocolate taste so good?

The key ingredient of chocolate is cocoa butter. Cocoa butter or theobroma oil is a pale-yellow vegetable fat, which is extracted from the cacao bean.

Cocoa butter forms crystals as a solid. There are six types of crystals that form. They all have the same chemical formula or composition but their shape varies. This is called *polymorphism*. The different polymorphs of cocoa butter can be identified using X-Ray Diffraction and Differential Scanning Calorimetry.

When the crystals melt they are indistinguishable, however the different shapes mean these crystals have different properties including melting points.



Image: Leanne West

Chocolate samples.

Chocolate is often described as 'melting in your mouth' which indicates the melting point of the form of cocoa butter used in chocolate is close to the temperature of your mouth. Form V, the best tasting polymorph, has a melting point of 34 to 35 °C slightly less than the interior of the human body. Chocolate manufacturers used procedures which ensure the production of the form V polymorph. This ensures the chocolate melts at the 'right' temperature, the texture is smooth (not crumbly) and the appearance is shiny not dull. When a 'snap' test is performed the chocolate breaks cleanly and an audible snap is heard.

Have you ever tasted chocolate which has been left out of the fridge and has consequently melted and hardened? Unfortunately, after

melting, the crystals may reform in a different form – which means a different melting point and texture.

Polymorphism is an important consideration for the pharmaceutical industry. Different types or morphs of the same crystal can have different capacities to dissolve and consequently have different capacities to have a therapeutic effect.

## TEACHING AND LEARNING ACTIVITIES

### LOWER PRIMARY

#### Chocolate Storage

Compare the storage of a chocolate bar in different places (e.g. in the sun, shade and fridge), over a period of time. Ask students to help develop the experiment and try to make it a fair test. Make sure that all of the chocolate bars are the same and are placed on the same surface (e.g. a white paper plate). Be careful that animals don't eat your chocolate! Place a thermometer with the chocolate bar and have students periodically check the temperature. Compare the results and discuss the effects of different temperatures on chocolate. Where is the best place to store chocolate?

#### Solid and Liquid Chocolate

Place some chocolate into a microwave safe dish and carefully melt it in a microwave (or use a double boiler). It is best to heat the chocolate in short bursts for 15-30 seconds, stir in between and stop as soon as it has all melted. Discuss the physical change (melting) that has occurred, what other substances have students seen melt? Carefully observe the solid and liquid chocolate and discuss the similarities/differences between them. The melted chocolate can then be poured into moulds or used to coat strawberries or grapes, so that students can observe the reversibility of the process. The chocolate changes state from a solid to a liquid when heated, and then back to a solid when cooled. A solid has a fixed shape and volume and a liquid has a fixed volume, but can change shape.

#### Safety

Complete a risk assessment for melting chocolate.

### COCOA BUTTER POLYMORPHS

POLYMORPH	CONDITIONS TO MAKE THE POLYMORPH	MELTING POINT (°C)
Form I	Rapidly cooling molten chocolate	17.4
Form II	Cooling the molten chocolate at 2°C	23.4
Form III	Solidifying the molten chocolate at 5-10°C or storing form II at 5-10°C	26
Form IV	Solidifying the molten chocolate at 16-21°C or storing form III at 16-21°C	27
Form V	Solidifying the molten chocolate while stirring. Needs a special process called 'tempering'.	34-35
Form VI	Storing form V for four months at room temperature	36-37

Cocoa butter polymorph table.

## PRIMARY - MIDDLE SCHOOL

### Float or Sink

You can perform this as a demonstration or a class activity. Have 2 (or more) different pieces of chocolate, at least one plain and one containing bubbles (e.g. Bubbly, Aero, etc.) Show the pieces of chocolate and ask the students to hypothesize whether the chocolate will float or sink in water. The plain chocolate sinks in water and the chocolate with bubbles, floats in water. Cut some pieces in half to reveal the bubbles inside. The bubbles of gas trapped inside the chocolate make the average density of the piece of chocolate less than water.



Bubbly chocolate is less dense than regular chocolate.

You can extend this activity by having a glass with water and oil – what will the chocolate do now? Ask students to write their hypothesis and then test it. The plain chocolate sinks to the bottom of the water layer. The chocolate with bubbles, sinks in the oil layer but floats on the water layer. Students can discuss why this happens and then list all of the substances in order of density. Older grades can work out the density of the different chocolates, by dividing the mass (using scales) by the volume (using water displacement in a measuring cylinder). **Extension:** research how the bubbles get inside the chocolate.

#### Safety

Remind students not to eat anything used for an experiment. Dispose of oil appropriately.

### Rocky Road

Students can investigate how chocolate changes state when heated (see method for melting chocolate above) and then

make rocky road to create a heterogeneous mixture. To create rocky road, add marshmallows, lollies, coconut, etc. to melted chocolate.

#### Safety

Do not add nuts and complete a risk assessment on melting chocolate.

Pour the mixture into a lamington tin lined with baking paper and refrigerate to set. Slice the rocky road carefully and ask students to analyse the mixture. A **heterogeneous mixture** is a mixture of two or more substances, where the components are still visible (the marshmallows, lollies, etc. can still be seen in the rocky road). A **homogeneous mixture** has the same uniform composition throughout and the components are not visible (e.g. a solution of salt water).

Ask students to investigate other mixtures and classify them. Examples of homogeneous mixtures: tea, coffee, salty water, sugary water and air. Examples of heterogeneous mixtures: pizza, chocolate chip cookies, sandy water, chicken noodle soup, a drink with ice, granite, water and oil and salad. Some mixtures visually appear to be homogeneous, such as milk, mayonnaise, whipped cream and blood, but are heterogeneous on a microscopic level. These mixtures are called colloids and are dependent on the particle size.

## UPPER SECONDARY

### Polymorphs of Cocoa Butter in Chocolate

Students will observe and taste two pieces of chocolate. One piece of chocolate will have been heated to melt and then allowed



Observing control bar and resolidified bar.

to solidify while the other is the control. Plain milk chocolates sold in individual servings are easy to use as the chocolate can be given to the students in wrappers avoiding hygiene issues.

### Chocolate Taste Test

1. Obtain 2 pieces of wrapped chocolate. Make sure that they are the same type and size (chocolate frogs in packets work well).
2. Melt one sample of chocolate and re-harden in the fridge.
3. Take note of the visual differences between the two samples of chocolate.
4. Snap the pieces of chocolate and observe the sound and feel.
5. Taste the chocolate, carefully taking note of any flavours and textures that are present. Record the results on a table (see below)

Students should think about how to make this experiment a fair test (e.g. reverse the order in which the chocolates are tasted). The chocolate that was melted and re-hardened should contain different polymorphs and therefore melt at a lower temperature in the mouth. The chocolate in its original form, should taste like 'normal' chocolate and have a smooth, creamy texture (good 'mouth feel'). The heat-treated sample will probably taste different and feel grainy in the mouth. Students should acknowledge that some scientists use taste as part of their job.

#### Safety

Check if students have food allergies to chocolate. Taste tests should not take place in the science laboratory.

### Chocolate Melting Point Test

Students use a water bath to melt the chocolate (in a test tube) and make observations. Using a hotplate with a water bath and slowly increasing the temperature will yield the better results, however the following method can be used:

CHOCOLATE	VISUAL OBSERVATION	SNAP TEST	TASTE AND TEXTURE
Sample A Melted and re-hardened			
Sample B Control			

Results table for the chocolate taste test.

### Equipment per group

- 2 samples of chocolate, one that has been melted and re-solidified (Form III) and an original sample (Form V); use approx. 2 squares per sample.
- 2 test tubes
- 2 glass rods
- 2 thermometers
- 250mL glass beaker
- hot water

### Safety

Take care with hot water and electrical appliances. Complete a risk assessment.

### Procedure

1. Break each chocolate sample into small pieces and place into separate test tubes.
2. Half fill a 250mL beaker with hot water (less than 50°C).
3. Take and record the temperature of the chocolate samples with the thermometer and then place the test tubes into the beaker of hot water. Take care not to get water into the test tubes.
4. Record the temperatures of the chocolate samples, every minute for 10 minutes, stirring gently between readings using a glass rod.
5. Observe the time it takes the chocolate samples to melt and the temperature(s) at which they melt.
6. Record results in a table and graph the data.
7. Compare the results to theoretical data and describe the polymorphs present.

### Teacher Notes

Ask students to describe the differences between the heating curves of the two samples. Form V temperature should plateau at its melting point of around 34-35°C. The temperature plateaus as energy is being used to break down the bonds

between the molecules in the solid chocolate so they can move around to make a liquid. The temperature of the Form III sample should steadily increase and there may be no levelling off. The melting point is lower, around 25°C. This is due to the weaker bonds and so less energy is needed to break them down.

### Further investigations

Students could design and conduct many other investigations involving chocolate, for example comparing white and dark chocolate.

Research could be conducted to investigate how drug patents depend on the polymorph form.



Students conducting chocolate experiment.

Image: Sue Monteath, Old Academy of Science

### Did you know?

1. Chocolate was first used over 2,500 years ago, originating in Central America. The Mayan civilisation considered Cacao to be a divine gift and so, it was held in high regard. It was used ceremoniously and sometimes as a form of currency. The name 'Cacao' is a Maya word meaning 'god food' which after being introduced to Europe in the 16th century, formed the basis of the Latin name for the Cacao tree *Theobroma Cacao* meaning 'food for the gods'. It is thought that the word 'cocoa' has come about through a mis-spelling of 'cacao.'
2. The name 'chocolate' comes from the Aztec word *xocolatl* meaning 'bitter water'. Not surprising, considering they made a drink, by mixing cacao beans with chillies, achiote (a spice) and cornmeal.



# MILK AND CHEESE

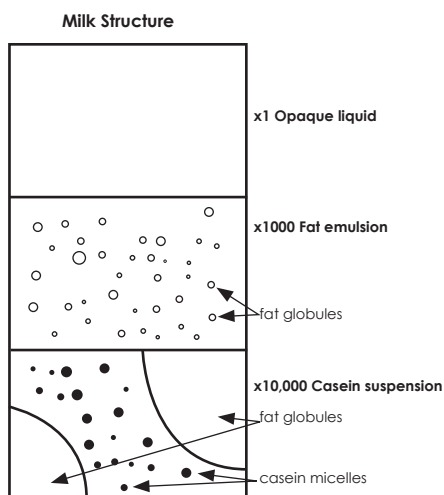
Milk and cheese are nutritious foods, which provide us with valuable sources of protein, vitamins and minerals. Due to their high calcium content, dairy products have been linked to many health benefits, including teeth and bone health, and reducing blood pressure and cardiovascular disease. The chemical reactions involved in cheese making allow many different varieties of cheese to be produced with varying textures and flavours.

## MILK

### What is milk?

Milk is mainly water (85-87%) but contains 3 to 4% protein, 3 to 4% fat and is a good source of calcium. The main structural components of milk are fat globules and casein micelles. Micelles are approximately 0.1 micron in diameter and are large enough, along with fat globules, to deflect light, giving milk its opaque white colour.

Milk is a fragile colloidal suspension of casein micelles and water, plus organic acids, lipids, soluble proteins, carbohydrates, lactose and minerals (Fox 1998).



The structure of milk.

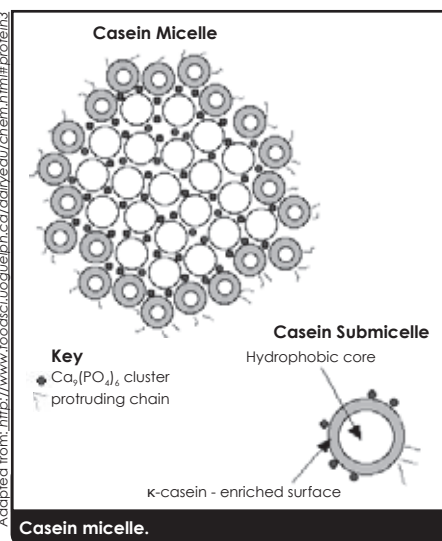
### Milk Fat

More than 95% of the total fat content of milk is in the form of a globule ranging in size from 0.1 to 15 microns in diameter.

### Milk Proteins

Milk proteins are made up of around 80% casein ( $\alpha$ ,  $\beta$ ,  $\kappa$  and  $\gamma$  caseins) and 20% whey proteins, mainly lactoglobulins and lactoalbumins. Casein proteins are bound into micelles.

Casein (globular protein) exists in milk as large complex molecules called micelles, which are 92% protein and 8% calcium phosphate. Calcium phosphate +  $\alpha$  and  $\beta$  casein are linked by  $\kappa$  casein which is localised on the surface of micelles. These  $\kappa$  casein molecules (submicelles) have a hydrophobic (water-hating) core and a hydrophilic (water-loving) tail. Micelles also have a negative electrical charge so repel each other, keeping them evenly dispersed in the surrounding solution.



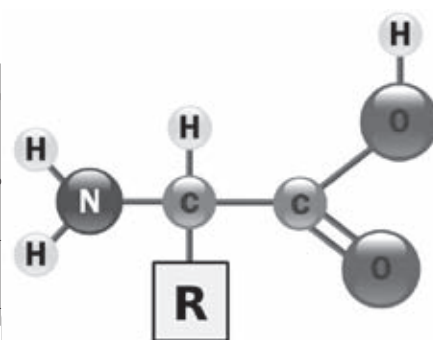
## COAGULATION OF CASEIN BY RENNIN

Casein proteins are important in cheese making.

Proteins are made up of amino acids. Amino acids are linked by peptide bonds to form peptides and proteins.

The amino acid chain of kappa ( $\kappa$ ) casein is broken by the proteolytic enzyme, rennin. Without the  $\kappa$  casein the casein coagulates.

Coagulation of milk for rennet cheeses is accomplished by the specific cleavage of the casein



Amino acid: The key elements of an amino acid are carbon, hydrogen, oxygen, and nitrogen. R represents a side-chain specific to each amino acid.

micelle-stabilizing protein,  $\kappa$ -casein, at the phenylalanine-methionine bond by acid proteinases (rennets). The significance of the primary, secondary, and tertiary structures of  $\kappa$ -casein on the sensitivity of this bond has been established (Fox 1989).

## CHEESE

Cheese is a solid food made from the milk of cows, but goat, sheep or buffalo milk can also be used. The process removes water, lactose and some minerals from milk to produce a concentrate of coagulated milk fat and protein.

Milk is curdled or coagulated by adding acids such as vinegar or lemon juice or acidified by bacteria, which turn milk sugars into lactic acid. The addition of rennet also assists in the coagulation of casein. Rennet is an enzyme or protein called chymosin or rennin.

## PASTEURISATION

The process of pasteurisation was named after Louis Pasteur who discovered that spoilage organisms could be inactivated in wine by applying heat at temperatures below its boiling point. This process was applied to milk and is the most important operation in the processing of milk to make it safe to drink.

Pasteurisation requires heating the milk or milk product to a specific temperature for a specified period of time. The milk needs to be stirred so that all parts reach the set temperature. This process must be followed by quickly dropping the temperature of the milk to prevent recontamination occurring.

The process of milk pasteurisation is conducted to:

- make milk and milk products safe for human consumption by destroying all bacteria that may be harmful to health (pathogens)
- improve the shelf-life quality of milk and milk products.

Pasteurisation can destroy some undesirable enzymes and many spoilage bacteria. The shelf life of milk can be 7 to 16 days, depending on the food manufacturer and the use by date they decide is necessary.

Microorganism destruction depends on the temperature and how long the milk is held at this temperature (holding time). Minimum temperature and time requirements for milk pasteurisation are based on thermal death time studies for the most heat resistant pathogen and require the applications of microbiology. The time and temperature combinations of the pasteurisation process are regulated to ensure all disease causing microorganisms are destroyed. Reference:

<http://www.foodsci.uoguelph.ca/dairyedu/pasteurization.html>

Pasteurisation must reduce spoilage organisms such as *Pseudomonas* (which grow well at low temperatures) to extend shelf life and destroy pathogens such as *Mycobacterium tuberculosis* and *Brucella abortus* and so make milk safe to consume.

UHT milk is made sterile by processing at very high temperatures (100° C<sup>+</sup>), and using aseptic packaging in airtight containers. The milk may be packaged either before or after sterilization. UHT milk is a good source of protein and calcium but some heat susceptible vitamins are lost. UHT milk that is not aseptically packaged will have a longer shelf life than pasteurised milk, but should be kept in the refrigerator.

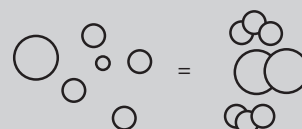
### Pasteurisation Methods

PRODUCT	PASTEURISATION METHOD
Milk	72 °C for 15 seconds then cool to 10 °C
UHT (ultra high temperature or ultra heat treatment)	not less than 132 °C for 1 second, usually 140-150 °C for 2 seconds  REQUIRES FAST COOLING

Milk Pasteurisation methods.

## GLOSSARY

**Aggregation:** The clumping of smaller particles into larger particles.



**Coagulation:** The aggregation of proteins. The aggregation process occurs when milk clots or curdles.

**Microorganism:** Any microscopic animal or plant-like organism including bacteria, yeasts, viruses and single-celled algae.

**Pasteurisation:** The controlled heating of a food to destroy all pathogenic microorganisms.

**Pathogen:** A microorganism that can cause disease.

**Sterilisation:** The process of eliminating all microorganisms so nothing is left living in a sterilised product. Commercial sterilisation involves the destruction of all pathogenic microorganisms as well as more heat-resistant organisms that could grow inside the processed food package under normal conditions of distribution and room temperature storage.

[http://school.discoveryeducation.com/foodscience/science\\_resources.html](http://school.discoveryeducation.com/foodscience/science_resources.html)

### References and resources

1. <http://www.foodsci.uoguelph.ca/dairyedu>
2. <http://www.ift.org/Knowledge-Center/Learn-About-Food-Science/K12-Outreach/Activity-Guides.aspx>
3. P.F. Fox. (1989) Proteolysis during cheese manufacture and ripening. *Journal of Dairy Science*. Volume 72, Issue 6, Pages 1379-1400
4. P.F. Fox and P.L.H. McSweeney. (1998). *Dairy Chemistry and Biochemistry*. Springer Verlag.
5. Australia Junket powder [http://www.simplyjunket.com.au/main/page\\_history.html](http://www.simplyjunket.com.au/main/page_history.html)



Little Miss Muffet.

to visualise what the curd and whey in 'Little Miss Muffet' looks like and how cheese is made from milk.

## TEACHING AND LEARNING ACTIVITIES

### LOWER PRIMARY

#### Making Cottage Cheese

*"Little Miss Muffet sat on a tuffet eating her curds and whey"*

Cheese is the curd produced when the milk protein, casein is coagulated and the whey is the remaining liquid. This can easily be demonstrated using pasteurised whole milk (not long life or UHT), junket tablets (unflavoured) and cheesecloth.

Make junket according to directions and then place the junket solid into the cheesecloth. Squeeze out the liquid. The remaining solid is a sweet type of cottage cheese and the liquid is the whey. This allows students

### PRIMARY

#### Cheesy Change

Discuss the differences between a chemical change and a physical change. Chemical changes occur when a chemical reaction has taken place and a new product is formed. The process usually cannot be reversed. A physical change does not alter what a substance is (e.g. solid ice, liquid water and gaseous steam are all H<sub>2</sub>O) and is usually reversible. The production of cheese is a chemical change and cannot be reversed. You can demonstrate this by mixing whole milk with some vinegar. Add 2 tablespoons of vinegar to half a cup of milk (not UHT) and stir. Leave for a minute and then filter the mixture

by slowly pouring it through some paper towel or coffee filter paper, into another container. Gently squeeze out the excess liquid (whey) and you'll be left with the curd. Ask students if sour milk can be changed back into fresh milk... why not? **Extension:** try adding some baking soda to the curd to make glue.

### Safety

Remind students not to eat anything from the experiment. Complete a risk assessment.

## MIDDLE SCHOOL

### The Chemistry of Cheese

'The Chemistry of Cheese' online video by Science 360 is a great introduction to this topic. Go to <http://science360.gov>, click on 'Chemistry Now' and then 'Cheeseburger Chemistry: Cheese' or go directly to <http://science360.gov/obj/video/5a1f0579-2bb5-4ec7-a8ee-24a96d7bd38d> to view.

### Making Cheese

Cheese making is a fast growing hobby in Australia. Cheese making kits are available online or from many home brew shops. Companies such as [www.madmillie.com](http://www.madmillie.com) provide all you need to make your own cheese or probiotic yoghurt.

### Further Food Chemistry Experiments

The Institute of Food Technologists (IFT) has produced comprehensive teacher information and activity guides on carbohydrates, lipids and proteins. All of the materials are available for use in the classroom and can be found at <http://www.accessexcellence.org/AE/AEPC/IFT/>

## UPPER SECONDARY

### Enzymic Coagulation of Casein Proteins

**Aim:** To investigate the coagulation of different milks using rennet tablets.

### Safety

Take care with heating apparatus. Complete a risk assessment.

### Equipment:

- water bath (per class)
- hot plates x 2 (per class)
- 100 mL beakers x 2
- test tubes x 8
- test tube holder
- test tube rack

- protective mat
- safety glasses
- measuring cylinder
- Pasteur pipette
- timer
- milk samples (unpasteurised raw, commercial pasteurised full fat milk, UHT milk)
- rennet (Junket Tablets)
- spatula

### Procedure

1. Prepare a rennet solution by mixing a quarter of a rennet tablet in 10 mL of warm water in a large test tube.
2. Hold the solution in a water bath at approximately 35°C.
3. Measure 20 mL of raw milk into each beaker.
4. Boil the first beaker of raw milk using a hot plate and allow it to cool. Transfer 10 mL of this milk to a test tube and label it A.
5. Pasteurise the second beaker of raw milk by placing the beaker on a hot plate with a thermometer. Ensure the milk temperature goes no higher than 70-75 °C for 15 seconds and then remove the beaker from the hot plate and allow it to cool. Transfer 10 mL of this milk to a test tube and label it B.
6. Collect four more test tubes and measure 10mL of each of the remaining milks (commercial pasteurised full fat milk, UHT milk, unpasteurised raw milk) into separate test tubes and label them as milks C, D and E as shown in the results table.
7. Hold the test tubes of milk in a water bath at 35°C.
8. Transfer 1 mL of the rennet solution to each of the test tubes A-E using a Pasteur pipette.
9. Record the time for clotting in each test tube and any differences in the type of curd.
10. Rank the different qualities of the curds made on the continuum below.

### Curd continuum

Thin/soft |-----| Thick/Viscous

**NOTE:** if unpasteurised milk from a local dairy processor is unavailable, then the experiment can be run using just 2 milk types: commercial pasteurised full fat milk, UHT milk. Commercial pasteurised full fat milk will replace boiled and cooled milk in A. B cannot be included if unpasteurised raw is not available.

### Teacher notes

UHT and boiled milk will not coagulate as the modifications to casein micelles by the heat treatment, impairs the access of the rennet enzyme to the binding sites.

### Questions:

1. Which milk produced the firmest/solid curd?
2. Which milk would you recommend industry use to make curd?
3. Looking at your results from the table can you suggest why industry does not boil the milk used in cheese production?
4. Rennet contains rennin – a proteolytic enzyme. How does this enzyme produce a curd when it is added to milk?

### Further exploration

Use soy milk and Epsom salts (*Magnesium sulphate*) to coagulate soy proteins.



MILK	TYPE	CLOTTING TIME (s)	CURD DESCRIPTION
A	Raw milk boiled and cooled		
B	Raw milk pasteurised in lab		
C	Commercial pasteurised milk		
D	UHT milk		
E	Unpasteurised raw milk		

Results table: Clotting (Coagulation) time and curd description of different milk varieties.



# VITAMINS AND NUTRITION

**A vitamin is a naturally occurring chemical that is required for life by humans but is not made in our own bodies. Vitamins are nutrients, which must be taken in as part of a healthy diet. Although humans cannot make most of the vitamins (humans can make vitamin D!) bacteria can. Vitamins move up the food chain and are ultimately consumed by humans as meat, vegetables, fruits, dairy products or grains.**

There are two major groups of vitamins that are essential in the diet, water-soluble vitamins and fat-soluble vitamins. Water-soluble vitamins are easily dissolved in water and can be found in the juices or extracts of foods, however; most water-soluble vitamins cannot be stored in the body. They travel through the bloodstream and whatever the body doesn't use comes right out with urination. Therefore, water-soluble vitamins need to be replaced often. Fat-soluble vitamins are found in the fat or oils of many foodstuffs. In many cases, megadoses of fat-soluble vitamins can cause serious health problems rather than benefits, as they are stored in the body's fat tissues and liver.

## VITAMIN C

Vitamin C (ascorbic acid) is a water-soluble vitamin found abundantly in many plants. Vitamin C is essential to growth in the human body because it is required for making collagen. Collagen is a structural protein, which provides much of the framework in the cell, just as the skeleton provides the framework for the body. If your diet is deficient in Vitamin C, the cells in your body may begin to stop growing or even die.

The disease that results from a severe deficiency in Vitamin C is called scurvy. People with scurvy get bruises easily because their blood vessels are very weak. Their skin and teeth become very unhealthy also. In the old days, sailors often got scurvy while at sea because their diets had little or no fresh fruits or

vegetables. Some sailors found that they could prevent scurvy by eating citrus fruits like oranges, lemons or limes (that is why sailors are nicknamed limeys).

This vitamin also strengthens your muscles and bones, and it helps you heal if you break a bone or get a scrape or gash. Vitamin C also helps your body resist infection. This means that even though you can't always avoid getting ill, Vitamin C reduces that risk. Along with many other vitamins, Vitamin C plays an important role in keeping you in optimal health.

Vitamin C also promotes the absorption of iron and is needed to regulate the rate of metabolism.

### How much Vitamin C do we need?

The minimum amount of Vitamin C needed to prevent symptoms of scurvy is 10 mg a day. Australian recommendations are 45 mg per day. However, it is known that at 100 mg all tissues are saturated (filled up) and extra Vitamin C is excreted. There are some medical conditions when extra Vitamin C is needed. For example, if someone suffers extensive burns, then a tremendous amount of scar tissue must form during healing. Vitamin C is vital for these situations.

## PRESERVING VITAMINS

Factors such as length of storage and exposure to heat, light and oxygen affect the amounts of many vitamins in food. Chemists at food companies add preservatives to food, not only to protect the taste but also to protect the nutrient value of the food.

Cooking methods also affect the amount of Vitamin C available for absorption. Rapid cooking with very little water and served immediately is the best way to preserve Vitamin C. Cooking methods such as steaming and microwaving will result in less Vitamin C loss.

Organically grown produce is the same as non-organic produce in vitamin content. Canned fruits and vegetables lose some of their Vitamin C value. By contrast, frozen fruits and vegetables lose very little of their Vitamin C.

## TEACHING AND LEARNING ACTIVITIES

### LOWER PRIMARY

#### Fruit Salad Science

Ask students to bring in a piece of fruit each. Aim to obtain a variety of different fruits (hard, soft, fibrous, grainy, watery, etc). Take time observing the attributes of the each fruit, both whole and cut. Compare the size, shape, smell, texture and (eventually) taste. Observe the different types of skin, seeds, flesh, etc. Draw a cross section of each piece of fruit and produce labelled diagrams. Discuss the vitamins and minerals contained in fresh fruits.

#### Safety

Check for food allergies and complete a risk assessment.

### PRIMARY

#### Wonderful Watercress

Watercress contains more than 15 essential vitamins and minerals. It is easy to grow and has a distinctive taste, which many children (strangely) love. To grow watercress, spread cotton wool over a shallow tray (or place in egg cartons), wet the cotton wool and pour off any excess water. Sprinkle the watercress seeds over the top and keep dark and moist until they sprout. Once sprouted, place in a sunlit position and keep moist. After a week or two, when you have small sprouts, the children can taste them. If you want to grow larger plants, sow the seeds directly into a pot of soil sitting in a bowl of water, so that the water level is lower than the top of the pot. Ask students to research the nutritional value of watercress. Websites such as <http://www.watercress.co.uk/health/chart.shtml> and <http://watercress.com> show the comparative nutritional value of watercress. Watercress is a good source of Vitamins B1, B6, Vitamin A, Vitamin C, Magnesium, Iron, Calcium, Potassium and Zinc.

#### Researching Vitamins and Minerals

Have students prepare an information report on an essential vitamin or mineral. <http://www.health.gov.au/>

[internet/healthyactive/publishing.nsf/content/vitamins-minerals](http://internet/healthyactive/publishing.nsf/content/vitamins-minerals) is a great place to start. Make posters about vitamins and minerals, using food pictures from magazines or the Internet.

## MIDDLE SCHOOL

### Kitchen Chemistry

<http://www.accreditedonlinecolleges.com/blog/2010/kitchen-chemistry-100-cool-food-science-experiments-for-kids-and-cooks/> has instructions for 100 food science experiments. There are many science fair projects that have been completed by students.

### Iron from Cereal

Students can extract iron from breakfast cereal. Using a blender or mortar and pestle, grind 50 grams of high iron cereal (such as Nutri-Grain) into a fine powder. Place the cereal powder into a snap-lock bag and add 250 mL of warm water. Seal the bag and allow it to sit for 2 minutes. Using a very strong magnet (Neodymium magnets work well), stroke the bag in one direction – towards one corner is good. Continue to stroke the bag with the magnet, until the small black pieces of iron accumulate in the corner of the bag. The fortified iron is sprayed onto the cereal and once ingested, can be absorbed in our stomachs.

#### Safety

Remind students not to eat anything from the experiment. Complete a risk assessment.

## MIDDLE SCHOOL - UPPER SECONDARY

### Titration

#### Introduction

The analytical technique, titration, is a very effective way of determining the amount of water-soluble Vitamin C in food by making a water extract of it, and to see how different storage and cooking conditions affects the amount of Vitamin C for absorption by the body.

Titration is used to determine the unknown concentration of a chemical in a solution. In a titration, a carefully measured amount of a second chemical with known concentration is gradually added to the solution. The added chemical (*titration solution*) reacts with the original chemical (*titrant*), whose concentration is unknown. The titration solution reacts with the titrant, and the progress of this

reaction is carefully monitored. When 100% of the original compound has reacted with the added chemical, the titration is complete. Now the concentration of the original chemical can be determined from the amount of titration solution that was added. In this case, Vitamin C is the titrant because the concentration is unknown. The titrating solution that will be added to the measured volume of titrant is iodine. Starch is added to Vitamin C solution and acts as an *indicator*: the starch changes the colour of the solution when the iodine/Vitamin C reaction is complete. As soon as the solution changes colour completely, stop adding the iodine solution.

### Qualitative Titration

Younger students can be introduced to the titration technique qualitatively by ranking the amount of Vitamin C present in various samples. This activity is simple and inexpensive. In addition to the Vitamin C, iodine and starch solutions, it requires a dropper pipette, plastic cup for each sample and paddle pop sticks for stirring. Please read 'Instructions for Making the Solutions' in the Upper Secondary Section.

Measure 30 mL of each Vitamin C solution into a separate plastic or paper cup. To this add about 10 drops of starch solution and stir. Add iodine to one of the solutions, a drop at a time. Stir the solution after the addition of each drop.

The colour of the solution will change after each drop. When the colour changes for the first time, stir for at least 20 seconds. If the original colour returns, continue adding iodine drop-wise with stirring until the colour change persists. At this point the endpoint has been reached, that is, all of the Vitamin C has reacted.

Record the number of drops needed to reach the endpoint. Repeat this procedure for each of the solutions you are testing. All of the solutions can then be ranked with the solution requiring the most drops of iodine to give a colour change containing the highest amount of Vitamin C.

#### Safety

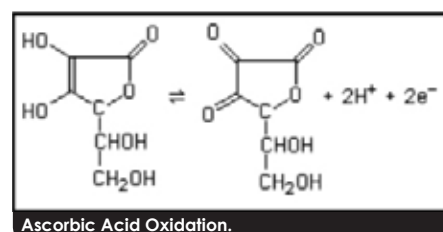
Complete a risk assessment. Consult the relevant Material Safety Data Sheets.

### Quantitative titration

Senior students can undertake the same comparisons by determining the concentration of Vitamin C in solutions using standard titration

techniques. The volumetric equipment used for these activities includes burettes, pipettes and volumetric flasks. Students can learn accuracy and precision as well as the chemistry behind the redox reaction between Vitamin C and iodine.

The chemical reaction of iodine with Vitamin C is called an oxidation-reduction (or redox) reaction. The ascorbic acid is oxidised to dehydroascorbic acid, and the iodine is reduced to iodide ions. Oxidation-reduction reactions always occur in pairs like this. The molecule that loses electrons is *oxidised*, and the molecule that accepts the electrons is *reduced*. See diagram below.



An example of the experimental procedure is as follows:

1. Place 30 mL of the food extract solution in a 250 mL flask or beaker.
2. Add 2 drops of the 0.1 M HCl to the flask.
3. Add 5 mL of the starch solution to the flask.
4. Fill a burette with the iodine solution. Record the initial volume reading.
5. Using the stopcock at the bottom of the burette, add the iodine solution in 1 mL increments to the flask while swirling the flask. Add iodine until the solution stays blue-black for 15 seconds.
6. Record the volume reading on the burette.

### How to make the solutions

#### Vitamin C food extract solution:

There are many juices and drinks that contain Vitamin C. Similarly, many foods also contain Vitamin C. A solution of Vitamin C from any fruit or vegetable (fresh, cooked, frozen and canned) can be easily prepared by blending 100 g of the food material with 100 mL water at the highest speed until the material is thoroughly pureed. It is then possible to filter the pulp from the liquid through cheesecloth. From this you can figure out how much Vitamin C there is per 100g of the fruit or vegetable you sampled.

**Iodine solution:** Dilute Aqueous Iodine Solution BCP (available at Chemists) 1:10 in distilled water to make your iodine titration solution.

1. Pour 30 mL Aqueous Iodine Solution BCP into a 500 mL graduated measuring cylinder.
2. Add enough distilled water to bring the total fluid volume to 300 mL and mix.
3. Store the solution in a clean, tightly covered glass jar that is clearly labelled, in a location that is protected from light.

**Starch indicator solution:** This can be anywhere from 0.5 to 1.0%. The exact amount of starch is not critical.

1. For a 0.5% solution, add 0.25 g of soluble starch to 50 mL of near-boiling distilled water.
2. Stir to dissolve, and allow to cool.
3. When cool, store the starch solution in a clean, tightly covered glass jar that is clearly labelled.

#### Safety

Complete a risk assessment. Consult the relevant Material Safety Data Sheets.

### Variations and Extensions

Some ideas that can be investigated using this activity include

- Which one has more Vitamin C – freshly picked and squeezed or store bought orange juice?
- Do different types and brands of orange juice contain the same amount of Vitamin C?
- Determine which of the three cooking methods: boiling, steaming, or microwaving, preserves the most Vitamin C in broccoli.
- The amount of Vitamin C in different fruits and vegetables.
- The amount of Vitamin C in different fruit juices (e.g. orange, apple, blackcurrant, lemon).
- The effect of light on the Vitamin C content of orange juice.
- The effect of temperature on Vitamin C in orange juice (e.g. room temperature, refrigeration or freezer storage).
- How many serves of particular vegetables would you need to eat to reach the RDI for Vitamin C?
- Do you have any ideas on how to get more vitamins from your meals?

### USEFUL REFERENCES

D.2 Laboratory Activity: Vitamin C Analysis in ChemCom: Chemistry in the Community (p. 237-239) *American Chemical Society*, 1988. (p 254 New edition)

Science Buddies, n.d – Which orange juice has the most Vitamin C? [http://www.sciencebuddies.org/science-fair-projects/project\\_ideas/Chem\\_p044.shtml?fave=no&isb=c2lkOjEsaWE6Q2hIbSxwOjUscmlkOjkzMzA3MTg&from=TSW](http://www.sciencebuddies.org/science-fair-projects/project_ideas/Chem_p044.shtml?fave=no&isb=c2lkOjEsaWE6Q2hIbSxwOjUscmlkOjkzMzA3MTg&from=TSW)

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University of Canterbury, n.d. *Determination of vitamin C Concentration by Titration*, Science Outreach Programme, College of Science, University of Canterbury, Christchurch, New Zealand [http://www.outreach.canterbury.ac.nz/chemistry/documents/vitaminc\\_iodine.pdf](http://www.outreach.canterbury.ac.nz/chemistry/documents/vitaminc_iodine.pdf)

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## A CRASH COURSE IN SAUSAGE SCIENCE

Sausages are simple: the humblest of sausages are just meat, salt, pepper and some added water. But the distinctive smell, striking colour and delicious taste of properly barbecued sausages come from molecules formed in a complex chemical process that was first studied 100 years ago by a French research chemist and medical doctor, Louis-Camille Maillard.



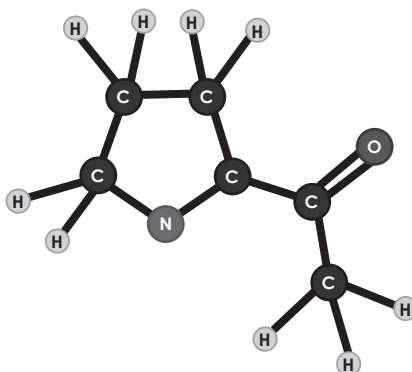
Image: Wikipedia

In the chemical reaction named after Maillard, the proteins and carbohydrates in meat break down into their sub-units – amino acids and simple sugars, and these subunits react with each other to make more than 200 different new chemicals. Many of these are brown with strong, distinctive smells and tastes.

This reaction will occur in any type of food that contains protein and carbohydrates and is one of the main causes of the aromas and brownness in cooking. Toast, cakes, roasted coffee beans, stir-fries, chips and baked potatoes all get some of their delicious smells and tastes from this reaction of amino acids and simple sugars.

## SOME OF THE MOLECULES

Complex carbohydrates are long molecular chains of Carbon (C) with Oxygen (O) and Hydrogen (H). Proteins are also long chains, additionally containing Nitrogen (N) and some Sulphur (S). Many of the intense smells come from small molecules that contain C, H, N, O and S that form in the Maillard reaction.



Chemical structure of 2-acetylpyrrole ( $C_6H_7NO$ )

Aroma compound 2-acetylpyrrole ( $C_6H_7NO$ ) can be found in freshly made toast, roasted coffee beans and cooked sausages. Some noses can detect this chemical from a hundred metres away!

Foods that are mainly carbohydrates turn brown in their cooking through caramelisation – a reaction of simple and complex carbohydrates producing a huge set of molecules different from the Maillard reaction products because they contain only C, H and O. Caramelised food is often bitter-sweet from the organic acids (like acetic acid) that form alongside long brown-coloured molecules and lots of other fragrant substances.

## TEMPERATURE

Sausages should be cooked on a low to medium even heat, turning them roughly every 10 minutes. Cooking them on a high flame can cause the water mixed in with the meat to turn to steam, causing pressure to build up inside the sausage casing. If these split, the sausages can lose lots of their flavoursome watery and fatty juices and become dry, tasteless and boring.

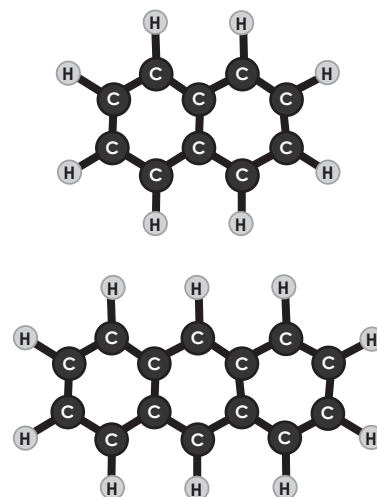
If the meat is cooked for too long or at very high temperatures, the fats, proteins and carbohydrates will break down completely, losing much of their N, O, H and S and making charcoal from the remaining carbon.

The perfect cooking temperature for most sausages is around 120-150° where the Maillard reaction becomes rapid and the food turns brown – not black. Meat cooked at lower temperatures (boiled or steamed frankfurts or hot dogs) don't usually become brown and have much more subtle flavours than barbecued sausages because the proteins and carbohydrates don't react as much.

If the temperature is too low, the sausages might not be safe to eat at all. There are many safe microbes naturally found on meat, but two – *Salmonella* and *E. coli* – can cause nasty infections, severe diarrhoea and sometimes even death. The grinding process leaves sausage meat more susceptible to infection because the meat comes in contact with more potentially infected surfaces. The grinding can also spread a small infection through a whole string of snags. *E. Coli* are killed at 68°C so it is important that the whole sausage exceeds that temperature to make them safer to eat. They should never be served rare.

## A BAD REPUTATION?

Snags contain iron and some other useful vitamins and minerals but the useful contents are wrapped up in a package that contains 25-30% fat – even higher in 'budget' or 'exotic' varieties. The fat is necessary for the grinding and to give the delicious moist sausage mouth-feel but sausages really aren't a health food. Even worse, snags cooked on smoky fires or on a very hot grill will have molecules called polycyclic aromatic hydrocarbons (PAHs) on their skins, which can cause cancer.



Chemical structure of Naphthalene  $C_{10}H_8$  (top) and Anthracene  $C_{14}H_{10}$  (bottom). Both are PAHs

The rules to a tasty snag are:

- buy sausages that contain 25-30% fat
- cook on a low to medium heat turning them every 10 minutes
- don't use a smoky barbecue
- NEVER prick the skin
- make sure they are cooked thoroughly
- and give a nod to Louis Maillard for your tasty snack!

## FOR MORE INFORMATION

On *Food and Cooking: The Science and Lore of the Kitchen* by Harold McGee (1984, Scribner: New York) is a fantastic collection of the scientific processes behind all types of food. Harold also writes a blog for the New York Times that is collated at <http://news.curiouscook.com/>

## TEACHING AND LEARNING ACTIVITIES

### PRIMARY

#### Toasty Reaction

Have students compare a slice of fresh bread with a slice of toast. Ask them to write down all of the similarities and differences between the bread and the toast. Can toast turn back into bread? The process of toasting bread causes a chemical reaction, which produces wonderful aromas and tastes – the Maillard reaction.

#### Colourful Brekky

Make some fun and colourful toast. Place a small amount of milk into a few paper cups, add 2 drops of a different food colour into each cup and swirl. Using a small, new paintbrush, paint a design on the bread (don't let it get too soggy). Toast the bread as normal and then admire your masterpiece. The milk wets the bread and therefore stops the Maillard reaction from occurring on those sections and therefore the colours stand out brightly.

#### Safety

Complete a risk assessment on using a toaster.

### MIDDLE SCHOOL

#### Toast

Study the Maillard reaction by making toast. Discuss the aroma and flavour changes when toast is made. Investigate

what happens when you wet the bread before it is toasted. Lightly score a piece of fresh bread with a butter knife, so as to divide the bread into quarters. Using a new paintbrush, paint one quarter with water, one with milk and leave the other 2 plain (it looks good if you leave the opposite corners plain, so as to create a chequered effect). Toast the bread as normal and observe the toast. Ask students to try to explain what has happened. The water and milk wet the bread, keeping it at a lower temperature and hence preventing the Maillard reaction from occurring. With further toasting, once the water has evaporated, the Maillard reaction will occur (the rest of the toast will probably burn though).

#### Safety

Complete a risk assessment on using a toaster. Be careful not to let the toast burn.

#### Sausage Sizzle

Fry or BBQ some sausages and observe the changes occurring during the cooking process. Compare fried sausages to boiled sausages, using visual observations and taste tests. To boil sausages, bring some water to the boil and then carefully add the sausages. Simmer until thoroughly cooked (around 30 mins) and compare with fried snags. Boiling sausages inhibits the Maillard reaction from occurring, as the temperature does not get high enough to produce the browning process. Boiled sausages not only lack visual appeal, but also have a more subtle flavour. People who boil



Image: Leanne West

A fried sausage has more flavour and visual appeal than a boiled sausage, thanks to the Maillard reaction.

sausages, often fry them at the end to make the sausage brown and crispy. Boiled or fried snags - what would you prefer?

#### Safety

Complete a risk assessment on cooking sausages.

### SENIOR SECONDARY

#### Design an Experiment

Ask students to design an experiment to investigate the Maillard reaction. Some suggestions are:

- attempt to produce different aromas by heating different proteins with sugars, <http://wyattskitchen.com/?p=390> has some suggestions.
- investigate possible methods of speeding up or slowing down the Maillard reaction. Visit <http://blog.khymos.org/2008/09/26/speeding-up-the-maillard-reaction/> and read the blog about speeding up the Maillard reaction.
- investigate the temperature at which the Maillard reaction occurs in different foods.
- investigate the Maillard reaction in the yellowing of albumen photographs, see <http://albumen.conservations-us.org/library/c20/reilly1982a.html>

#### Colour of French Fries

Investigate the effect of refrigerated storage on the colour formation in French fries at <http://www.ift.org/Knowledge-Center/Learn-About-Food-Science/K12-Outreach/Food-Science-Experiments/Experiments-in-Food-Science.aspx>

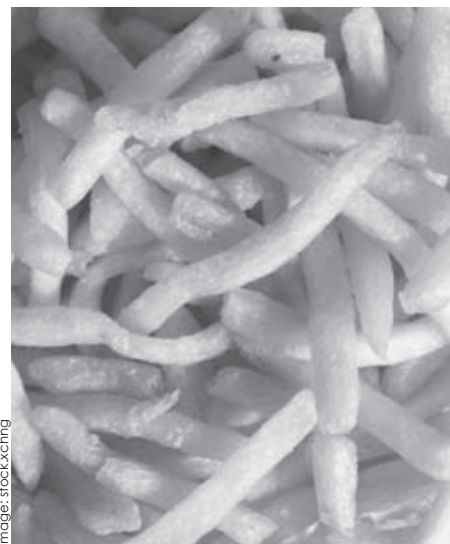


Image: stock.xchng

French Fries.

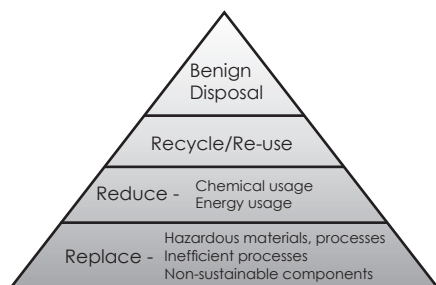
# CHAPTER 2 - GREEN CHEMISTRY

**Green Chemistry is designed to reduce the negative impacts of chemistry and the chemical industry, to society and the environment.**

**Green Chemistry aims to find alternative chemicals, conditions and processes to reduce risks to the environment and human health. For industrial applications, this chemical philosophy aims to conserve energy, minimise waste and maximise the end product, hence reducing resources and costs.**

Green Chemistry is an area that endeavours to make chemicals and processes less damaging to the environment and to society. It does this through a number of ways including:

1. Using better methods to produce industrial chemicals that minimize waste and pollution.
2. Using safer chemicals that carry less safety concerns and improved biodegradability.
3. Improving energy use and the use of renewable resources.



**Green Chemistry Triangle.**

The practice of green chemistry is to make all chemical processes 'greener'. This can be through small improvements, such as replacing a solvent with a less hazardous one, or by an incremental decrease in the amount of waste. Examples from Australia include the phasing out of leaded additives from petrol in

Australia during the 1970s, and the replacement of asbestos by fibreglass and wool as insulation materials.

Examples of implementing 'greener chemistry' in schools include resigning distillation experiments to minimize the use of water condensers, substitute food products for various reagents (e.g. use red cabbage extract as acid-base indicator), use environmentally-friendly solvents, reduce waste and conserve energy wherever possible.



Images: stockxchng

## **Twelve Principles of Green Chemistry**

1. **Prevention:** It is better to prevent waste than to treat or clean up waste after it has been created.
2. **Atom Economy:** Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. **Less Hazardous Chemical Syntheses:** Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. **Designing Safer Chemicals:** Chemical products should be designed to effect their desired function while minimizing their toxicity.
5. **Safer Solvents and Auxiliaries:**  
The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.
6. **Design for Energy Efficiency:** Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
7. **Use of Renewable Feedstocks:** A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
8. **Reduce Derivatives:** Unnecessary derivatisation (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
9. **Catalysis:** Catalytic reagents (as selective as possible) are superior to stoichiometric (having the exact proportions for a particular chemical reaction) reagents.
10. **Design for Degradation:** Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.
11. **Real-time analysis for Pollution Prevention:** Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. **Inherently Safer Chemistry for Accident Prevention:** Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

Extract from: Anastas, P. T.; Warner, J. C. (1989) *Green Chemistry: Theory and Practice*, Oxford University Press: New York, p.30.



**DAVID ORME**

**MASSON**, professor of chemistry at the University of Melbourne from 1886 to 1923, founded the Society of Chemical Industry of Victoria and was co-founder of the (now Royal) Australian Chemical Institute. During World War 1 he organised Australian chemists to travel to Britain and work in the munitions industry.

**HENRY GEORGE SMITH**

investigated the chemistry of the essential oils of *Eucalyptus* species in the early years of last century. He believed that the chemical constitution of the oils could be used in taxonomy but alas, the oils turned out to be too variable in composition to be reliable 'fingerprints'.

**EZIO RIZZARDO**

is a CSIRO scientist who discovered new ways to make polymer chains of any size and shape. Known as RAFT (Reversible Addition-Fragmentation Chain Transfer), the discovery is protected by a number of patents and the technique is now very widely used.

**JANE OPPENHEIM**

has been Scientific Director of Ego Pharmaceuticals since 1990. Ego produces products like QV lotions, Pinetarsol and products for acne treatment and sun protection and are sold in 46 countries.

**PAUL FRASER**

is an atmospheric researcher with CSIRO, specializing in detection of trace gases in the atmosphere, in particular the CFCs and other substances that are associated with destruction of the ozone layer.

**ARTHUR BIRCH**

was working in England when he discovered the chemical reaction that facilitated the laboratory synthesis of natural products such as the synthetic steroids used in hormone replacement therapy and the contraceptive pill. The Birch Reduction (as it came to be known) employed sodium and liquid ammonia to add hydrogen atoms to aromatic systems.

# A COLLAGE OF AUSTRALIAN



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**FRANCIS SEPAROVIC**

a professor at the University of Melbourne, uses high-resolution nuclear magnetic resonance to study biological molecules in solution. The structural details revealed can be related to the action of enzymes and other bio-molecules.

**ROBYN ELLIOTT**

has worked in the pharmaceutical industry for 25 years, and today she is the managing director of IDT Australia Limited, a company that provides drug development and evaluation services to industry. Their laboratories are specially equipped to handle highly toxic and highly potent materials such as anti-cancer drugs.

**JEFF TAYLOR**

a geochemist, is a Director of the consultancy firm Earth Systems Pty Ltd, specialising in water quality, environmental geochemistry, contaminated site remediation and nutrient pollution. Most of the company's work is with the mining industry in Australia and SE Asia.

**CARL SCHIESSER**

leads the Centre of Excellence for Free Radical Chemistry and Biotechnology in which scientists from a number of institutions collaborate to explore reactive species. They study the way that free radicals can be used in organic synthesis and the impact that radicals have on human health.

**HANA HAMDEN**

uses her chemical knowledge to ensure that chemicals introduced in Australia are managed with care. She works for the National Industrial Chemical Notification and Assessment agency that is part of the Health and Ageing portfolio.

**ANDREW HOLMES**

has joint appointments at the University of Melbourne and CSIRO Chemical and Polymers. He is the inventor of solar energy collectors that are flexible and have niche applications unlike rigid silicon collectors that are widely used in Australia and other countries.

**MILTON HEARN**

heads the Green Chemistry Centre at Monash University. The Centre's criterion for new chemistry is that it should be sustainable, employ non-toxic substances, and produce no waste.

**DAVID DODDRELL**

developed equipment and methods for Magnetic Resonance Imaging (MRI), making Queensland the epicentre for this medical technology. Whereas X-ray images show bone and tissue density, MRI images show how mobile the water and lipid molecules are and do not involve exposure to possibly damaging X-rays.

**ALAN BAKER**

in the Defence Science and Technology Organisation (DSTO) has found ways to use boron-reinforced epoxy patches to repair damage to metal components of aircraft. The technology is used worldwide on military and civil airframes, enhancing safety and saving millions of dollars.



# OID OF N CHEMISTS

## LEW MANDER,

a chemistry professor at the Australian National University, completed laboratory syntheses of plant 'hormones' gibberellins, thus making them available for commercial applications such as synchronizing the ripening of fruit or the blooming of flowers so that they can all be harvested at the one time.

## IAN WARK

provided the theoretical basis for flotation, a mineral separation process that is a vital part of Australia's mineral industry. He was able to explain why some bubbles stuck to only some minerals and carried them to the frothy surface of the flotation cell. His 1938 book *Principles of Flotation* stamped his authority on the field.

## MARK VON ITZSTEIN

designed, and in 1989 synthesized, a drug molecule that blocks replication of the influenza virus and prevents it leaving an infected cell to spread the infection. The Biota Company supported his work in Australia. The drug (originally known as Zanamivir) is now marketed by GlaxoSmithKline as Relenza.

## LEN WEICKHARDT,

a Ballarat boy who studied at the Working Men's College (now RMIT University) and the University of Melbourne, worked for ICI Australia for 35 years and also made major contributions to the Royal Australian Chemical Institute. A highlight of his career was leadership of the project undertaken during World War 2 to produce sulfa drugs (antibiotics) in Australia.

## DAVID BLACK,

an organic chemist from the University of NSW, is now in his second term as Secretary General of the world body, the International Union of Pure and Applied Chemistry (IUPAC).

## BEN SELINGER

is best known for his book *Chemistry in the Market Place*, which ran to five editions. His many contributions to public life include some years as the inaugural chairman of Australia's pesticide regulator and a regular spot on the TV program 'Burke's Backyard'.

## NAOMI MCSWEENEY,

a PhD student at the University of Western Australia, is using micro-organisms to destroy the toxic sodium oxalate that forms as a by-product when bauxite is treated with caustic soda in the Bayer process for preparing alumina.

## COLIN RASTON

in Western Australia has developed methods for generating and studying nanoparticles – new forms of matter with unusual properties caused by their enormous surface areas.

## JOCHEN MUELLER

uses advanced methods in analytical chemistry to assess environmental pollution in Australia. Tetrachlorodibenzo-dioxins and -furans have been tracked in soils and in human blood, and more recently there has been a focus on brominated flame retardants.

## GEOFF SCOLLARY

of Charles Sturt University has made detailed studies of the chemistry of wine, including the crystallization of tartrate salts. Large, well-formed crystals will settle out and not affect wine quality, but very fine crystals remain in suspension and can spoil an otherwise-acceptable wine.

## IAN RAE,

an active retiree, serves as an adviser on chemical matters for the UN Environment Program and his state EPA, and also writes a monthly essay (Letter from Melbourne) for the Royal Australian Chemical Institute's magazine *Chemistry in Australia*.

## PAUL HADDAD

of the University of Tasmania heads a group of specialists in analytical chemistry, seeking faster and more accurate methods for a range of applications. The detection of explosives – before and after their use – is a major interest.

## LEO RADOM

is Australia's leader in theoretical chemistry, using computer power and chemical insight to probe the structure of existing molecules, for which structural data may be available, and transient or hypothetical species which are not accessible to experimental methods like spectroscopy or crystallography.

## DAVID BROCKWAY

is Chief of the CSIRO Division of Energy Technology where a wide range of scientific and technical considerations are brought to the study of new energy sources and more efficient use of existing sources.

## MARY GARSON

investigates how marine plants produce the chemical substances that chemists have detected in them. While studies of Australia's terrestrial plants have been a strong interest for over a century, Mary is one of very few scientists to take to the water.

## GREEN CHEMISTRY APPLICATIONS

### Case Study 1: Biodegradable plastics

Most plastics (polymers) are made from petroleum, a non-renewable source. Polymers are formed in a process called polymerisation, by joining small molecules (monomers) into larger molecules (polymers). They are hard to breakdown and last in the environment for a long time. Most plastics are addition polymers (see information box below).

The Canadian company, EPI Environmental Technologies <http://www.epi-global.com/>, makes a biodegradable plastic for the Australian market. EPI™ plastics are used as the material for some shopping bags and as the covering for some magazines sent through the mail; the EPI™ logo is printed on them. These plastics

are addition polymers but have additives, which are bonded to the carbon 'backbone'. This causes the backbone to break down over months or years, which is much faster than without these additives.

Another class of plastics is condensation polymers (see information box). Most condensation polymers can be degraded by the addition of water (hydrolysis) or by microbial action. Hydrolysis is the reverse of the condensation reaction: by adding H<sub>2</sub>O across the bond that joins the monomer units, the bond breaks and reforms the original OH or NH and acid functional group.

The Melbourne-based company, Plantic™ <http://www.plantic.com.au/> uses cornstarch as the basis for its plastics. Since starch-based plastics are condensation polymers, the Plantic™ plastics are derived from renewable sources and are biodegradable. Plantic™ plastics are used in packaging applications, such

as the trays for certain chocolates. The Plantic™ logo is printed on the bottom of the boxes for these chocolates.

### Did You Know?

Just 8.7 plastic checkout bags contain enough embodied petroleum energy to drive a car 1 kilometre. <http://www.cleanup.org.au/au/LivingGreener/plastic-bag-facts.html>

### Case Study 2: Supercritical carbon dioxide, a less hazardous solvent

Solvents are liquids, which dissolve solid substances. For example, water is often called the universal solvent because it can dissolve many salts, minerals, medications, proteins and other substances. However, water is not able to dissolve significant amounts of most organic compounds (e.g. greases and oils). These require oil-based solvents, which are obtained from petroleum sources and are environmentally unfriendly. Supercritical carbon dioxide (sc-CO<sub>2</sub>) is finding increasing use as an environmentally friendly solvent. Sc-CO<sub>2</sub> has been used to remove caffeine from coffee beans and even as a dry cleaning solvent.

### What is supercritical carbon dioxide?

When carbon dioxide (CO<sub>2</sub>) is compressed to pressures above 520 kPa, it can form a liquid. Under further compression to pressures above 7 380 kPa and temperatures above 31.1°C (304 K), a supercritical fluid is formed, which has both gas-like and liquid-like properties. Since carbon dioxide is extracted from the atmosphere, it is a renewable resource and any spillages quickly evaporate back into the atmosphere.

### How does supercritical carbon dioxide work?

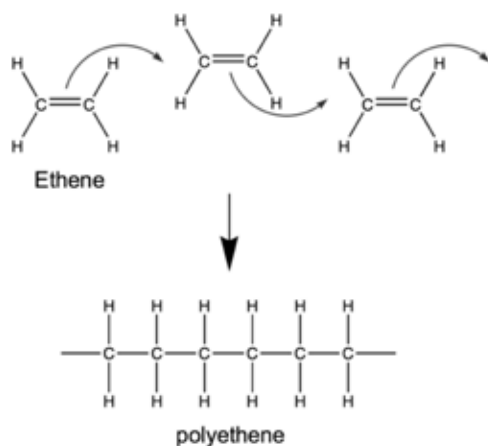
The carbon atoms in CO<sub>2</sub> have a very small positive charge, while the oxygen atoms have a very small negative charge. These charges are normally too small to dissolve material, but when CO<sub>2</sub> is compressed to form supercritical carbon dioxide, the CO<sub>2</sub> molecules are so closely packed that the large number of small attractive interactions are sufficient to dissolve many substances. When the pressure is decreased, the CO<sub>2</sub> molecules move apart, lessening the solvation and depositing the dissolved materials.

### Did You Know?

In 2004, a team of undergraduate students from the University of NSW designed a dishwasher to clean dirty crockery using sc-CO<sub>2</sub> as the solvent.

### Addition polymerisation

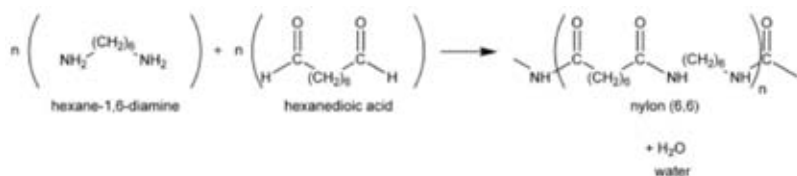
Monomers containing a multiple bond are joined to form a polymer. In this process the multiple bond is broken and monomers attach to each other. An example of this is how polyethene (polyethylene) is formed from ethene (ethylene):



The curved arrows are drawn from the ethene double bonds, which are broken, to the location of the new bonds, which are formed to join the separate ethene molecules into a long chain of polyethene.

### Condensation polymerisation

In condensation polymerisation, monomers usually contain a functional group at each end (eg. organic acid, COOH, and amine, NH). These functional groups react to give off a small product such as water ("condensation"). This allows for the monomers to join and form a polymer. An example of this is the synthesis of nylon, which is a polyamide polymer:



Polyesters and proteins are other examples of condensation polymers.



### Manufacture of ephedrine using sc-CO<sub>2</sub>

Associate Professors Andrew Smallridge and Maurice Trehwella from Victoria University in Melbourne, have developed an innovative process for the manufacture of ephedrine using sc-CO<sub>2</sub>. Ephedrine is used to produce drugs for treating allergy conditions, narcolepsy, depression and Myasthenia Gravis, increasing blood pressure, and strengthening heart contractions. About 1,500 to 2,000 tonnes of ephedrine products are consumed per year, worldwide.

Benzaldehyde and pyruvic acid are first reacted in sc-CO<sub>2</sub> through a column of solid bakers' yeast to form 1 phenylacetylcarbinol (I PAC). Manipulation of temperature and pressure allows pure product (I PAC) to be separated from the reaction mixture and then passed to a second reactor. There, sc-CO<sub>2</sub> is again employed as the solvent; I PAC is reacted with hydrogen and methylamine over a metal catalyst to yield ephedrine. Again, manipulation of temperature and pressure enables pure product (ephedrine) to be isolated. The recovery and re-use of unreacted benzaldehyde and I PAC increases reaction yield and decreases waste.

### Case Study 3: Generating electricity from poo

Methane is a major product when anaerobic bacteria break down sewerage. The Global Warming Potential of methane, calculated over a 20-year period, is 56 times that of carbon dioxide. In the 1990s, Melbourne Water put huge plastic covers in place to capture most of this methane emission and to use it to run methane-powered electrical generators. These covers trap about 87,000 cubic metres of methane a day at the Western Treatment Plant. The power stations burn methane to

produce electricity; they also convert methane to carbon dioxide, which is less harmful to the environment. Currently, the Western Treatment Plant produces 71,500 megawatt-hours of renewable electricity every year. In turn, this has reduced the demand for electricity from the electricity grid, preventing the emission of the equivalent of more than 87,000 tonnes of carbon dioxide from coal-fired power stations every year. As an added benefit, the covers also trap and remove other gases, which make up the smelly odours of decomposing sewerage.

### Did You Know?

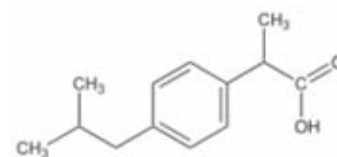
The use of methane from pig poo, as an energy source, was featured in the 1985 Australian movie, *Mad Max 3: Beyond Thunderdome*.

### Case Study 4: More efficient manufacture of pharmaceuticals

Ibuprofen is a common medication that relieves pain and inflammation. Prior to the 1990s, the manufacture of ibuprofen from isobutylbenzene required at least 6 steps, with each step producing waste in the form of side products. Now, the Hoechst-Celanese process from the same starting material, isobutylbenzene, involves only three steps. This process results in greater efficiency and less waste.

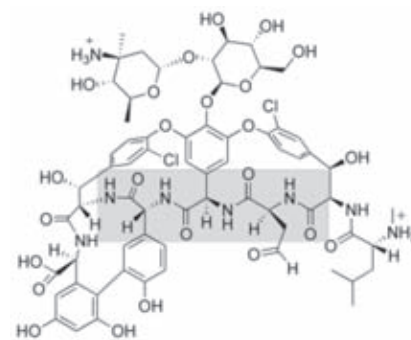
In Australia, scientists are trying to develop methods of making pharmaceuticals, which require fewer synthetic steps, use less solvent and are more energy efficient. Dr Fred Pfeffer and his research group at Deakin University are investigating the production of a simpler way to make antibiotics.

Vancomycin is isolated from a fermentation process, but as some strains of golden staph develop



Ibuprofen.

resistance to vancomycin, there is a need to change the peptide portion of the drug molecule to counter this resistance. Any modification to the peptide portion requires synthetic methodology in place of the fermentation process – a process that requires over thirty steps. Researchers at Deakin University aim to produce simpler vancomycin mimics, which have a less complicated rigid molecular backbone, and only require about ten synthetic steps to incorporate new peptide sequences.



Vancomycin, with highlighted peptide portion.

## TEACHING AND LEARNING ACTIVITIES

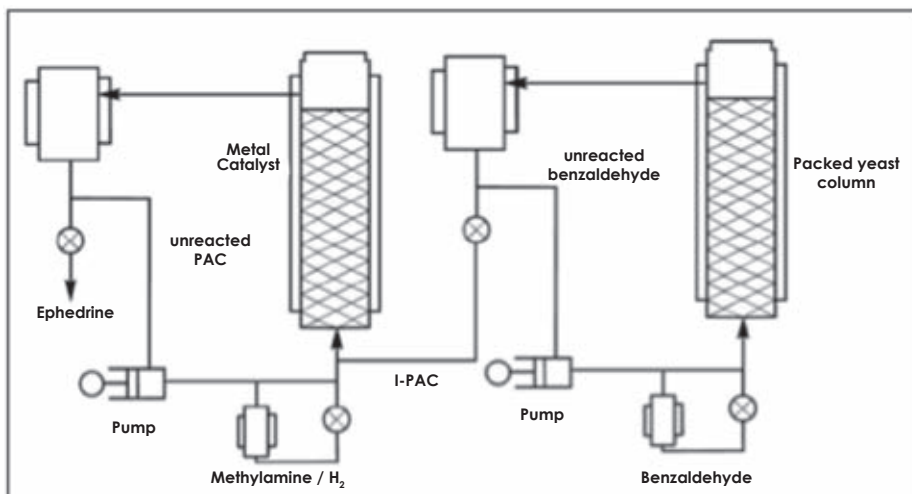
### PRIMARY

#### Comparing plastics

Collect different samples of plastic. Make sure that Plantic™ and EPI™ plastics are included in the samples. (The Plantic™ and EPI™ logos are printed on the outside of the relevant packaging.) Cut each sample into 5 or more pieces, so that there are 5 or more collections of each type of plastic. Put the samples in various locations: compost heap, cool dark cupboard, window sill exposed to strong sunlight, soaking in hot water, soaking in bleach, etc. Monitor any changes in the plastics over a school term and discuss which different plastics are most likely to cause litter and pollution.

#### Safety

Using hot water and household chemicals, such as bleach, is hazardous. Complete a risk assessment.



Manufacture of ephedrine.

## Making a plastic from milk

Mix 1 cup of whole milk with 3 teaspoons of vinegar in a saucepan. Heat to about 55°C and stir frequently. The liquid will separate into small lumps (curds) and a clear liquid (whey). Collect the whey by straining the liquid through a cloth. Put the curds back into the saucepan and add enough water that the mixture can be stirred. Now slowly stir in one teaspoon of baking soda into the water/whey mixture. The baking soda will 'fizz'. Slowly stir in more teaspoons of baking soda until no more bubbles are formed. Strain the liquid again. The solid whey can be kneaded and shaped. It will harden on drying. Paint if desired.

### Safety

Complete a risk assessment; take care with heating the milk.

### Why does this work?

Milk 'fats' contain casein, which is a protein. This casein protein is a naturally occurring polymer. Vinegar is an acid, which causes the casein to separate from the liquid in the milk. Baking soda is a base, which uses up the vinegar acid to form bubbles of gas. While the casein is wet, water permits the casein protein chains to move. However, on drying, the water is removed, locking the casein protein chains in a rigid shape.

## MIDDLE SCHOOL

### Polymer packaging

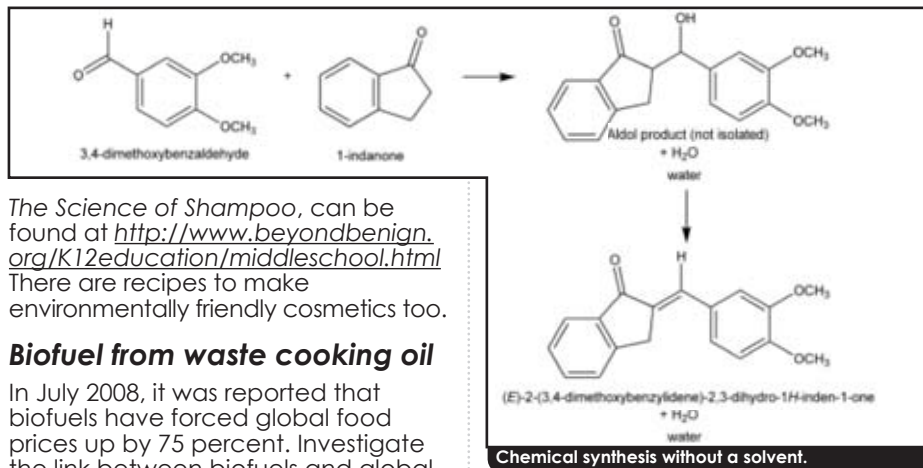
Ask students to design an experiment to compare polystyrene packaging beads with cornstarch packaging beads. Discuss how to make it a fair test. Students should consider a variety of factors, such as: weight, price, ability to hold shape, dust creation, electrostatic charge, environmental concerns, etc. Students may like to 'package' a raw egg to test the effectiveness of the different beads.

### Safety

Complete a risk assessment. Packaging beads are a choking hazard, if ingested.

### Beyond Benign: Green Chemistry Education

Beyond Benign, see <http://www.beyondbenign.org/>, is a "non-profit organization that promotes sustainable science in order to create an environmentally, socially and economically prosperous world". An introductory unit to green chemistry called *Chemistry with a Conscience*:



## UPPER SECONDARY

### Beyond Benign: Green Chemistry Education

A unit called *Green Chemistry in the High School: Lessons from Beyond Benign* can be found at <http://www.beyondbenign.org/K12education/highschool.html>. This includes a general introduction to green chemistry, industry examples and replacement laboratory lessons that use green chemistry principles.

### Chemical synthesis without a solvent

Most chemical syntheses require a solvent. This activity is an example of a solid-solid reaction. The absence of a solvent decreases waste. The aldol condensation reaction is a reaction between two carbonyl-containing compounds, usually between two aldehydes, or between an aldehyde and acetone. This reaction illustrates a green chemistry process and the formation of a carbon-carbon bond to form a longer organic molecule.

Mix 0.25 g of 3,4-dimethoxybenzaldehyde (methyl vanillin) and 0.20 g of 1-indanone in a small (10 mL) vessel. Crush the two solids together using a metal spatula, until the mixture becomes a brown oil. Add 0.05 g of finely-ground sodium hydroxide catalyst and continue stirring and scraping the mixture until the product solidifies. The product can be purified by adding acid to neutralise the sodium hydroxide catalyst and recrystallising from a very small quantity (typically 5-10 mL) of 9:1 ethanol/water mixture.

### Safety

Consult the relevant Material Safety Data Sheets and complete a risk assessment.

Students should calculate and discuss the atom efficiency (atom economy), environmental impact factor (E-factor = mass of total waste / mass of product) and yield.

### Why does this work?

The presence of impurities lowers the melting point of a substance, which is why adding salt will cause ice to melt at temperatures lower than 0°C. In this activity, the 3,4 dimethoxybenzaldehyde is an impurity in the 1 indanone, and vice versa. The mixing lowers both melting points until the mixture melts, even without increasing the temperature. The sodium hydroxide then catalyses the reaction to form the aldol product. The name "aldol" refers to the hydroxy (i.e. alcohol) aldehyde that is formed as a product. In this synthesis, the newly-formed hydroxy group is converted to a double bond.

## USEFUL WEBSITES

Green Chemistry, Royal Society of Chemistry <http://www.rsc.org/Education/Teachers/Resources/green/>

ASC Green Chemistry Institute [http://portal.acs.org:80/portal/acs/corg/content?nfpb=true&pageLabel=PP\\_TRANSITIONMAIN&node\\_id=830&use\\_sec=false&sec\\_url\\_var=region1&uid=7176e501-f78c-4456-80c7-d811537421c9](http://portal.acs.org:80/portal/acs/corg/content?nfpb=true&pageLabel=PP_TRANSITIONMAIN&node_id=830&use_sec=false&sec_url_var=region1&uid=7176e501-f78c-4456-80c7-d811537421c9)

Green Chemistry Educational Resources [http://portal.acs.org:80/portal/acs/corg/content?nfpb=true&pageLabel=PP\\_SUPERARTICLE&node\\_id=1444&use\\_sec=false&sec\\_url\\_var=region1&uid=9fea7253-b9a8-46fb-8b03-928e3deefd06](http://portal.acs.org:80/portal/acs/corg/content?nfpb=true&pageLabel=PP_SUPERARTICLE&node_id=1444&use_sec=false&sec_url_var=region1&uid=9fea7253-b9a8-46fb-8b03-928e3deefd06)

Centre for Green Chemistry, Monash University <http://www.chem.monash.edu.au/green-chem/>

Green Chemistry, VCE Chemistry Unit [www.vcaa.vic.edu.au/vce/studies/chemistry/greenchemistry.doc](http://www.vcaa.vic.edu.au/vce/studies/chemistry/greenchemistry.doc)

# CHAPTER 3 - ENVIRONMENTAL CHEMISTRY

**Environmental Chemistry involves the chemical interactions between humans and nature. The chemical properties and reactions of natural and man-made substances greatly influence how we live – from what we eat, to how we travel around. Human activities impact on chemical processes in the environment, therefore environmental scientists**

**aim to monitor, detect and resolve problems that humans have created in nature. Environmental concerns have social, political and economic implications, both locally and globally.**

Environmental chemistry includes chemistry of the atmosphere (air), biosphere (life), hydrosphere (water), and lithosphere (soil). The global chemical and energy cycles (e.g. water, carbon and nitrogen cycles) form the interaction processes between the spheres.

## POLLUTION

Pollution occurs when harmful substances contaminate the natural environment and consequently chemicals exist in higher quantities than naturally present. Toxic chemicals may have damaging effects on ecosystems, although sometimes the damage isn't apparent until later. Government and private scientific organisations are continually trying to reduce pollution and its negative outcomes, including those detrimental to human health. Environmental chemists research, analyse and endeavour to resolve environmental problems by using air, water and soil monitoring techniques and designing methods for environmental sustainable processes.

Environmental indicators (such as water quality, air quality, species numbers, atmospheric temperature, etc.) can be used to inform individuals and society about the state of the environment and whether particular environmental objectives are being met.

<p><b>Atmosphere</b></p> <ul style="list-style-type: none"><li>- contains all of Earth's air</li><li>- retained by gravity</li><li>- layers have different compositions and temperatures</li><li>- air is approx 78% nitrogen &amp; 21% oxygen</li></ul>	<p><b>Biosphere</b></p> <ul style="list-style-type: none"><li>- contains all living things</li><li>- plants, animals and micro-organisms</li><li>- integrated system</li><li>- some scientists use anthrosphere for humans</li></ul>
<p><b>Hydrosphere</b></p> <ul style="list-style-type: none"><li>- contains all of Earth's water</li><li>- solid, liquid and gaseous forms of water</li><li>- 97% salty water</li><li>- fresh water found in rivers, groundwater and mostly frozen water (cryosphere)</li></ul>	<p><b>Lithosphere</b></p> <ul style="list-style-type: none"><li>- contains the Earth's land</li><li>- crust and upper mantle</li><li>- varied landforms throughout</li><li>- soil layer is called the pedosphere</li></ul>

## Additional resource

Further information and student activities on Earth's atmospheric layers, global climate and climate change and the human impact on Earth can be found in *Planet Earth – Planet of Change. A resource book of ideas for teachers and National Science Week 2008* (ISBN 0-9580663-6-1) published by the Australian Science Teachers Association. Available from ASTA (02) 6282 9277.





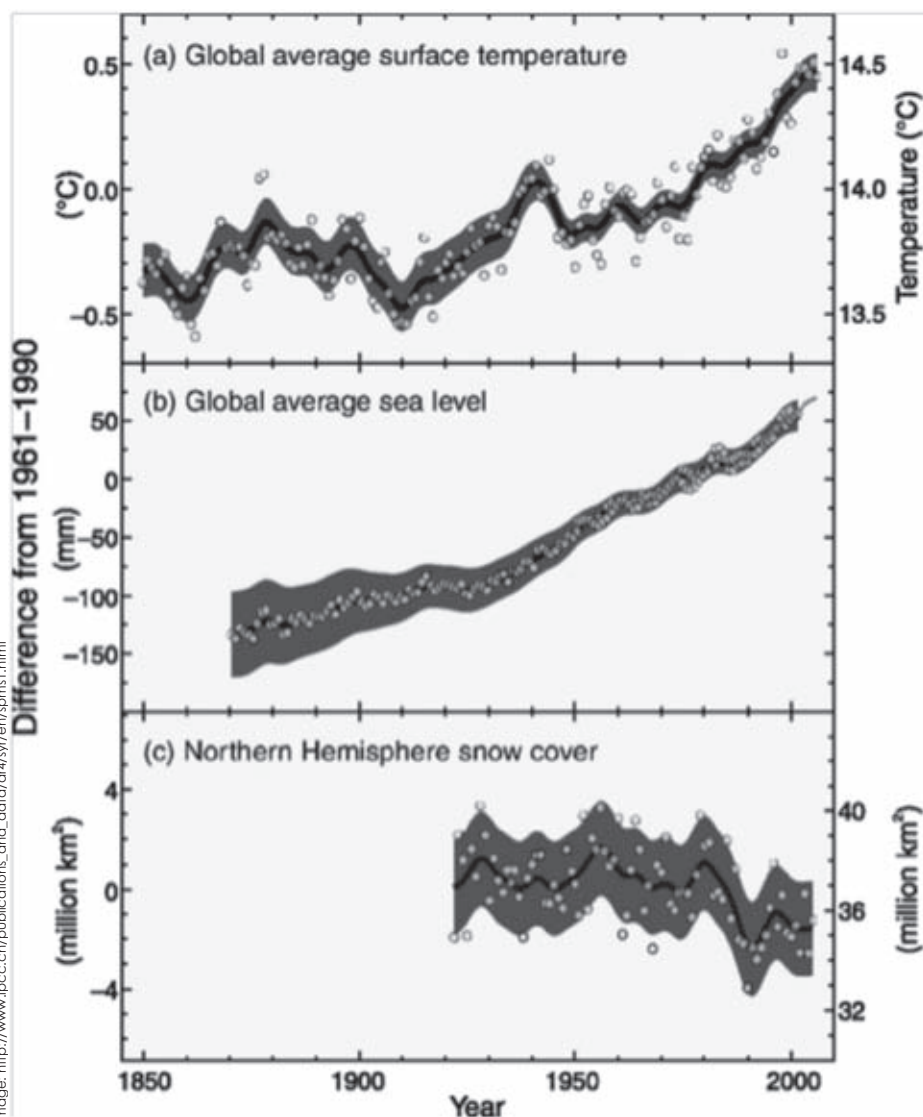
The Earth's atmosphere reaches approximately 10,000 km above the Earth's surface and comprises many layers. The atmospheric layers are distinguished by changes in air pressure, density, chemical composition and temperature. The five main layers (from the Earth) are: troposphere, stratosphere, mesosphere, thermosphere and exosphere. Most of Earth's air and moisture is found in the troposphere, the lowest and densest layer. Environmental chemists research the possible causes, effects and solutions to changes in the atmosphere, such as: acid rain, global climate change, photochemical smog and ozone depletion.

## GLOBAL CLIMATE CHANGE

The Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report (2007) declared: 'Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.' ([http://www.ipcc.ch/publications\\_and\\_data/ar4/syr/en/spms1.html](http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms1.html)) This statement is accompanied by supporting data (see diagram right).

Recent extreme catastrophic climatic events around the world, including a rash of them in Australia during late 2010 and early 2011 have weakened (but not eliminated) the arguments of climate change skeptics.

What is not in question is a sharp increase in the concentration of carbon dioxide ( $\text{CO}_2$ ) in our atmosphere over time, since the beginning of the industrial revolution compared with a relatively constant level over the previous 800 years (see figure page 33).



Changes over time of global average surface temperature, sea level and northern hemisphere snow cover.

### Did You Know?

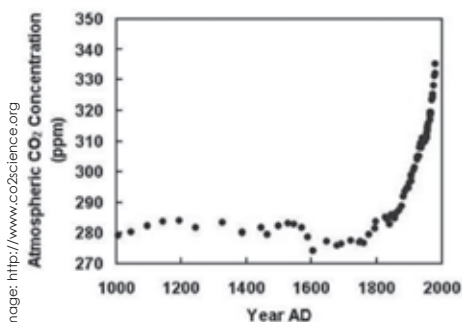
The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts.

The IPCC is a scientific body that reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters. The IPCC is an intergovernmental body and is open to all member countries of the United Nations (UN) and WMO. Currently 194 countries are members of the IPCC.

There is debate about how much of this relatively recent increase in  $\text{CO}_2$  concentration is anthropogenic (that is, originating from human activities), and what the effect of this component is.

### THE GREENHOUSE EFFECT

Carbon dioxide, present at a moderate concentration, as well as methane ( $\text{CH}_4$ ) and nitrous oxide ( $\text{N}_2\text{O}$ ), both present in smaller but increasing concentration, are said



Change of carbon dioxide concentration (parts per million by volume) over the past 1000 years.

to be greenhouse gases. This is because their effect (but not the mode of operation) corresponds with the retention of energy by greenhouses. If energy radiated from the Earth's surface is captured by the greenhouse gases, rather than allowed to pass through the atmosphere, the atmosphere is warmer than it would otherwise be.

### Did You Know?

Water vapour is also a greenhouse gas, but its concentration in the atmosphere is relatively constant and in any case, not controllable. The focus is on greenhouse gases whose concentration can be changed, thus changing the average temperature of the surface of Earth.

In fact, carbon dioxide has always been a significant component of the Earth's atmosphere. The planet would be inhospitable to humankind if it were not there, acting as a greenhouse gas. Over relatively short time spans, the temperature of the Earth's surface is reasonably constant as a result of a balance between energy in (from the Sun) and energy out (the difference between that which is radiated or reflected from the Earth's surface and that 'captured' by greenhouse gases).

## TEACHING AND LEARNING ACTIVITIES

### PRIMARY

#### Climate Change for Children

Activities on climate change can be found at <http://www.squidoo.com/global-warming-for-children>, which includes experiments, songs and information about how to explain the concept to children. The United States Environmental Protection Agency has activities about air quality and climate change at <http://www.epa.gov/kids/air.htm>.

## MIDDLE SCHOOL

### Air Experiments

There are many general air experiments produced by the American Chemistry Society at: [http://portal.acs.org:80/portal/acs/corg/content?nfpb=true&pageLabel=PP\\_SUPERARTICLE&node\\_id=1964&use\\_sec=false&sec\\_url\\_var=region1&uuid=db63866f-f6c9-4b23-9a97-98cdf1ed50a](http://portal.acs.org:80/portal/acs/corg/content?nfpb=true&pageLabel=PP_SUPERARTICLE&node_id=1964&use_sec=false&sec_url_var=region1&uuid=db63866f-f6c9-4b23-9a97-98cdf1ed50a) or explore the five main layers of the atmosphere at: <http://acswebcontent.acs.org/scienceforkids/index.html#Atmosphere>.

### Local Climate Change

Research how the temperature and/or air quality has changed over time in your area. The Bureau of Meteorology <http://www.bom.gov.au/> is a good starting point or see your state's Department of Environment or Environmental Protection Agency websites.

### Climate Change Resources

The US EPA has produced a list of actions that schools, educators and students can do to help reduce greenhouse gas emissions. See *Climate Change – What You Can Do* at <http://www.epa.gov/climatechange/wycd/school.html>. The Australian Government Department of Climate Change and Energy Efficiency can be found at <http://www.climatechange.gov.au/>.

## UPPER SECONDARY

### Climate Change Free eBook

CSIRO has produced a free eBook called *Climate Change: Science and Solutions for Australia* available for download at <http://www.csiro.au/resources/Climate-Change-Book.html>. It contains current scientific information on climate change in Australia.

### Visualising and Understanding the Science of Climate Change

Most of the chemical processes related to climate change can be understood by appropriate visualisation, as distinct from written words and chemical equations. The recent online publications of the King's Centre for Visualization in Science <http://www.kcvs.ca/site/>, based at The King's University College, Edmonton, Alberta, Canada contains many science-based visualisations. For climate change activities involving animations and simulations, see their website *Visualizing and Understanding the Science of Climate Change* at <http://www.explainingclimatechange.ca/>. Students can use this site and others to investigate the following questions or to pose their own questions for group discussion.

### Questions for stimulation, discussion and research

- What is meant by 'global average surface temperature'? How can it be measured?
- What are some of the arguments of the skeptics who do not accept the IPCC claim on global climate change?
- Given that climate and weather (phenomena that people experience) are regional or local, why do you think that the label 'global warming' has been changed to 'global climate change'?
- What might be some issues addressed for the IPCC Fifth Assessment Report on climate change, due to be published in 2014. See overview at <http://www.ipcc.ch/pdf/ar5/ar5-outline-compilation.pdf>.
- How can scientists estimate what the carbon dioxide concentration in the atmosphere was in, say, 1200 BCE?
- What are some possible sources of atmospheric carbon dioxide other than those due to human activity?
- With regard to acceptance, or otherwise, that global climate change is real and largely due to human activities, try to evaluate what is the attitude of (i) the Federal government; (ii) your State government; (iii) business organisations; (iv) various mining companies; (v) your parents, friends and relatives.
- What is the difference between the meanings of weather and climate? Keeping this difference in mind, if you experience an unusually cold winter is it correct to suggest that this is evidence against global warming?

## RELATED READING

Increases in the concentration of carbon dioxide in the lower atmosphere must necessarily give rise to higher concentrations in the surface regions of oceans (Henry's Law). This, in turn, causes the water to become more acidic (lower pH) with potentially disastrous implications for corals and shellfish. An informative, scientifically sophisticated report is:

Royal Society, *Ocean acidification due to increasing atmospheric carbon dioxide*, 30 June 2005, at <http://dgc.stanford.edu/labs/caldeiralab/Caldeira%20downloads/RoyalSocietyOceanAcidification.pdf>

# SOIL CHEMISTRY

Soil is a mixture of inorganic and organic solids, air and water. Soil chemistry involves the chemical reactions and processes between these components and particularly focuses on investigating the fate of contaminants and nutrients within soils. Knowledge of soil chemistry allows scientists to monitor, control and predict the effects of pollutants in the environment. Chemical knowledge combined with understandings from the Earth sciences, physics and biology are needed to understand, prevent and remediate environmental issues with soils. (Please note: Glossary included p38).

## DEFINING AND MEASURING SOIL PH

The pH of a solution is used to describe how acidic or alkaline a substance is. Pure water is neutral and has a pH of 7. Substances with a pH of less than 7 are considered acidic (e.g. vinegar) and those greater than 7 are alkaline (eg. ammonia). In solutions, pH is a measure of hydrogen ion activity and is defined as  $-\log_{10}\{H^+\}$ , where  $\{H^+\}$  is hydrogen ion activity. As pH

is measured on a logarithmic scale, the difference between each level is 10 times, so the difference between 3 levels would be  $10 \times 10 \times 10 = 1000$  times (e.g. a substance with pH 4 is 1000 times more acidic than a substance with pH 7).

In soils, pH is also a useful concept and is defined as  $-\log_{10}\{H^+\}$  in a solution which is in chemical equilibrium with soil particles. In practice, soil pH is measured by shaking a known mass of soil (to make a suspension) in a defined volume of water or dilute salt solution, and then the pH is measured using a calibrated pH electrode.

Image: [http://www.deim.qld.gov.au/land/ass/what\\_ore\\_ass.html](http://www.deim.qld.gov.au/land/ass/what_ore_ass.html)

14	Most alkaline
13	Caustic soda pH 13.8
12	
11	Ammonia pH 11.4
10	Milk of magnesia pH 10
9	
8	Calcium carbonate pH 8.5
7	Neutral
6	
5	
4	Beer pH 4
3	Vinegar pH 3
2	
1	Battery acid pH 1
0	Sulfuric acid pH 0 Most acid

Most Australian soils (pH 3-10)  
Australian agricultural soils (pH 4.5-9)  
Optimal plant growth (pH 5-7)

The pH scale.

## SOIL PH

Soil pH is a fundamental property that affects a surprisingly large range of chemical, physical and biological processes in soils. Through a complex and interlinked set of chemical reactions and other biophysical processes, soil pH itself depends on other soil properties, such as the amount and type of minerals present, the organic matter content, and

the dynamics of water and oxygen. Soil pH is important because of the effect that it has on the availability of essential elements, or nutrients, in soils (see table below). For example, many elements can be taken up by plants more easily if the soil pH is near-neutral to marginally acidic (about pH 6-7). Outside this pH range, plants may be deficient in some elements, or some elements may become toxic.

## SOIL PH BUFFERING

Some of the solid particles in soils are surprisingly chemically reactive. Depending on their composition, soils can resist or buffer changes in pH, because of different reactions between soil particles and acidic or alkaline water. Of the materials present in soils, two of the most important are the clay minerals and organic matter (humus), which also have the important property of existing as very small particles. These particles are often less than 0.001 mm or  $10^{-6}$  m. Soil particle size is usually measured in microns ( $\mu\text{m}$ ),  $1 \mu\text{m} = 10^{-6}$  m.

Clay minerals from the phyllosilicate group are very important in soils. Most naturally occurring clay minerals have a crystal structure with a charge imbalance; the anion charge is greater than the cation charge. The charge deficit is balanced by cations (e.g.  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{H}^+$ ) that do not form part of the clay structure, but instead are attracted weakly to the surface of clay particles by electrostatic forces. Soil organic matter generally consists of very large molecules, which have weakly acidic functional groups (mainly carboxylic acid,  $\text{R}-\text{COOH}$ ) as part of their chemical structure. Depending on the pH of the soil, these groups dissociate, leaving a negatively charged (anionic) particle (having many  $\text{R}-\text{COO}^-$  groups). This negative charge can also be balanced by any cation. The weakly associated cations are in rapid equilibrium, and can 'swap' for other cations in a process known as ion exchange.

## Atoms

Atoms are made up of protons, neutrons and electrons. The protons and neutrons are found in the centre of the atom, called the nucleus. The electrons move around the nucleus in orbitals. Each particle carries a different electrical charge: neutrons are neutral, protons have a positive charge and electrons have a negative charge.

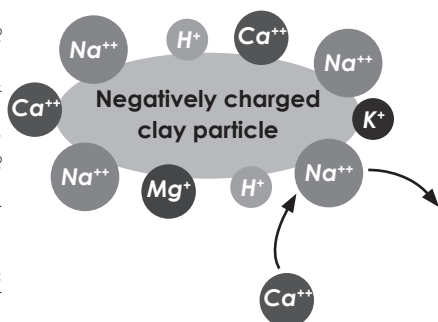
AGRICULTURAL CROPS		VEGETABLES		FRUIT	
barley	6.0-8.0	Bean	5.5-7.5	apple	6.0-7.0
canola	6.0-7.5	Carrot	6.5-7.5	banana	6.5-7.0
cotton	5.0-6.0	Garlic	5.5-8.0	citrus	6.0-7.5
lucerne	6.0-8.0	Potato	4.5-6.0	melon	7.0-8.0
lupins	5.0-6.5	Spinach	7.0-8.0	pineapple	5.0-6.0
rice	5.0-6.5	Tomato	6.0-7.0	watermelon	5.0-5.5
sugar cane	5.5-8.0				
wheat	5.0-7.5	<b>TREES &amp; ORNAMENTALS</b>			
<p>In acidic soils, many agricultural crops require lime (<math>\text{CaCO}_3</math>) to be applied to neutralize the acidity.</p>		acacia, rose	6.9-7.0	<p>In many agricultural regions of Australia, farming practices have acidified the soils.</p>	
		bottle brush	6.0-7.5		
		pinus	5.0-6.5		
		wattles	5.5-7.0		
		Geraldton wax	5.5-6.5		
		Eucalypts	5.1-5.6		

Recommended pH ranges for various plant species.



## Ions

When an atom loses or gains electrons, it is called an ion. A **cation** (*cat-eye-on*) is an atom (or group of atoms) that has lost electrons and therefore has a net positive charge (e.g.  $H^+$ ,  $NH_4^+$ ). An **anion** (*an-eye-on*) is an atom (or group of atoms) that has gained electrons and therefore has a net negative charge (e.g.  $O^{2-}$ ,  $OH^-$ ).



An example of Ion Exchange.

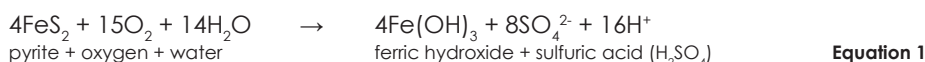
## DISCOVERING ION EXCHANGE – MEASURING SOIL PH IN DIFFERENT SOLUTIONS

Soil pH can be measured in several different solutions, each one giving a slightly different result. Two of the most common solutions are deionised water (which is readily available) and 0.01 mol/L  $CaCl_2$  solution (used because it is thought to, very approximately, mimic the composition of the pore water in soils). The existence of ion exchange on clays and other small soil particles means that the ionic composition of a solution used for pH measurement will affect the result. In most cases, the higher the ionic strength of the measurement solution, the lower the measured pH (soils are variable and complex, so a pH decrease is not always observed). A higher concentration of some ions (e.g.  $Ca^{2+}$ ) perturbs the ion exchange equilibrium so that hydrogen ions are released into the aqueous phase of the suspension.

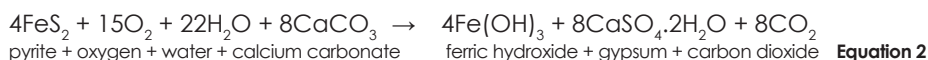
## ACID SULFATE SOILS

Acid sulfate soils are a significant environmental issue and more than one scholarly article has described acid sulfate soils as 'the nastiest soils in the world'! Acid sulfate soils (ASS) form following human disturbance of soils or sediments, which contain sulfide minerals, commonly the iron disulfide mineral (pyrite or  $FeS_2$ ). Pyrite and other sulfide minerals such as

mackinawite ( $FeS$ ) and greigite ( $Fe_3S_4$ ) are chemically stable under reducing conditions, such as where there is very little oxygen. In this state these soils are known as potential acid sulfate soils (PASS). In the presence of oxygen, however, sulfide minerals oxidise to produce sulfuric acid (Equation 1), forming actual acid sulfate soils (AASS).



If no alkaline mineral (e.g. calcite,  $CaCO_3$ ) is present to neutralise the acid formed (Equation 2), the soil becomes permanently acidic. This acidification starts off a cascade of other effects; other soil minerals may dissolve, releasing toxic ions such as  $Al^{3+}$  and some trace elements into waterways.



### Case Study: Acid Sulfate Soil at East Trinity

An example of a significant acid sulfate soil location exists near Cairns in North Queensland, Australia. The East Trinity site is a former estuarine wetland, which was drained for sugar cane production in the mid-1970s. The estuarine mud contained abundant sulfide minerals, and their oxidation resulted in extensive actual acid sulfate soils and the export of acid, heavy metals and arsenic to the estuary. On most of the drained land, cane farming was abandoned. More than 30 years later, some of the East Trinity site is still severely acidic, with significant contamination problems. One of the treatment strategies for East Trinity has been to re-flood some of the area with seawater. Re-flooding helps to re-establish anoxic conditions, and has been combined with the addition of lime ( $Ca(OH)_2$ ) to neutralise any excess acid formed.

For further information on this case study see:

Hicks, W. S., Bowman, G. M. & Fitzpatrick, R. W. 1999. East Trinity Acid Sulfate Soils: Part 1: Environmental Hazards. CSIRO Land and Water Technical Report 14/99.

Keene, A. F., Johnston, S. G., Bush, R. T., Burton, E. D., and Sullivan, L. A., 2010. Reactive trace element enrichment in a highly modified, tidally inundated acid sulfate soil wetland: East Trinity, Australia. *Marine Pollution Bulletin* 60, 620-626.

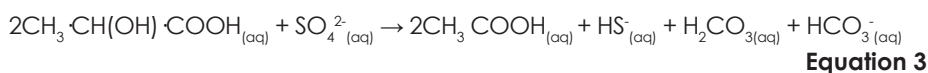
Powell, B. and Martens, M., 2005. A review of acid sulfate soil impacts, actions and policies that impact on water quality in Great Barrier Reef catchments, including a case study on remediation at East Trinity. *Marine Pollution Bulletin* 51, 149-164.

## HOW PYRITE FORMS AND STAYS IN SOILS

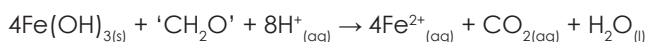
Many environments at the Earth's surface contain oxygen, either as a gas or dissolved in water. The main process controlling oxygen concentrations in soils and sediments is microbial *respiration*, where microorganisms such as bacteria, fungi and archaea, consume oxygen as they convert a wide range of organic compounds to carbon dioxide to produce energy.

Soils and sediments are porous media, meaning they have spaces between the mineral grains, which can be filled with a fluid: usually either water and/or air. If the soil is not *saturated* with water, some of the pores will contain air, allowing gases to diffuse freely and allowing atmospheric oxygen to replace oxygen used up by respiration. If the soil is saturated, all of the pores will contain water. The diffusion of gases is about 10,000 times slower in water than in air, so any oxygen used up by respiration will not be replaced. This creates anoxic conditions in the soil, allowing sulfide minerals such as pyrite to remain.

The same anoxic conditions allow sulfide minerals to form in the first place. Some specialised bacteria can use substances other than oxygen (such as ferric oxides, sulfate or nitrate) to metabolise carbon compounds. In coastal environments, marine or estuarine water contains high concentrations of sulfate ( $SO_4^{2-}$ ). In anoxic conditions sulfate reducing bacteria metabolise carbon compounds (Equation 3 shows lactic acid) using sulfate rather than oxygen.

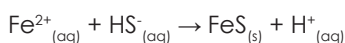


Reduction of sulfate produces sulfide ( $S^{2-}$  or  $HS^-$ , depending on pH). Other bacteria can metabolise carbon compounds (Equation 4 shows a 'carbohydrate average' formula ' $CH_2O$ ') using ferric oxides or hydroxides.



Equation 4

Reduction of ferric minerals produces ferrous ions ( $\text{Fe}^{2+}$ ). In anoxic systems sulfide and ferrous ions react to form sulfide minerals, because of the low solubility of these minerals (equation 5).



Equation 5

(minerals like mackinawite,  $\text{FeS}$ , commonly form first, then transform to pyrite,  $\text{FeS}_2$ )

## TEACHING AND LEARNING ACTIVITIES

### LOWER PRIMARY - PRIMARY

#### Make a Terrarium

Make a simple terrarium out of a plastic drink bottle (3 L plastic juice bottles work well). Carefully cut the top off the bottle, add some small rocks (for drainage) and place soil on top. Plant a seedling or small plant in the soil and add water so that the soil is damp. Tape the top of the bottle back on and close the lid. Terrariums are a great way to discuss ecosystems and the importance of the balance in nature.

#### Safety

Wear gloves and a face-mask when handling soil. Have an adult cut the top off the bottle.

#### Wild Watering

Investigate the importance of clean water by 'watering' some seedlings or plants with different liquids. Ask students to help design the experiment by thinking of different liquids to water the plants with, for example: water (control), milk, cordial, cola, lemonade, vinegar, soapy water, etc. Make sure that all other variables (e.g. light, amount of liquid, plant type, soil type, etc.) remain the same. Research and discuss the possible impacts of chemical runoff on soil and the environment.

**Extension:** Make some red cabbage pH indicator by boiling red cabbage with water, letting it cool and then decanting off the liquid. Test the various liquids with the red cabbage indicator to help work out which are acids or bases.

#### Safety

Remind students not to eat or drink anything when working with soil. Use gloves and face mask when handling soil. Take care when boiling cabbage.



Sediment containing "monosulfidic black ooze" or MBO; the black material is likely to be rich in mackinawite and/or amorphous  $\text{FeS}$ .

#### Long Term Soil Experiments

The Environmental Science Institute: GK-12 Program has created a document called *Using Long-term Soil Experiments to Engage Students in Scientific Learning*. It has many great ideas, photos and work samples and is available at <http://www.esi.utexas.edu/gk12/documents/Gordongsa2004.pdf>.

#### Teaching Resources and Activities by Dr. Dirt

Dr Clay Robinson provides many soil-based activities at <http://www.wtamu.edu/~crobinson/DrDirt.htm>

### MIDDLE SCHOOL - UPPER SECONDARY

The chemical properties of soils and sediments offer many opportunities for exploring chemical principles and reactions in the context of earth surface environments. A thorough understanding of concepts such as soil pH and acid sulfate soils, requires comprehension of mineral and organic structures, acid-base reactions, solubility and redox reactions, and their interaction with biological (mainly microbial) processes.

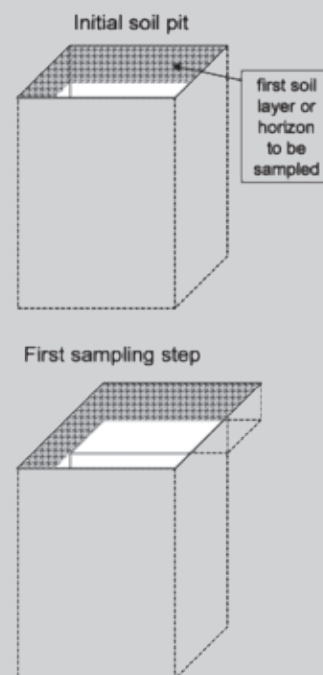
#### pH of Different Soils

Collect soil samples from a range of environments based on where they are found and obvious visual

### Collecting Soil Samples

Soil can be sampled in several different ways, and the most convenient is probably with simple tools such as a spade and trowel. It's a good idea to dig a pit first to observe the *soil profile* in its natural state. Try to dig a pit that has flat, vertical sides and is rectangular in plan view (try approximately  $40 \times 40$  cm). The soil profile is exposed on the vertical faces of the pit. Sampling can be done in depth increments (e.g. every 10 cm) or by sampling each soil horizon. A horizon is a distinguishable soil layer (layers may have different colours or textures), which is formed by a combination of chemical, physical and biological processes; soil scientists call soil formation 'pedogenesis'.

Cut a 'step' at the top of the pit as shown below. From the soil removed, collect a sample of about 1 kg of soil and mix well. Smaller portions of the 1 kg sample can be used for activities like pH measurement.



or tactile differences. Make sure all samples are accurately labelled. Weigh approximately 10 g (dry) of each soil into a plastic container with a firm-fitting lid, add 50 mL deionised water, and shake for about 1 minute. (If drying soils is problematic, or if measurements are being made in the field, add 1 volume of soil to 5 volumes of deionised water.) Leave for about 1 minute (until coarse solids have settled) and then measure

the pH of the suspension above the settled solids with a calibrated pH electrode. Try to explain any differences in pH of the soils (e.g. soils formed over limestone will probably have a high pH, around 8-9; some organic soils can have low pH, around 5).

### Safety

Ensure that gloves and facemasks are used when working with soil. Take care when handling a pH electrode. Complete a risk assessment.

## pH Buffering of Different Soils

Collect soil samples from a range of environments based on where they are found and obvious visual or tactile differences. Make sure all samples are accurately labelled. For each soil, weigh approximately 3 × 10 g samples into 3 plastic containers with firm-fitting lids, and add 50 mL of 0.01 mol/L CaCl<sub>2</sub> solution. To one of the containers for each soil add 2 mL 0.1 mol/L HCl, and to the other add 2 mL 0.1 mol/L NaOH (add nothing to the other container). Shake every 5 minutes for 30 minutes, allow to settle and then measure the pH of the suspension above the settled solids with a calibrated pH electrode. Well-buffered soils (e.g. having lots of clay, limestone or organic matter) will change pH less than poorly-buffered (e.g. sandy) soils.

### Safety

Ensure that gloves and facemasks are used when working with soil. Take care when handling chemicals and pH electrodes. Complete a risk assessment.

## Soil pH in Different Solutions

Repeat pH of different soils activity, but instead of adding 50 mL water, add 50 mL of 0.01 mol/L CaCl<sub>2</sub> solution. The measured pH will commonly be about 0.5-1 pH units lower in 0.01 mol/L CaCl<sub>2</sub> solution than in water. The simplest explanation for this is that the higher concentration of Ca<sup>2+</sup> in the 0.01 mol/L CaCl<sub>2</sub> solution causes displacement of some of the H<sup>+</sup> that is balancing electrostatic charges around clay and organic matter particles in soil. The displaced H<sup>+</sup> enters the solution in which the soil is suspended, where it can be measured with a pH electrode.

### Safety

Ensure that gloves and facemasks are used when working with soil. Take care when handling chemicals and pH electrodes. Complete a risk assessment.

## Finding Potential Acid Sulfate Soils

This could be a convenient exercise if you are near an estuary. Excavating sand on many estuarine beaches often exposes wet, dark-coloured material at depth, which is caused by the presence of sulfide minerals. The visual signs of sulfide minerals are sometimes accompanied by an unpleasant 'rotten egg' odour of hydrogen sulfide (H<sub>2</sub>S). The H<sub>2</sub>S is present if sulfide ions are present in the pore water, according to the acid-base equilibrium:  
$$\text{H}_2\text{S} = \text{HS}^- + \text{H}^+ = \text{S}_2^{2-} + 2\text{H}^+$$

Excavation of soil on low-lying land surface near estuaries or freshwater wetlands can sometimes expose sulfidic material as well.

### Safety

Complete a risk assessment.

## UPPER SECONDARY

### Measuring Potential Acid-Forming Ability of Soil

The acid-forming ability of potential acid sulfate soils can be measured by comparing the pH before and after oxidation. Oxidation is achieved using hydrogen peroxide solution (30% H<sub>2</sub>O<sub>2</sub>).

### Safety

Wear safety glasses, gloves and protective clothing for this activity. Peroxide solution is corrosive and may produce significant heat and frothing when added to sulfidic soil! Complete a risk assessment.

1. Place approx. 1 cm depth of soil sample in a heat-stable container (plastic centrifuge tubes are ok).
2. Just cover the soil with 30% hydrogen peroxide solution (pH pre-adjusted to 5 with NaOH).
3. Stir with a plastic spoon and leave for 10 minutes. It can be a slow reaction; warm slightly if there is no reaction.

4. Add a few more drops of peroxide once the reaction has stopped to ensure that all the pyrite has been used up and allow to cool.
5. Use a calibrated meter to measure the peroxide pH (pH<sub>FOX</sub>).
6. Measure the pH separately in water (substitute deionised water for 30% H<sub>2</sub>O<sub>2</sub>); this is field pH (pH<sub>F</sub>).

A difference between pH values ( $\Delta\text{pH} = \text{pH}_F - \text{pH}_{\text{FOX}} > 0$ ) indicates that sulfides are present. The higher the value of  $\Delta\text{pH}$ , the more acid has been produced. A soil that has a vigorous reaction with peroxide but little or no drop in pH may have a high carbonate content. You can test this by using a dropper to add a few drops of 1 mol/L HCl to a separate soil sample; carbonate-containing soils will fizz visibly. A 'false positive' reaction with peroxide can also be observed if the soil has a high manganese oxide content, but this is less common.

[Download the activity sheets 'Finding soil type' and 'Testing for potential acid sulfate soils (PASS)' from [www.qm.qld.gov.au/microsites/mangrove/pdf/scienceskills/QM\\_testing\\_for\\_PASS.pdf](http://www.qm.qld.gov.au/microsites/mangrove/pdf/scienceskills/QM_testing_for_PASS.pdf) and [www.qm.qld.gov.au/microsites/mangrove/pdf/scienceskills/QM\\_finding\\_soil\\_type.pdf](http://www.qm.qld.gov.au/microsites/mangrove/pdf/scienceskills/QM_finding_soil_type.pdf).]

## USEFUL WEBSITES

Australian Government – Department of Sustainability, Environment, Water, Population and Communities – Acid Sulfate Soils  
<http://www.environment.gov.au/water/topics/acid-sulfate-soils.html>

Queensland Museum Mangrove Challenge – links to 'Finding soil type' and 'Testing for potential acid sulfate soils (PASS)'  
<http://www.qm.qld.gov.au/microsites/mangrove/resources.asp>

Queensland Government – Department of Environment and Resource Management Acid Sulfate Soils' <http://www.derm.qld.gov.au/land/ass/>



Testing soil.



New South Wales Government –  
Department of Environment, Climate  
Change and Water *Acid Sulfate Soils*  
[http://www.environment.nsw.gov.au/  
acidulfatesoil/index.htm](http://www.environment.nsw.gov.au/acidulfatesoil/index.htm)

Acid sulfate soils fact sheets  
(Government of Western Australia  
– Department of Environment and  
Conservation) [http://www.dec.  
wa.gov.au/content/view/3581/2124/](http://www.dec.wa.gov.au/content/view/3581/2124/)

### Textbooks

White, R. E., 2006. *Principles and  
Practice of Soil Science: The Soil as a  
Natural Resource*. Blackwell Science  
Ltd., Malden, MA, USA.

## Glossary

**amorphous:** having an irregular, poorly-ordered crystal structure.

**anion:** an atom (or group of atoms) that has gained electrons; negatively charged ion.

**anoxic:** containing no or negligible oxygen.

**aqueous phase:** the water and dissolved substances (in mixtures of solids and water).

**cation:** an atom (or group of atoms) that has lost electrons; positively charged ion.

**diffusion:** movement of ions or molecules through a gas or liquid to areas of lower concentration, without the fluid moving itself.

**disulfide:** a compound containing the disulfide anion  $S_2^{2-}$ .

**essential elements:** elements required for the growth and survival of living organisms (also called nutrients).

**estuarine:** relating to an estuary, which is an area at the mouth of a river where nutrient-rich fresh water meets with salty ocean water.

**greigite:** an iron sulfide mineral having the formula  $Fe_3S_4$ .

**horizon:** a layer in soil formed by pedogenesis rather than non-soil processes like sediment deposition.

**humus:** the well decomposed, more or less stable part of the organic matter in soils.

**ion exchange:** the interchange between an ion in solution, and other ion(s) of the same charge attracted to a negatively charged particle, such as clay or organic matter. In soils this mainly involves cations.

**limestone:** sedimentary rock composed of carbonate minerals, especially calcium carbonate.

**mackinawite:** an iron sulfide mineral having the formula  $FeS$ .

**metabolise:** convert carbon compounds to simpler ones (often  $CO_2$ ) to generate energy (referring to living organisms).

**nutrients:** elements required for the growth and survival of living organisms (also called *essential* elements).

**organic matter:** organic material in soils and sediments derived from the dead tissues of living organisms.

**pedogenesis:** soil formation by within-soil processes; controlled by climate, biota; topography, parent material and time.

**phyllosilicate:** minerals having layer structures composed of linked octahedral aluminate and tetrahedral silicate sheets.

**pyrite:** the iron disulfide mineral  $FeS_2$ .

**reducing:** characterised (in soils) by lack of oxygen, and a tendency for elements to exist in their lower oxidation states.

**respiration:** a metabolic process whereby electrons are transferred from a reduced carbon compound to an electron acceptor such as oxygen or sulfate.

**soil profile:** a vertical section of the soil through all its horizons.

**sulfide:** compound containing the simple sulfide anion  $S^{2-}$ .

**suspension:** a fluid mixture containing solid particles that are sufficiently large and dense to settle out.

**trace elements:** elements occurring in natural materials at low concentrations (commonly  $<0$ )

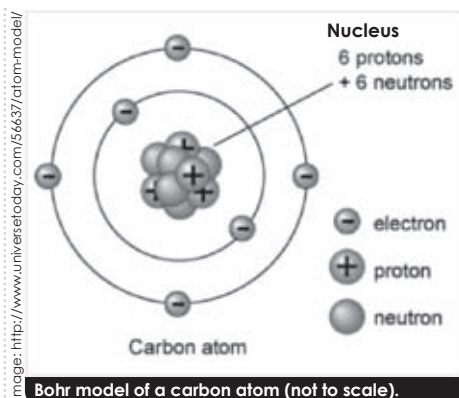
# CHAPTER 4 - LIGHT CHEMISTRY

The chemistry of light is important for many applications of science, such as: medical, industrial and environmental. Light is a form of electromagnetic radiation (EMR). Electromagnetic radiation consists of electric and magnetic fields, oscillating at right angles to each other and is how energy travels through space. Electromagnetic radiation comes in many forms: low energy EMR, such as radio waves, through to high energy EMR, such as gamma rays. Visible radiation (light) is one small section of the electromagnetic spectrum, which describes the different types of electromagnetic radiation in order of frequency.

## THE ATOM

Atoms are the smallest unit of an element. An atom consists of an extremely small positively charged nucleus surrounded by a cloud of negatively charged electrons. The simplest model of an atom is the Bohr model proposed by Niels Bohr in 1913 (See diagram above). In this model, electrons within the atom orbit the nucleus in particular circular orbits whose distance from the nucleus is proportional to its energy.

Although the nucleus is less than one ten-thousandth of the size of an atom, it contains more than 99.9% of the mass of an atom. The nucleus consists of positively charged protons and uncharged (neutral) neutrons. The atomic number of an element is derived from the number of protons it possesses (for example, carbon has an atomic number of 6, as it has 6 protons). The atomic mass of an element is equal to the sum of the protons, neutrons and electrons,



however the term 'mass number' is used to describe the mass of the nucleus, and is equal to the sum of the protons and neutrons. Carbon-12, for example, has a mass number of 12 (6 protons and 6 neutrons), whereas carbon-13 has a mass number of 13 (6 protons and 7 neutrons).

## ISOTOPES

Atoms of the same element can have different numbers of neutrons. The various forms are called 'isotopes' of that element. As an example, hydrogen has three isotopes: hydrogen-1 (hydrogen – one proton, no neutrons), hydrogen-2 (deuterium – one proton, one neutron) and hydrogen-3 (tritium – one proton, two neutrons).

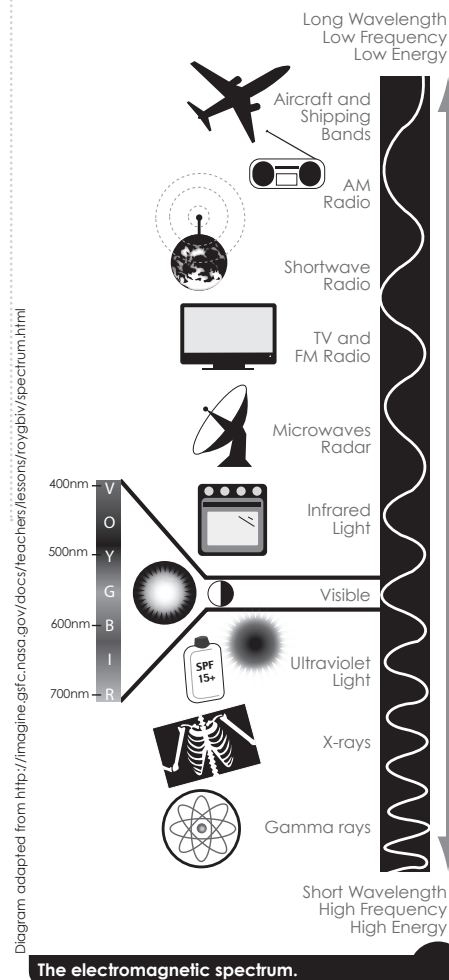
## RADIATION

Radiation describes a process in which energetic particles or waves travel through a medium or space. The energy radiates from its source. There are two types of radiation: ionising and non-ionising.

Ionising radiation consists of particles or electromagnetic waves that have enough energy to remove electrons from other atoms or molecules. The amount of energy depends on the properties of the individual particles, not their number. For example, instant exposure to a large number of particles will not cause ionisation if each particle does not carry enough energy to be ionised, however ionisation can occur from a small number of particles or waves if they have high enough energy. Non-ionising radiation is lower in energy but can still excite molecules and atoms.

## THE ELECTROMAGNETIC SPECTRUM

The electromagnetic spectrum is the range of all possible frequencies of electromagnetic radiation. It extends from low frequency waves, such as those used for the modern radio, to high frequency gamma waves. Energy is directly related to frequency. Gamma rays and x-rays are of sufficiently high energy to be ionising, whereas visible and lower-frequency waves are non-ionising. The human eye sees the frequencies of the visible waves. Ultra Violet (UV) waves are described as non-ionising, however overexposure to energetic UVB waves can cause sunburn and is believed to induce DNA damage. UVC waves, which are even more energetic, are the most dangerous type of UV light, but the atmosphere mostly filters out those generated by the Sun.



The electromagnetic spectrum.

# NUCLEAR CHEMISTRY

**Nuclear science is the study of the atomic world. Learning what atoms do and what happens when they combine is of critical importance. The areas of molecular engineering and rational drug design, for example, benefit from the use of nuclear science. There are also key medical applications including the treatment of diseases with radiotherapy, which is reliant on nuclear science.**

## RADIOACTIVE DECAY

Radioactive decay is the spontaneous disintegration of an atomic nucleus resulting in the release of energy in the form of particles (alpha and beta radiation), gamma radiation or neutrons. It is the process through which unstable atoms can become more stable.

**Alpha decay ( $\alpha$ )** – a positively charged particle is emitted from the nucleus of an atom. An alpha particle consists of two protons and two neutrons (a helium-4 nucleus). Although these particles are normally highly energetic, they travel only a few centimetres in the air and are stopped by a sheet of paper or the outer layer of dead skin.

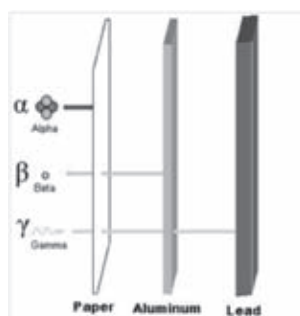
**Beta decay ( $\beta$ )** – a beta particle is an electron with either negative or positive electric charge. These particles may travel metres in air and several millimetres into the human skin. Most can be stopped by a small thickness of light material, such as aluminium or plastic.

**Gamma decay ( $\gamma$ )** – a gamma particle is a high-energy photon that is emitted from the nucleus of an atom when it has too much energy. Gamma particles travel in a wave-like pattern at the speed of light. They can only be stopped by a dense material, such as lead, steel, concrete or several metres of water.

## NUCLEAR REACTIONS – FISSION VS FUSION

There are two possible nuclear reactions – when atoms split apart or when atoms join together.

Image: <http://www.citizenela.org/Radiation>



Penetration levels of different types of radiation.

**Nuclear fission** is when an atom's nucleus is split during a reaction. When this happens, a tremendous amount of energy is released in the form of both heat and light. In nuclear reactors used for generating power or for research, uranium atoms are split apart in a controlled chain reaction. In a chain reaction, neutrons released by the splitting of an atom, go off and strike other uranium atoms, releasing even more neutrons available to react with more atoms. In reactors, the reaction is controlled using control rods.

**Nuclear fusion** is when smaller nuclei join together to make a larger nucleus. The Sun is powered by the nuclear fusion of hydrogen atoms into helium atoms. This gives off heat, light and other radiation, and does not have similar issues (to fission) with radioactive waste. It is the holy grail of energy production, which has scientists working hard to design a prototype fusion reactor.

## RADIATION IS ALL AROUND

The human body is continually exposed to radiation that can cause damage. Sources of radiation include: cosmic radiation, the Earth, the materials in our home, the food we eat, aeroplane travel and, the most significant, medical procedures. The effect of radiation on human tissue is measured in Sieverts (Sv) and is called the Equivalent Dose. Exposure occurs over time and so it is of interest to measure exposure as an amount over a specific time period. This is called the dosage rate. In Australia the dosage rate from background radiation is about 2 millisieverts per year.

## APPLICATIONS OF NUCLEAR SCIENCE

### Research Reactor

The Open Pool Australian Lightwater (OPAL) Reactor, located at the Australian Nuclear Science and Technology Organisation (ANSTO) in Australia, is a multi-purpose research

reactor. OPAL's benefits encompass radioisotope production, irradiation services and neutron beam research. All three play key roles in a wide range of applications, from next generation medicine and nutrition, to designing tomorrow's safer, smarter materials. Visit [http://www.ansto.gov.au/discovering\\_ansto/anstos\\_research\\_reactor](http://www.ansto.gov.au/discovering_ansto/anstos_research_reactor) for further information.

### Nuclear Medicine

Nuclear applications are important in the diagnosis and treatment of some medical conditions. For example, an injection of a small amount of a low-level radioactivity tracer into the body, sends signals that are picked up by a special gamma camera, which turns them into an image showing organ activity. Doctors can then determine if an organ is malfunctioning or if cancer is growing and then allocate the appropriate treatment. ANSTO provides 80% of the nuclear medicines to Australian hospitals to help doctors diagnose and treat disease.

### Case Study: Tracing the spread of melanoma

Melanoma is a deadly form of skin cancer, with about 160,000 new cases diagnosed around the world each year. Melanoma is difficult to treat with surgery or medication, and most people diagnosed with it will not survive longer than six months. Australian-based research to try and improve both diagnosis, and ultimately treatment options for melanoma has been underway as part of the work program of the CRC for Biomedical Imaging Development (CRCBID). Taking a molecule initially developed at the laboratories at the ANSTO in Sydney, researchers from ANSTO and the Peter MacCallum Cancer Centre have been working with commercial partners, Cyclotek (Aust) Pty Ltd to successfully develop a novel radiopharmaceutical or tracer, known as MEL050, that has the potential to be developed for assessing the spread of melanoma in patients by targeting melanin in the tumours. A phase 1 clinical trial is currently being conducted and the results appear to be positive. Further research will be required, including additional clinical trials. Website: [www.crcbid.com.au](http://www.crcbid.com.au)

### Environmental Research including Carbon Dating

Many different forms of environmental research are conducted at ANSTO including



research into climate change, carbon dating of various objects, air pollution analysis and isotopic analysis of natural water systems, to help to understand water movements and what must be done to ensure future water supply.

To undertake this work, ANSTO has some of the most sensitive instruments for this kind of research in the world. Two of these instruments are powerful particle accelerators used in climate change analysis, carbon dating, tracking of air pollutants and conducting radiation research.

### Did You Know?

Carbon-14 is a radioactive isotope of carbon with a nucleus containing 6 protons and 8 neutrons. Over time, carbon-14 decays to the nitrogen-14 element, through radioactive beta decay (i.e. elimination of an electron). Carbon-14 has a half-life of 5,730 years. This means that a 10 g sample of carbon-14 will become a 5 g sample in 5,730 years. Since plants fix atmospheric carbon during photosynthesis, the level of carbon-14 in plants and animals when they die is approximately equal to the level of carbon-14 in the atmosphere at that time. The level of carbon-14 decreases thereafter, from radioactive decay, allowing the date of death to be estimated (carbon dating).

Radiocarbon dating is used extensively in archaeology to date ancient artefacts and what they are found with. For example, seeds and papyrus remains found in King Tutankhamun's tomb in Egypt were dated to 4,500 years ago thus confirming the age of his tomb.

### Silicon Doping

ANSTO is a leading provider of irradiated silicon for use in advanced electronic devices, integrated circuits and other industrial applications. The doping process involves treating large silicon crystals with neutrons from OPAL, in a process that transforms a small number of silicon atoms inside the crystals into phosphorus atoms. This transforms the silicon into a semiconductor.

## TEACHING AND LEARNING ACTIVITIES

### PRIMARY

#### Glow Stick Chemistry

Show students a variety of glow stick products (readily obtainable from discount stores). Ask students

to hypothesise what is going to happen when they are activated. Most students will have some prior knowledge about glow sticks – what colours they become, how long the light lasts, etc. In a darkened room, activate the light sticks according to the instructions. Ask students to predict the effect of temperature on the glow sticks. Observe the effect of temperature on the chemical reaction by placing one stick in a glass of room temperature water (control), one stick in hot water and one in cold water. Discuss the importance of keeping all of the other variables constant, for example: the colour of the glow stick, the amount of water, the size of the glass, etc). When the light stick is activated, the inner compartment breaks allowing the chemicals to react and produce light. The chemical reaction occurs faster with heat; therefore the glow stick in hot water should be brighter than the one in cold water.

#### Safety

Do not break or crack the glow sticks open. Follow the safety instructions on the pack. Take care with hot water.

### Visible Spectrum

Explore the visible spectrum by separating white light into the component colours: red, orange, yellow, green, blue, indigo and violet. To make a rainbow, shine a beam of light through a prism or simply take a crystal or CD into the sun and manoeuvre around until it produces a rainbow. There are many different methods of making a rainbow at <http://www.wikihow.com/Make-a-Rainbow>

#### Safety

Do not let students look directly at the Sun.

## MIDDLE SCHOOL

### Radiation is all around

Download the 'Personal Radiation Dose' worksheet from ANSTO *Radiation: from the inside out – Science lesson plan for K-6 Teachers* at [http://www.ansto.gov.au/data/assets/pdf\\_file/0009/37377/K-6.pdf](http://www.ansto.gov.au/data/assets/pdf_file/0009/37377/K-6.pdf). Students can describe the most common sources of radiation, calculate and record their total annual radiation dose and discuss the effects of a large radiation dosage.

### Light Fantastic

The Light Fantastic unit at <http://www.science.org.au/primaryconnections/curriculum-resources/light-fantastic.html>

<http://www.primaryconnections.org.au/light> from Primary Connections, provides opportunities for students to explore where light comes from, how it is used, how light travels and how it helps us to see. The University of California has produced an interactive light tour, great for examining different types of light and wavelengths, at [http://cse.ssl.berkeley.edu/light/light\\_tour.html](http://cse.ssl.berkeley.edu/light/light_tour.html)

### Protons, Neutrons and Electrons

The American Chemical Institute has produced <http://www.middle-school-chemistry.com/lessonplans/chapter4/lesson1> to explore the properties of protons, neutrons and electrons. To investigate the size of an atom, a paper cutting activity can be found at <http://www.miamisci.org/af/sln/phantom/papercutting.html>

## UPPER SECONDARY

### ANSTO Senior Chemistry Workbook

ANSTO has produced a senior chemistry workbook at [http://www.ansto.gov.au/data/assets/pdf\\_file/0005/16781/Yr12\\_ChemwkbBook\\_web.pdf](http://www.ansto.gov.au/data/assets/pdf_file/0005/16781/Yr12_ChemwkbBook_web.pdf) to go along with a tour of their facilities. Even without the site tour, it is still a useful resource and contains many good questions.

### Electromagnetic Spectrum

Ask students to explore the electromagnetic spectrum with an online Applet available at <http://lectureonline.cl.msu.edu/~mmp/applst/Spectrum/s.htm>

### Isotopes

WebElements have a fantastic interactive periodic table to explore the chemical elements in detail. The isotopes section describes the different isotopes of each element and can be found at <http://www.webelements.com/isotopes.html>

### Nuclear and Radiation Accidents

Ask students to research various nuclear and radiation accidents. Discuss the importance of weighing up the risks versus the benefits with science. Hold a debate regarding the pros and cons of nuclear science.

### Speed of Light

CSIRO Science by Email shows how to use a microwave and a bar of chocolate to work out the speed of light, see <http://www.csiro.au/helix/sciencemail/activities/hotchocolate2.html>

# SYNCHROTRON CHEMISTRY

**A synchrotron light source is a machine that accelerates charged particles, such as electrons, to extremely high speeds. When these very fast electrons are forced to change their direction of travel, they emit extremely intense light. Slower electrons will also emit light, but light that is useful for scientific experiments requires electrons travelling close to the speed of light.**

The Australian Synchrotron is a national facility, which is located in the south-eastern suburbs of Melbourne. Construction of the Australian Synchrotron started in 2003, and the facility opened in 2007. There are about twenty similar facilities around the world.

## HOW IS SYNCHROTRON LIGHT CREATED?

Electrons at the Australian Synchrotron travel at about 299,792 kilometres per second, which is 99.9999% of the speed of light. Powerful magnets squeeze the electron beam, so that it is on average 60 micrometres wide, and control the beam direction, so that it deviates less than 5 micrometres. By comparison, a human hair is about 80 micrometres wide. To stop the electron beam colliding with gas molecules, the electrons are in an ultra-high vacuum of around 0,000,000,000,1 millibar (roughly equivalent to the Moon's atmosphere).

### Did You Know?

The Australian Synchrotron currently has eight beamlines, supporting many different experiments, with the potential to have another twenty-eight beamlines. A ninth beamline for imaging and medical therapy began commissioning in 2009 and is expected to be fully on-line in 2012.

## WHY IS SYNCHROTRON LIGHT SO USEFUL?

Synchrotron light has features that make it very useful to scientists and enables them to perform experiments that would otherwise take too long or be impossible. These features include high brightness, polarisation and collimation,



A schematic diagram of the Australian Synchrotron

and a large spectral bandwidth. The light produced in synchrotrons is often thousands of times brighter than standard lab-based light sources. Unlike lab sources, the light is available at a wide range of wavelengths (from infra-red to hard x-rays), which scientists are able to screen to get the particular wavelength for their specific needs.

### Did You Know?

The Australian Synchrotron generates light that is around one million times brighter than the Sun.

## HOW IS SYNCHROTRON LIGHT USED?

Synchrotron x-rays can be used to determine the spacings between atoms inside a sample using diffraction techniques. This enables scientists to discover the spatial arrangement of atoms and to relate this structure to the properties of various materials or discover how disease organisms function, which could be used to develop new drugs.

By looking at the light that is absorbed, reflected, or emitted (fluoresced) by different materials in spectroscopy experiments, scientists can determine the chemical composition of those materials. By moving a sample through the beam of light, scientists can get information about the location (spatial) information as well as chemical information.

## HOW DOES INFRARED SPECTROSCOPY WORK?

Materials absorb different colours of visible light. Materials can also absorb different 'colours' of invisible light. The particular colours of infrared light that are absorbed are related to the type of bond and the masses of the atoms involved. Hence, infrared spectroscopy gives information about the chemical composition of materials by identifying the presence of functional groups, which are small groupings of particular atoms within the much larger number of atoms that make up the entire material. Many chemical reactions involve functional groups.

### Did You Know?

Synchrotrons can produce light ranging from x-rays to infrared light, including ultraviolet and visible light, but the Australian Synchrotron is specifically designed to produce x-rays and infrared light.

## EXAMPLES OF RECENT SCIENCE AT THE AUSTRALIAN SYNCHROTRON

### Case Study 1: Discovering Hidden Art

Towards the end of his career, Australian artist, Arthur Streeton, often painted over earlier canvases and reused them. A faint portrait was visible on one such canvas, which was covered by white lead paint, but no details could be distinguished. Collaboration between the National Gallery of Victoria (NGV), CSIRO and the Australian Synchrotron used x-ray fluorescence microscopy (XFM) to scan across the entire canvas, collecting chemical information. By identifying the distribution of the elements present on the canvas, the researchers were able to map the distribution of paint pigments and hence reconstruct a self-portrait of Arthur Streeton.

### How does this work?

When atoms absorb x-rays, the energies of electrons inside the atoms are increased. This excess energy is lost as the atoms emit or fluoresce, at wavelengths that are slightly longer than the original absorbed x-rays. The x-rays that are emitted have wavelengths that are characteristic of the elements present and their chemical environment. X-ray absorption spectroscopy (XAS) and x-ray fluorescence (XRF) are complementary techniques, each with its own advantages.



David Thurrowgood (NGV) and Deborah Lau (CSIRO) position a painted-over Streeton self-portrait for analysis on the XFM beamline at the Australian Synchrotron. Behind them, Daryl Howard (AS) checks the alignment of the x-ray microprobe.



### Did You Know?

Scientists used x-ray fluorescence microscopy to map the precise location of heavy metals in a single horse's hair, to confirm that racehorse Phar Lap did indeed die of arsenic poisoning.

### Case Study 2: Combating Disease

Viruses grow and multiply inside a host cell, eventually disrupting the normal function of the cell and causing disease. Viruses are difficult to study because they are hidden inside cells.

Scientists have used micro x-ray crystallography (MX) to study viral polyhedrin protein crystals that grow inside infected insect cells. The use of synchrotron light has enabled the x-ray beam to be focused to a spot size of 20-30 micrometres, which permitted the analysis of the microcrystals. Analysis of the diffraction pattern determined the types and 3-dimensional locations (i.e. the connectivity) of the atoms with the protein crystals. This should enable other scientists to design drugs that can specifically target the virus protein.

### How does this work?

Inside a crystal, atoms are arranged in a regular, repeating pattern. X-rays interact with the atoms in the crystal and are diffracted, or 'bounced off' at specific angles. These angles are related to the spacing of the atoms and the wavelength of the incoming x-ray beam. By analysing these angles and the intensity of the diffracted X-rays, scientists can determine the 3-dimensional arrangement of the atoms.

### Did You Know?

The Bragg equation, which relates diffraction angle, wavelength and the spacing of atoms, is named after father-and-son researchers William Henry Bragg and William Lawrence Bragg. The younger Bragg was born and educated in Adelaide but they did their diffraction research after the Bragg family returned to England. The Braggs were awarded the Nobel Prize in 1915, when Lawrence was 25 years old.

### Case Study 3: Thinking Small

Sunscreens, plastics and paints often contain zinc oxide nanoparticles, which protect skin and other surfaces from harmful ultraviolet rays. The advantage of nanoparticles is that we can't see them on our skin, unlike larger particles that appear white. In response to recent claims that nanoparticles of zinc oxide could

increase the risk of sunlight damaging the skin if they were absorbed into the skin, Australian researchers are using synchrotron techniques to explore the detailed toxicology and reactivity of zinc oxide.

Scientists in industry, CSIRO, Monash, RMIT and Deakin Universities and medical researchers are looking closely at how introducing very small quantities of cobalt or manganese atoms (either inside the nanoparticles or on the surface) might influence zinc oxide nanoparticle properties. A single nanoparticle is typically 20-30 nanometres across and might contain around 200 cobalt or manganese atoms, so high-precision analysis is essential. Modifying the manufacturing conditions can control the position and number of the cobalt or manganese atoms.

The researchers have used Synchrotron soft x-ray absorption, x-ray absorption spectroscopy and powder diffraction techniques to characterise the positions of the cobalt and manganese atoms even when these are present in very small numbers. Their next step will be to use the x-ray fluorescence microprobe to look at where the nanoparticles might end up inside the skin cells. Their research will help ensure that zinc oxide nanoparticles are safe for human use and don't adversely affect the environment, and that legislation governing the use of nanoparticles is based on accurate scientific data.

## TEACHING AND LEARNING ACTIVITIES

### SECONDARY

#### MicroWorlds

MicroWorlds is an interactive tour of current research in the materials sciences at Berkeley Lab's Advanced Light Source and can be found at <http://www.lbl.gov/MicroWorlds/tour.html>

#### Seeing Science

Produced by the Science and Technology Facilities Council (UK), Seeing Science explores bright light and parts of the electromagnetic spectrum at <http://www.seeing.science.cclrc.ac.uk/Light/home.aspx>. Key Stage 3 examines how synchrotron radiation is used to look at the structure of proteins and viruses.

### SENIOR SECONDARY

#### Measuring the thickness of various fibres using diffraction

**Aim:** To demonstrate how diffraction can be used to take measurements, such as the size of an object.

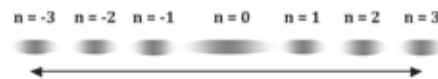
**Materials:** Laser pointer, ruler, retort stand and clamps, screen, cardboard frame, various fibres, micrometer.

### Safety

Complete a risk assessment. Do not look directly into a laser beam.

### Method:

1. Create a frame using cardboard, roughly 3cm x 3cm and cut a 1cm<sup>2</sup> hole in the middle.
2. Cut fibres from various objects such as paint brush fibres, hair and fine wires to length and stick them to the frame, so that they run straight across the hole in the frame. Be sure to label each fibre.
3. Place the laser pointer in the retort stand clamp so that it is continuously on and direct the laser light towards the screen. The laser may need to be 1-2m away from the screen in order to accurately take measurements.
4. Place the frame in front of the laser so that the light strikes one of the fibres. Once a clear pattern is produced on the screen, accurately measure the distance from the screen to the fibre.
5. Carefully measure the distance from the third dot each side of the bright central dot. See figure below.



6. For small angles,  $n\lambda = \delta \sin \theta$  approximates to  $n\lambda = \chi \delta / L$  where  $n$  is the order of the bright spot,  $\lambda$  is the wavelength of the light used,  $\delta$  is the thickness of the fibre and  $L$  is the distance from the fibre to the screen. Using this information, determine the thickness of each fibre.
7. Use a micrometer to measure the thickness of each of the fibres and compare these to your calculated thickness.

### Questions

1. How does the pattern change with the thickness of the fibre?
2. Did the measurement match the calculation? If not, explain what factors in the experimental setup may have contributed.

### Useful Websites

Australian Synchrotron <http://www.synchrotron.org.au/>

Monash University Centre for Synchrotron Science information for students and teachers <http://www.sync.monash.edu.au/students.html>

News, information, and educational materials about the world's synchrotron and free electron laser light source facilities <http://www.lightsources.org>

Jefferson Lab has activities, games and information at <http://education.jlab.org/>



# CHAPTER 5 - MATERIALS SCIENCE

## WHAT IS MATERIALS SCIENCE?

Materials science investigates the relationship between the structure of materials at atomic or molecular scales and their macroscopic properties. It also deals with fundamental properties and characteristics of materials.

Companies who work in materials science study the structure of materials and use research to develop innovative solutions for products. They study the properties of materials in order to improve the properties of current materials or even create new materials.

## WHO IS BAYER MATERIALSCIENCE?

Bayer MaterialScience is among the world's largest polymer companies. Bayer MaterialScience focuses on the manufacture of high-tech polymer materials and the development of innovative solutions for products used in many areas of daily life. Some of these areas are the automotive, electrical and electronics, construction and the sports and leisure industries.

## High-quality, innovative products

Bayer MaterialScience produces high quality, innovative products in three areas:

- 1. Coatings, adhesives and specialties systems** based on polyurethane raw materials from Bayer MaterialScience reliably protect surfaces against the effects of weather and chemicals, while offering high-quality mechanical properties at the same time.
- 2. Polycarbonates** are indispensable when it comes to the production of automotive components, data carriers such as CDs and DVDs, sheeting products for construction and a large number of other everyday items.
- 3. Polyurethanes** are an integral part of many aspects of daily life. Their broad application range extends from

mattresses, via automobile seats, refrigerator insulation and car bumpers, through to shoe soles.

- 4. Thermoplastic polyurethanes** unite the properties of high-grade polyurethane elastomers with the efficient processability of thermoplastics. These are used in technical films and textile coatings, belts, hoses, cables and profiles, in the automotive sector (interior, exterior, chassis), in a multitude of applications in sports and leisure (e.g. ski and sport shoes and sport equipment) agriculture, mechanical engineering and industrial applications.

## Coatings, adhesives and specialties systems

Coatings, adhesives and specialties include raw materials for system solutions in many different industries that are based mainly on polyurethane chemistry. They exhibit extraordinary resistance to chemicals and scratching.

### Applications

**Auto refinish:** Auto refinishing relates to the aftermarket repair of automotive coatings. Bayer MaterialScience provides a wide range of solventborne and waterborne systems for refinishing systems. These are environmentally friendly and easy to use. They not only meet the processing requirements very well, but their quality matches those of the original coatings.

**Wood coating:** Wood coatings based on waterborne polyurethane raw materials show the same high quality properties of solventborne systems or even exceed them, while at the same time being more environmentally friendly and easy to process. They can be used for a wide range of wood coating applications including flooring and furniture.

**Adhesive bonding:** Polyurethane raw materials for adhesives allow bonding of not only foam-to-foam but most types of foam-to-fabric and -timber and can be used in many industries including bedding and upholstery.

Bayer MaterialScience raw materials allow the adhesive to achieve

solvent-based performance using the latest water-based technology. The adhesive is also environmentally friendly with low volatile organic compounds (VOC's). It also reduces fire hazards associated with other flammable solvents.

**Protection against graffiti:** The need to prevent the adhesion of graffiti—or at least the easy removal of it without any trace—has triggered efforts by the coatings industry to offer a solution for this problem.

Bayer MaterialScience has developed water-based polyols (alcohols containing more than one hydroxyl group (OH)) and polyisocyanate (any polymer prepared from an isocyanate, especially a polyurethane) hardeners for a two-component polyurethane coating system, that prevents the color pigments and dyestuffs from entering into the coatings layer underneath the top-coat, while at the same time being durable enough to withstand the repeated removal procedure without damage for a long time.

## Polycarbonates

Polycarbonates are a particular group of thermoplastic polymers. Polycarbonates have many applications because they are easily worked, moulded, and thermoformed.

Polycarbonates received their name because they are polymers containing carbonate groups (-O-(C=O)-O-). Most polycarbonates of commercial interest are derived from rigid monomers. A balance of useful features, including temperature resistance, impact resistance and optical properties, position polycarbonates between commodity plastics and engineering plastics.

### Applications

**Residential Construction:** Polycarbonate roofing for residential purposes includes pergolas, gazebos and carports as well as vertical cladding. Bayer MaterialScience markets their range of polycarbonate roofing under the Laserlite® brand.

**Commercial construction:** The use of plastics begins where aluminum, glass and other materials stop in a

commercial construction application. Polycarbonate sheeting has greater design flexibility and is as durable. Bayer MaterialScience offers the strength, clarity and durability of Makrolon® polycarbonate sheeting to the commercial construction market. This high-tech plastic can be used in such construction applications as transparent hall and stadium roofs, signage and skylights in shopping centres.



Stadium with polycarbonate roofing.

**Automotive:** Polymer materials influence the style, performance, fuel efficiency and safety of all classes of automobiles today. Polycarbonate products are used in a long list of automotive applications including in electrical systems, interior lighting and headlamps, front and rear systems, bumpers to body panels, interior trims, and lighting to windows.

In the application of LED headlamps, a collimator (a device for producing a parallel beam of rays or radiation) lens made of Makrolon® polycarbonate bundles the LED light and aims it precisely at the road. Polycarbonate has several advantages over glass and Poly(methyl methacrylate) (PMMA is a transparent thermoplastic) in this application. The fine lens geometries can be produced more accurately and more cost-effectively by injection molding in polycarbonate than with processes using glass.



Car headlight.

**Mass Transport – Rail:** Polycarbonate blends from Bayer MaterialScience are extremely fabrication-friendly, and thermoform with faster cycle times than most comparable materials. Therefore, it is ideal for many thermoformed interior and exterior rail parts such as structural seating components, wall cladding, window reveals, ceiling panels, and carriage bumpers. Adding to the possibilities, after forming it can be easily decorated with standard paints to provide a high gloss finish,

and is available in multiple textures and colors for increased rail interior design flexibility.

**Electrical:** Due to its UV stability and flame inhibiting properties, polycarbonate sheet is suitable for applications including interior aircraft components, switchgear covers, electrical devices, thermoformed equipment housings, and other current-carrying components.

### Polyurethanes

A **polyurethane** is any polymer consisting of a chain of organic units joined by urethane (carbamate) links. Polyurethane polymers are formed through step-growth polymerisation (also known as polyaddition) by reacting a monomer containing at least two isocyanate functional groups with another monomer containing at least two hydroxyl (alcohol) groups in the presence of a catalyst.

Polyurethanes are widely used in high resiliency flexible foam seating, rigid foam insulation panels, microcellular foam seals and gaskets, durable elastomeric wheels and tires, automotive suspension bushings, electrical potting compounds, high performance adhesives, surface coatings and sealants, Spandex fibres, seals, gaskets, carpet underlay, and hard plastic parts (such as for electronic instruments).

**Thermoplastic polyurethanes** are a class of polyurethane plastics with many useful properties, including elasticity, transparency, and resistance to oil, grease and abrasion

### Applications

**Construction:** One use of polyurethane is as insulation in the construction industry.

Insulating panels/slabs made of rigid polyurethane and polyisocyanurate foam have excellent heat-insulating properties, high mechanical strength and long-term stability. Rigid polyurethane foam has the lowest thermal conductivity of all commercial insulating materials. Insulating layers can therefore be much thinner than with other insulating materials and yet still deliver the same level of heat insulation.

Metal-faced sandwich panels filled with polyurethane are ideal for uses including walls of large industrial and refrigerated buildings, cold stores, warehouses, exhibition and sports halls, schools and other large buildings best constructed from components which provide thermal insulation while also meeting other technical requirements such

as stability, inexpensive assembly, freedom from maintenance and easy disassembly and reconstruction.

The specific advantages of insulating panels/slabs featuring polyurethane include:

- Minimal loss of space in the building/on site
- Controlled quality
- Biologically and chemically resistant
- Emission-free and moisture-resistant in dry construction
- High thermal insulating capacity for high heating energy savings
- Lightweight
- Hydrochlorofluorocarbon free
- High compressive strength
- Excellent long-term thermal insulating performance
- Easy to install
- Good dimensional stability

### BAYER'S COMMITMENT TO SUSTAINABILITY

Bayer MaterialScience is committed to Bayer's vision of 'Science For A Better Life'. In keeping with the principles of sustainable development, Bayer MaterialScience strives to balance economic, ecological and social benefits through our activities.

This is demonstrated throughout product development with projects such as building insulation, insulation throughout the cool chain, materials for solar modules and wind power plants, lightweight materials for automotive and transportation, waterborne coatings, and high solid coatings.

Bayer MaterialScience is involved in several projects, which provide groundbreaking examples of initiatives aimed at tackling the consequences of climate change and supporting climate protection including the Solar Impulse Project and the Eco-Commercial Building.

### Case Study: Solar Impulse Project

Bayer MaterialScience is an official partner of the Solar Impulse project; the world's airplane aiming to fly night and day around the world only propelled by solar energy.

Bayer MaterialScience is committed to supporting the Swiss-based Solar Impulse initiative with technical expertise, high-tech polymer



materials and energy-saving lightweight solutions including carbon nano-technology, innovative adhesives, lightweight polyurethane foams and extremely thin, unbreakable polycarbonate films and sheet for the cockpit glazing.

In December 2009, the prototype Solar Impulse HB-SIA made his inaugural 'flea hop' and the plane has since gone on to successfully complete a number of test flights including a 26 hours long flight. A second prototype is currently being designed.

For more information visit [www.solarimpulse.com/edu/](http://www.solarimpulse.com/edu/)



Solar Plane.

### Case Study: Eco Commercial Building

Sustainable construction as an all-in solution is a novel idea in the construction industry. The Eco Commercial Building program of Bayer MaterialScience is part of the Bayer sustainability program. The Eco Commercial Building is a sustainable, environmentally friendly, energy-optimized and economic concept for commercial and public buildings through integral planning all the way to the zero-emission building. The concept also factors in local climate conditions and building traditions.

As part of this program, Bayer MaterialScience is working with a network of members from various disciplines to support professionals such as architects, project managers, construction managers, developers and managers of larger companies in the creation of public and commercial

buildings that far outstrip previous sustainability standards. The services on offer range from energy efficiency assessments during the planning phase and the use of environmentally friendly materials to the employment of renewable energies.

For more information visit <http://www.climate.bayer.com/en/ecocommercial-building.aspx>

## TEACHING AND LEARNING ACTIVITIES

### PRIMARY

#### Which insulation works best?

What sorts of materials provide the best insulation? Try this experiment to find out.

#### Materials:

- Some warm water cool enough to put your hand in
- Six rubber bands
- A newspaper
- Black garbage bag
- Wool socks
- Aluminium foil
- Five glass jars or plastic soda bottles with lids

#### Procedure:

1. Stand the jars in a row on the table. Wrap the first jar with a layer of newspaper. Wrap the second jar with a wool sock, the third with a layer of black plastic and the fourth with aluminum foil. Hold the layers of insulation on with two rubber bands each.
2. Leave the fifth jar unwrapped.
3. Fill each jar with warm water and cover with the lids.
4. Every ten minutes, lift each lid and feel how warm the water is

in each jar. Use a thermometer to measure the temperature of the water.

5. Which jar/bottle stays warm the longest? Which material was the best insulator based on the student data? Which had the smallest change of temperature? What material(s) would the students recommend? If groups reached different conclusions, take a poll to find out which materials worked best overall. As a class, agree on a concluding statement for the experiment based on everyone's research findings. Solicit suggestions from students as to other materials they could use, ways to extend or refine the test, and other possible insulation tests they could conduct.

### MIDDLE SCHOOL

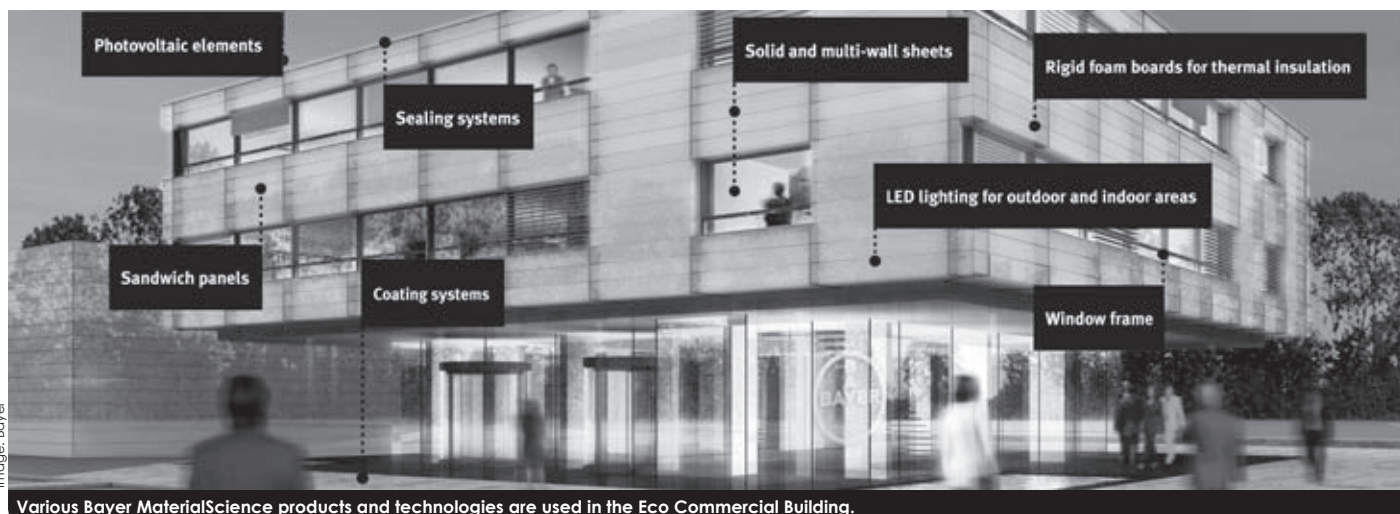
#### Pizza box solar oven

#### Equipment:

- Pizza box
- Aluminium foil
- Black paper
- Plastic sheet (e.g. overhead transparency)
- Newspaper
- Glue and sticky tape
- String
- Scissors
- Pen

#### Procedure:

1. Make a flap on the top of the pizza box that will reflect the sunlight onto your food. To do this, draw a square 2 cm from the edges on the lid of the pizza box.
2. Cut along the lines you have drawn, leaving one side of the square uncut. This side can be folded up to create a flap.



Various Bayer MaterialScience products and technologies are used in the Eco Commercial Building.



- Once you have your flap cut out, cover it on the inside with aluminium foil.
- Sticky tape the plastic sheet over the now open square on the top of the pizza box lid – this will help the heat stay inside your oven.
- Now it is time to insulate your pizza box solar oven. Scrunch up newspaper and stuff it into the sides of the pizza box.
- Place a sheet of aluminium foil over the top of the newspaper and smooth it out so that there is a box-shaped space in the middle. Use sticky tape to secure the edges of the foil to the box.
- Cut out a square piece of black paper and glue it to the inside base of the box. You can now close the pizza box and get ready for some scorching.
- Take your pizza box oven outside to a sunny spot. Position your reflective flap so it reflects the sunlight into the oven, remembering the sun will move over time. You can do this by taping string to the back or by propping it up with a straw. You will be able to see the ray of sunlight being reflected by the foil into the oven.
- Now for the exciting part - place food inside your oven (e.g. muffins with cheese, marshmallows and chocolate) and watch it warm up!

### What this means?

The Sun radiates heat and light energy. Solar cookers work by capturing sunlight and insulating the heat inside, a bit like a hot car that has been sitting in the sun all day.

The aluminium foil on the flap and walls reflects light inside the box and onto the black base.

When sunlight enters the pizza box, the black base warms, as the colour black absorbs the sunlight's light and heat. In contrast, the colour white reflects light and does not get as hot.

The newspaper, foil and plastic sheet insulating the box are all helping to keep all the heat inside.

(Adapted from CSIRO Science by Email [www.csiro.au/helix/science/mail/activities/solaroven.html](mailto:www.csiro.au/helix/science@mail/activities/solaroven.html))

### Safety

Don't use the solar oven to cook meat or other foods that could cause illness if not properly cooked. Complete a risk assessment.

## MIDDLE SCHOOL - UPPER SECONDARY

### Sticky Icky (or make your own polymer!)

#### Equipment:

- PVA glue
- food colouring
- water
- Borax
- two plastic cups or similar containers
- a sealable plastic bag
- some paper towels
- a pop stick for stirring
- at least two plastic spoons.

#### Procedure:

- Measure three teaspoons of PVA glue into the plastic cup.
- Add three teaspoons of water and stir.
- If you'd like to add a little colour, add a few drops of food colouring to glue and water now.
- Place approximately one cup of water into the other plastic cup.
- Stir in one heaped teaspoon of Borax powder. Once the mixture has been stirred thoroughly you have made a Borax solution.
- Add one teaspoon of Borax solution to the glue paste and stir. You might need to add a little more Borax solution. Be careful when you are adding the Borax solution. If you add too much the Sticky Icky will go hard.
- If the Sticky Icky feels very wet and slippery (but is not still runny), remove it from the container and knead it in your hands. In a few minutes, any extra Borax solution will evaporate or be absorbed.
- Place the Sticky Icky into a sealable plastic bag and it should keep for a while.

### What this means?

The glue and water mixture contains molecular chains called polymers, which move relatively freely as a liquid. Polymers are very large molecules, formed by repeated patterns of chemical units strung together. The Borax solution is a 'cross-linking' substance that binds the polymer chains together to make the glue solution thicker. Binding the polymer chains together restricts the movement and causes the liquid to turn into a plastic.

(Adapted from CSIRO Science by Email [www.csiro.au/helix/science@mail/activities/Slime.html](mailto:www.csiro.au/helix/science@mail/activities/Slime.html))

### Safety

Consult the relevant Material Safety Data Sheets and complete a risk assessment.

### Water proofing filter paper

#### Materials:

- filter papers (9 cm diameter paper is a convenient size for a standard petri dish)
- petri dish
- 2 different brands of water proofing spray
- tongs
- spray bottle containing water

#### Procedure:

- Hold a piece of filter paper in the tongs and spray one surface well with water proofing spray. Follow directions on the can for spraying distance etc.
- Repeat with the second brand of spray on another filter paper.
- Once the treated filter papers are dry, spray water on them. What happens? Try this with an untreated filter paper and note what happens.
- Try spraying different materials such as cotton, leather, vinyl etc. and test them for waterproofing. Can they all be equally waterproofed with the sprays?
- What other applications can you think of where a surface might be changed to improve function or performance? One idea is coating windshields so water flows off faster.....what can you think of?

### Safety

Ensure that the directions on the waterproofing can are followed. Ensure students wear protective goggles, use tongs and perform spraying in a well-ventilated area. Complete a risk assessment.

### RESOURCE LINKS:

[http://www.bayerus.com/MSMS/MSMS\\_Home.aspx](http://www.bayerus.com/MSMS/MSMS_Home.aspx)

<http://www.bayerboost.com.au>

<http://www.csiro.au/resources/CarbonKids.html>

<http://www.sciencefestival.com.au/>

<http://www.bayermaterialscience.com.au/>

<http://www.bayer.com.au>

# WATER – A CHEMICAL SOLUTION

- A GLOBAL EXPERIMENT FOR THE INTERNATIONAL YEAR OF CHEMISTRY

Presented by the International Union of Pure and Applied Chemistry (IUPAC) and the United Nations Educational, Scientific and Cultural Organisation (UNESCO)

**To celebrate the International Year of Chemistry, school students around the world are being invited to explore one of the Earth's most critical resources, water, and contribute the results of their investigations to the Global Experiment, possibly making the biggest chemistry experiment ever.**

The global experiment is an initiative of the IUPAC Committee for Chemical Education and has been developed to appeal to students from primary school to senior high school. The activities that make up the experiment help students appreciate the role of chemistry in issues of water quality and purification. At the same time students contribute to a global map, reporting on their investigations of water quality and water treatment.

The activities that make up the experiment have been designed to require minimal equipment and resources, but at the same time, allow increasing levels of sophistication. Four activities have been developed to examine local water sources.

These activities have been designed to be used as stand-alone experiments for classes that want to participate in the event, or to be built into an existing water-related curriculum unit. Many science or environmental units in existing school curricula involve more extensive measurements of water quality and treatment and will require at the most minor adjustments to include reporting to the global maps.

In the other cases, the resources provide detailed procedures and background knowledge to allow teachers at each level of schooling to implement them with their class and enjoy the reporting of results to the global maps as a culminating event.

The Global Experiment was launched early in the International Year of Chemistry and the website

will open for data submission through to the culminating event in Brussels in December 2011.

The Global Experiment website is the central source of information both for schools and for other interested groups. It is interactive and the site for data reporting. It can be accessed through the IYC website: [www.chemistry2011.org](http://www.chemistry2011.org).

The website contains more detailed descriptions of the activities. These include extensive notes for teachers; results from trials of the activities as well as extension activities and background information on the science involved.

## Experiment One (Upper Primary and Secondary)

### PH OF THE PLANET (ACIDITY)

Acids are one of the first groups of substances that we recognize for their chemical properties; in the kitchen and the laundry as well as in the factory and the laboratory.

This activity will allow your class to explore the idea of acidity as it applies to our water supplies using the most common measure of acidity, pH. Students will learn a method of measuring pH and how to check its reliability.

The class can contribute to the Global Experiment by submitting a class average for the pH of their local water and will be able to compare their results with others from around the world. Information about the source of the water and the conditions are also needed.

Full details of this experiment including additional teacher instructions and notes, colour charts, student worksheets and results sheets are available from the Global Experiment website <http://water.chemistry2011.org/web/iyc/24>

### Learning Outcomes

The students will:

- Measure acidity and assess the quality of the data.

- Interpret data in terms of the environment and nature of the water involved.
- Ask scientific questions.
- Carry out scientific investigations.

### Experiment Outline

Students should work in small groups (usually pairs) to measure the pH of a local natural source of water. The activity involves two sections:

- Measure the pH of the sample from the local water source (and other samples if appropriate).
- Analyse the data and report results to the Global Experiment Database.

### Materials

- 6 (six) sample containers (white or transparent containers to hold 1 cm depth of liquid).
- a dropper or pipette
- a bottle of rinsing water
- bromothymol blue indicator (see notes)
- *m*-cresol purple indicator (see notes)
- colour charts for indicators
- local water sample from local natural water body (see notes)

### Optional

- other water samples
- universal indicator

### Notes on Materials and Equipment

**Indicators:** Bromothymol blue is widely available from aquarium stores for use in testing fresh water aquariums. *m*-Cresol purple is used for testing marine samples. Primary school teachers may want to collaborate with local high schools if they need to make up the indicators from the solid samples provided in test kits.

### Bromothymol blue recipe:

Dissolve 0.1 g of bromothymol blue in 16 mL of 0.01 M NaOH. When dissolved, slowly add 234 mL of water (distilled if possible). Store at room temperature.

**m-Cresol purple recipe:** Dissolve 0.1 g of m-Cresol purple in 26 mL of 0.01 M NaOH. When dissolved, slowly add 224 mL of water (distilled if possible). Store at room temperature.

**Water samples:** The water samples can be collected in plastic drink bottles (1.5 L will be plenty). If samples need to be kept they should be stored in a refrigerator, allowed to come to room temperature before use, and used promptly after opening. The local natural water source sample to be reported to the Global Experiment Database might come from the sea, a river, lake or large pond. Try to find a source that is a recognisable landmark that will be identifiable by students from other schools for comparative purposes. Collect the water sample as close as possible to the time the class will be carrying out the measurements. If your students will be testing a range of other local samples you can ask them to collect samples and bring them to school. You should make sure you have some universal indicator in case students bring in samples that have pH values outside the range for most natural waters.

## Method

### Part A - Testing the local water source

1. Label the sample containers 1 – 6 and mark 0.5 cm depth on each container.
2. Take a portion from the local water sample and fill three of the containers up to the mark.
3. Add three drops of **bromothymol blue** indicator to each container and swirl it to mix the solution thoroughly.
4. Use the colour chart to estimate the pH of each solution and record the result for each container to one decimal place.
5. If the pH of the sample is 7.6 or greater, repeat the test three times using **m-cresol purple** as the indicator and record the results to one decimal place.

### Part B – Analysing and Submitting the Results

6. Decide which indicator gave the best measure of the pH of the sample.
7. Calculate the average result for your water sample using the results from the best indicator.

8. Add your result to the Class Table of Results.
9. When the class results are complete, calculate the class average result for the local water sample.
10. Submit the class average for the local water sample to the Global Experiment Database.

### (OPTIONAL Other water samples)

11. Repeat the method, Part A and B, for other water samples that are available.
12. Rinse the containers thoroughly between tests to avoid contamination.

## Safety

The materials used in this activity are not hazardous in the form of the dilute solutions suggested in the procedures. However the solid indicators may cause irritation particularly if ingested. They should be handled with care when making up the indicators and hands should be washed afterwards. Complete a risk assessment.

## Experiment Two (Secondary)

### SALTY WATERS (SALINITY)

The focus for this experiment is a property of water that makes it vitally important, namely the ability to dissolve a wide range of substances. Many substances, such as sugar or salt apparently disappear when they dissolve in water, but appearances are deceptive and the sugar and salt can be recovered from solution by evaporating the water. This activity makes use of this property to measure the amount of salt in some natural waters. Chemists measure the amounts of many of the substances that are present in water samples and we use the information to both understand how the world works and to keep us safe and healthy.

The class can contribute to the Global Experiment by submitting the class average value of the salinity of their water sample together with details of where the sample was collected and the conditions.

Full details of this experiment including additional teacher instructions and notes, and results sheets are available from the Global Experiment website <http://water.chemistry2011.org/web/iyc/25>

## Learning Outcomes

Students will:

- Explore the properties of water solutions containing salts.
- Use the process of evaporation to extract the salts from solution.
- Measure the concentration of salts in a water sample and use the class average to estimate the quality of the measurement.

## Experiment Outline

The experiment has been designed in three parts:

- Initially pairs of students set up the experiment, measuring the mass of the dish they are using, the volume of the salty water they are adding and the combined mass of the water and the dish. Students can increase the precision of their measurements if they measure each value several times and practice the transfer processes to minimise losses.
- The length of time required for the evaporation part of the activity depends critically on the local conditions. Pre-testing the length of time required for the equipment that students will use will ensure the experiment goes smoothly.
- The third part involves carrying out the calculation. Normally repetition of measurements would be recommended to check the quality of the results, but in this case the length of time for the measurement would make this arduous and the repetition is achieved through the averaging of all the individual results in the class.

## Materials

- Shallow glass or plastic dish or Petri dish (preferably clear to make it easy to see the salt).
- Cover for the dish that allows air circulation.
- Graduated measuring cylinder or jug.
- Balance that can weigh to 0.1 g with the capacity to weigh the dish and water (see method).
- Water sample/s - Seawater samples are particularly good for this activity because the amount of salt in seawater is readily measurable, usually around 3.5% which means that students using 100 mL water samples are measuring masses of salt between 3 and 4 g. Samples collected from the sea, or from estuaries will work well.



## Method

### Measuring Salinity by Mass

1. Collect a sample, (at least 100 mL) of seawater or other water with a significant salt content. (If appropriate, this can be the same sample as used for the pH of the Planet activity).
2. Weigh the dish as accurately as possible and record the result on the results sheet,  $m_D$ .
3. Measure the volume of about 100 mL of water as precisely as possible and place it in the dish,  $V_w$ .
4. Weigh the dish and water together,  $m_{D+W}$ .

**Evaporate the water** by one of two methods:

5. EITHER - **Solar evaporation:** place the dish in full sunlight and, if necessary to prevent dust, cover it with a transparent cover that allows the air to circulate. It may take a day or more to evaporate so monitor it periodically.
6. OR - **Hotplate evaporation:** Heat a hotplate to about 80°C and place the dish on it. Monitor the process periodically, making sure the water does not boil and splatter

**Dryness check** – carry out this check to ensure the sample is dry. This process is called drying to constant weight.

7. Weigh the dish with the salt and record the result on the results sheet.
8. Return the dish to the sunlight, or the hotplate, and leave it for 15-30 minutes.
9. Allow it to cool and reweigh it, recording the result.
10. If the second weight is less than the first, repeat the process once more and record the results.
11. Continue the process until the weight does not change.
12. The final weight is the mass of the dish and salt,  $m_{D+S}$ .

### Calculating salinity

13. First calculate the amount of salt by taking the final mass of the dish with the salt and subtracting the initial mass of the dish using the formula:

$$\text{mass of salt} \\ m_S = m_{D+S} - m_D \quad (\text{g})$$

14. Now calculate the mass of saltwater in the experiment:

mass of saltwater

$$m_{SW} = m_{D+SW} - m_D \quad (\text{g})$$

15. Finally calculate the salinity using the formula for the salinity:

$$\text{absolute salinity } S = \frac{m_S}{m_{SW}} \times 1000 \quad (\text{g/kg})$$

This is the value that will contribute to the class average that will be entered in the Global Database.

### Safety

The materials used in this activity are not hazardous in the form of the dilute solutions suggested in the procedures. However the solid indicators may cause irritation particularly if ingested. They should be handled with care when making up the indicators and hands should be washed afterwards. Complete a risk assessment.

## Experiment Three (Middle Primary to Senior Secondary)

### WATER: NO DIRT, NO GERMS (FILTRATION)

At the time of Madame Marie Curie's acceptance of the 1911 Nobel Prize in Chemistry, water treatment to provide clean, safe drinking water was becoming common in many places in Europe and North America. As we celebrate the International Year of Chemistry, waterborne diseases, such as typhoid fever and cholera, have yet to be completely eliminated, although the chemical technology 'tools' are available. This activity will raise awareness of the critical use of chemistry to provide one of the most basic human needs, clean drinking water. Starting with local natural surface waters, students will replicate one or both of the main steps of drinking water treatment – **clarification** and **disinfection**. Younger students will clarify natural surface water and observe disinfection done by their teacher. Older students will both clarify and disinfect natural water.

The class can contribute to the Global Experiment by submitting photographs of their filtration activity and a class average for the number of drops of bleach required to disinfect a sample of the filtrate.

Full details of this experiment including further teacher instructions and student worksheets are available from the Global Experiment website <http://water.chemistry2011.org/web/iyc/26>

### Learning Outcomes

The students will:

- Observe and compare the appearance of untreated and treated water.
- Measure free available chlorine in terms of quantitative data using colour matching methods.
- Record the scientific data and observe in an appropriate manner.
- Interpret data in terms of environment and nature of the water involved.
- Ask scientific questions about water treatment and water in the environment.
- Carry out scientific investigations by selecting and controlling variables.

### Experiment Outline

Students should work in small groups (4 – 6, or pairs if numbers permit) to treat water from a natural local source. They will carry out one or both of the main steps of water treatment:

- 1) clarification (including aeration, coagulation, sedimentation, filtration and disinfection,
- 2) disinfection

### Materials

#### Part A - For Water Clarification

- 2 litres of "dirty" natural water (or you can add 1 cup of dirt or mud to 2 litres of water)
- 1 two litre plastic soft drink bottle with its cap (or cork that fits tightly into the neck).
- 2 two litre plastic soft drink bottles, one with its bottom cut off to use as a funnel and one with the top cut off to use for sedimentation.
- 1 large beaker (with a volume of 500 ml, or 2 cups) or measuring bowl that will hold the inverted two litre bottle (or you can use another two litre plastic soft drink bottle with its top cut off so the other bottle will fit inside of it).
- 2 tablespoons of alum
- 1½ cups fine sand
- 1½ cups coarse sand
- 1 cup small pebbles

- 1 coffee filter
- 1 rubber band
- 1 large spoon
- A clock with a second hand or a stopwatch

### Part B - for Water Disinfection

- Liquid laundry bleach (sodium hypochlorite)
- About 10 chlorine test strips (pool test strips are ideal)
- One eye/medicine dropper or disposable pipette
- One large spoon
- A clock with a second hand or a stopwatch

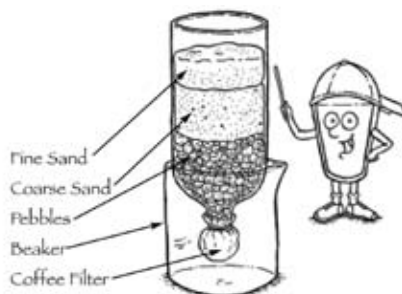
### Procedure for Water Clarification

1. Pour dirty river/dam water (or the water sample you made by mixing dirt and water) into the two litre bottle with a cap. Describe the appearance and smell of the water.
2. Place the cap on the bottle and vigorously shake the bottle for 30 seconds. Continue the aeration process by pouring the water into another bottle or the beaker, then pouring the water back and forth between them about 10 times. Once aerated, gases have escaped (any bubbles should be gone). Pour your aerated water into your bottle with its top cut off.
3. Add two tablespoons of alum to the aerated water. Slowly stir the mixture for 5 minutes. Describe the appearance and smell of the water.
4. Allow the water to stand undisturbed in the container (see photo to the right). Observe the water at 5-minute intervals for a total of 20 minutes. Write down what you see – what is the appearance of the water now?



Image: stock.xchng

5. Construct a filter from the bottle with its bottom cut off as (see illustration). Clean the filter by slowly and carefully pouring through 3L (or more) of clean drinking water. Throw away the water that has passed through the filter.



6. After a large amount of sediment has settled on the bottom of the bottle of river/dam water, carefully—without disturbing the sediment—pour the top two-thirds of the river/dam water through the filter. Collect the filtered water in the beaker/plastic bottle.
7. Compare the treated and untreated water. Has treatment changed the appearance and smell of the water?
8. OPTIONAL Place samples of the treated and untreated water side-by-side and take a photo for submission to the Global Database.

Based on U.S. Environmental Protection Agency activity at: [http://www.epa.gov/safewater/kids/flash/flash\\_filtration.html](http://www.epa.gov/safewater/kids/flash/flash_filtration.html)

### Procedure for Water Disinfection (FOR SENIOR STUDENTS ONLY)

1. Dip a chlorine test strip into 500 ml (approximately 2 cups) of the clear liquid obtained from the filtration activity (the “filtrate”) above and use the product color-code chart to estimate the “free available” chlorine level of the liquid. Record the level of chlorine in the filtrate in the table on the Students’ Result Sheet for Water Disinfection.
2. Add 2 drops of bleach to the filtered liquid, stir gently for 5 seconds, and repeat the test strip reading immediately. Record the results in the table. Keep adding 2 drops at a time, and record the number of drops added, until a chlorine level registers on the test strip. As chlorine bleach is added to the filtered water, chlorine is being used up in destroying harmful germs, so it could take a few additions of bleach before a chlorine residual can be observed.

3. Once the chlorine residual is noted, wait 10 minutes WITHOUT ADDING MORE BLEACH and again record the free available chlorine level.
4. If the chlorine residual disappears over the course of 10 minutes, add two more drops and see if a free chlorine level reading of at least 1 – 3 parts per million can be measured 10 minutes after adding the chlorine. (If after 2 drops and 10 minutes, no chlorine residual is noted, increase the number of drops by 2, trying 4 drops. Wait 10 minutes and check for the chlorine residual. If no chlorine residual appears, increase the number of drops to 6, etc., until a chlorine residual can be noted after 10 minutes.) When this happens, you have added enough chlorine bleach to destroy many of the germs in the water, leaving a small excess of chlorine.
5. Calculate the total number of drops used for the disinfection and report it to help determine the class average.

### Safety

Safety glasses must be worn at all times during this activity. The water is not safe to drink. Direct contact with alum and disinfectant should be avoided. The household bleach should be handled with care. Senior high school students may be allowed to do the disinfection activity. Class demonstrations are recommended for junior classes. Complete a risk assessment.



A filter made from a bottle.

## Experiment Four (Middle Primary to Junior Secondary)

### SOLAR STILL CHALLENGE (DISTILLATION)

The solar still is a device that uses solar energy to purify water. Different versions of a still are used to desalinate seawater, in desert survival kits and for home water purification.

In this activity students will make a solar still and measure its efficiency. They will develop their understanding of water in liquid and gaseous states and how distillation can be used to purify water. They will be challenged to design and make a more efficient still.

The class can contribute to the Global Experiment by submitting the efficiency of their most efficient still design together with a diagram and photograph of the still.

Full details of this experiment including further teacher instructions and results sheets are available from the Global Experiment website <http://water.chemistry2011.org/web/iyc/27>

#### Learning Outcomes

The students will:

- Learn about the liquid and gaseous state of matter (water) and their inter-conversion (evaporation and condensation).
- Learn about the use of the process of distillation to purify water.
- Develop an appropriate level of scientific explanation for the distillation process.
- Use their knowledge about distillation to carry out a technology process improving the efficiency of a solar still.

#### Experiment Outline

The activity is most successful if students work in pairs but can be carried out individually. The activity involves two sections:

1. Students make a simple still and use it to purify some water. They are invited to develop their explanation for how the still works.
2. Students are challenged to improve the yield of purified water by modifying the still or the way it is used.

After they have carried out their experiments they draw a diagram explaining how their new design has improved the % water purified which is a measure

of the efficiency of the still. If possible they should include a photograph of their improved solar still. At the completion of the activity collect the work from all the groups that have completed the challenge and select the winning entry for the challenge. If appropriate this can be made into a culminating event for the Global Experiment and the class can be involved in the selection.

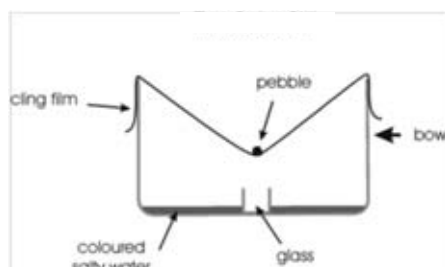
#### Materials

- Large metal or plastic bowl
- Small, shallow glass or cup (clean)
- Measuring jug or cylinder
- Cling film (wider than the bowl)
- Small stone (pebble)
- Hot water
- Food dye and salt

#### Method

##### Part A – Building a Solar Still

1. Add a measured volume of hot water (about 1 cm) to the bowl.
2. Add some food colouring and about a teaspoonful of salt to the water in the bowl.
3. Take all the equipment out to a sunny, level place.
4. Place the glass or cup in the middle of the bowl making sure no water splashes into it.
5. Cover the bowl loosely with cling film, sealing the film to the rim of the bowl. (Use tape or string if necessary.)
6. Place the stone in the middle of the film above the cup.



The Solar Still

7. Leave the still for at least an hour (the longer the better) and then check that there is some water in the cup.
8. Take the still back indoors, remove the cling film and take out the cup without splashing any water into or out of the cup.
9. Measure the amount of water in the cup.
10. Observe the colour of the water in the cup and test it for salt.

11. Calculate the percentage of the water that was purified:

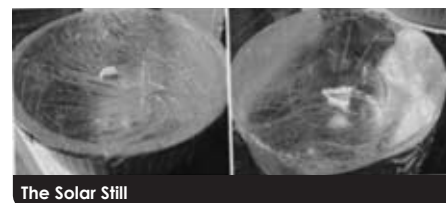
$$\% \text{ water purified} = \frac{\text{volume collected}}{\text{volume added to still}} \times 100$$

12. Look at your results and see if you can explain what happened to the water. Why is it called 'purified water'?

#### Part B – The Design Challenge

The challenge is to modify or make a more efficient solar still than the one made in Part A.

1. Write down some ideas about how you might improve the still. For example you might try using different coloured containers to find out which absorbs the sunlight most efficiently.
2. Discuss your ideas with your teacher and get his/her permission to carry out the experiment.
3. Carry out the experiment recording the volume of water you start with and the volume you purify.
4. Calculate the % water purified and record it.
5. If you have time, you can develop your design further. Make sure you get permission from your teacher for each experiment you carry out.
6. Draw a diagram of your most efficient still showing why it is more efficient than your first still. Take a photo of your still if you can.
7. Hand in your results to your teacher so that the most efficient still can be selected and uploaded to the Global Experiment Database.



The Solar Still

#### Safety

There is very little hazard involved in carrying out the activity. Standard laboratory safety rules suggest that students should not taste or smell the products of activities. However the easiest test for salt is taste, and this can be used if food hygiene safety standards, such as those used in home economic classes, are applied.



# CHEMIST PROFILES



Image: Wikipedia

## MARIE CURIE

Marie Skłodowska Curie (7 November 1867 – 4 July 1934) was a physicist and chemist of Polish upbringing and subsequent French citizenship. She was a pioneer in the field of radioactivity and the first person honoured with two Nobel Prizes — in physics and chemistry. She was also the first female to be awarded a Nobel Prize and the first female professor at the University of Paris.

Marie Curie was born in Warsaw, Poland and lived there until she was twenty-four. She received a general education in local schools and some scientific training from her father. In 1891, she went to Paris to continue her studies at the Sorbonne where she obtained Licentiate degrees in Physics and the Mathematical Sciences. She met Pierre Curie, Professor in the School of Physics in 1894 and in the following year they were married. She succeeded her husband as Head of the Physics Laboratory at the Sorbonne, gained her Doctor of Science degree in 1903, and following the tragic death of Pierre

Curie in 1906, she took his place as Professor of General Physics in the Faculty of Sciences, the first time a woman had held this position. She was also appointed Director of the Curie Laboratory in the Radium Institute of the University of Paris, founded in 1914.

Together with her husband, Mme. Curie discovered polonium and radium. The discovery of radioactivity by Henri Becquerel in 1896 inspired the Curies in their brilliant researches and analyses which led to the isolation of polonium, named after the country of Marie's birth, and radium. Mme. Curie developed methods for the separation of radium from radioactive residues in sufficient quantities to allow for its characterisation and the careful study of its properties, therapeutic properties in particular. Mme. Curie throughout her life actively promoted the use of radium to alleviate suffering and during World War I, assisted by her daughter, Irene, she personally devoted herself to this remedial work.

Mme. Curie, quiet, dignified and unassuming, was held in high esteem and admiration by scientists throughout the world. Together with her husband, she was awarded half of the Nobel Prize for Physics in 1903, for their study into the spontaneous radiation discovered by Becquerel, who was awarded the other half of the Prize. In 1911 she received a second Nobel Prize, this time in Chemistry, in recognition of her work in radioactivity. This Nobel Prize enabled her to get funding from the French Government to fund the building of a private Radium Institute (now the Institut Curie) at which research was conducted in chemistry, physics and medicine. Four future Nobel Laureates studied at this Institute, including her daughter Irène Joliot-Curie and her son-in-law, Frédéric Joliot-Curie who both shared the Nobel Prize for Chemistry in 1935 for their discovery of artificial radioactivity.

"Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less"  
- Mme Marie Curie



## BRIAN ANTHONY

### Industrial Chemist, Dow Polyurethanes Australia

- 1. Why did you choose a chemistry-related career?** I found chemistry classes in secondary school very interesting and was lucky to have excellent teachers who made learning the subject enjoyable and rewarding.
- 2. What subjects did you study at school and university?** I studied mostly science subjects but Music A (piano) and Italian as well. Mixing up your subjects a little gives you more options and lets you see other ways of learning.
- 3. How did you get into science and particularly into chemistry?** I began a Science Degree at Monash University and after first year, took a break from study and worked for a chemical company. That work experience let me see the interesting jobs people had following their studies in chemistry. When I returned to university, I focused mainly on chemistry.
- 4. What is it that you do?** I am an industrial chemist at Dow Chemical, supporting Dow's Polyurethane Business. I provide technical support to customers and am involved in developing new products across the Pacific region.
- 5. What do you like most about your work? What do you like least?** I like the interaction with customers and colleagues across the Pacific Area and other global regions. Participating in late night teleconferences with global colleagues is probably my least favourite part of the job.
- 6. What do you see as your greatest achievement?** I was the project manager for the establishment of a pilot scale, flexible foam machine laboratory at the Dow Chemical Altona site.
- 7. What has been your biggest challenge?** Getting the polyurethane foam machine lab up and running was also the biggest challenge.
- 8. What are you working on now?** Developing new types of high quality polyurethane foams for furniture and bedding applications.
- 9. What advice would you give to a young person thinking about entering this field of science?** Think about where you would like to work (e.g. Industrial, Research etc.) and don't be shy about trying to gain some work experience in that setting. Seeing people apply chemistry in the workplace is an excellent way to understand where chemistry could take you and how you could make a living in that profession.
- 10. If you were a chemical, which chemical would you be and why?** Toluene Diisocyanate (TDI) – Highly reactive with two –NCO groups ready to produce a huge range of polyurethane polymers!



## ANNETTE LARWOOD

**Laboratory Team Leader, BHP Billiton Nickel West Kwinana**

- 1. Why did you choose a chemistry-related career?** I enjoyed science and maths as subjects at school, so I investigated career paths until I narrowed it down to chemistry. Both my parents came from farming families and neither had finished high school, but they encouraged me to consider tertiary education.
- 2. What subjects did you study at school and university?** In Year 11 & 12 I did TEE Chemistry, Physics, English Literature (as UWA did not use English to calculate your entrance exam), Maths II and Maths III (as they were then known) and Home Economics to give my brain a rest. I then went to Curtin University and did a BSc in Applied Chemistry.
- 3. How did you get into science and particularly into chemistry?** Whilst at high school I attended career nights, open days and did work experience in a laboratory. Chemistry was my favourite subject so I narrowed it down to chemical engineering or chemistry. Since I enjoyed the analysis and laboratory side more than the engineering side I chose chemistry. It's all about doing what you enjoy.
- 4. What is it that you do?** I manage the laboratory at the BHP Billiton Nickel Refinery at Kwinana in WA. It's a 24 hour laboratory that provides results to all the areas of the refinery. Nickel refining is a hydrometallurgical process that requires complex analysis 24 hours a day and my job is to make sure that the laboratory is capable of providing that service in a safe manner as well as always looking on how we can improve that service and develop the staff working in the laboratory.
- 5. What do you like most about your work? What do you like least?** I enjoy working in laboratories at industrial scale chemical operations – my job requires knowledge of both process chemistry so we can assist operations and engineers with any process issues, but also an in depth knowledge of analytical chemistry so we can analyse the varied types of samples we receive including various gases, waters, process liquors, solids, and metals. Nickel chemistry is complex and quite specialised. I also enjoy being a supervisor – I get a great deal of satisfaction from developing a team. There's not really anything I don't like in my job. There are many challenges that come with it at times, but I'd get bored if there wasn't.
- 6. What do you see as your greatest achievement?** I've worked in some very challenging environments and locations – it was tough but very rewarding. I've commissioned a lot of different instrumentation around the country. I was a senior chemist by the time I was 21 and a NATA signatory for a very large (100+ staff) laboratory that analysed gold and base metals for many operations in northern Australia and south east Asia. Becoming a lab manager whilst still in my early 30s was another highlight, particularly for a company like BHPB.
- 7. What has been your biggest challenge?** I've worked in remote locations and regional centres - Nhulunbuy in Arnhem land and Pine Creek NT, Meekatharra and Kalgoorlie WA as well as FIFO. Remote sites always present challenges in getting technological assistance, supplies and staff. The biggest challenge was probably my first job after graduation as a chemist. I started work in Meekatharra where they made me shift supervisor on my first day at work.
- 8. What are you working on now?** Upgrading some of the laboratory technology and recruiting a couple of extra staff.
- 9. What advice would you give to a young person thinking about entering this field of science?** Start with your preferred area of interest (as in what you enjoy) and hone it down as you research where that field can take you. You've got to find that balance of doing something you truly enjoy with making sure that there's actually some sort of career path that comes from it. I would also encourage people to work in places they would not initially consider – such as remote areas as I did.
- 10. If you were a chemical, which chemical would you be and why?** Argon. The analytical instrumentation that is my particular speciality is ICPOES (Inductively Coupled Plasma-Optical Emission Spectroscopy), so it'd be nice to be the noble gas that can become a plasma.



## DR. MELISSA NIKOLIC

**ARC Postdoctoral Fellow, CRC for Polymers, Queensland University of Technology**

- 1. Why did you choose a chemistry-related career?** It's a very interesting and diverse field. It dabbles into all the other areas of science as well.
- 2. What subjects did you study at school and university?** I studied maths and science at high school in conjunction with violin and speech and drama externally for 12 years. At university, I studied a Bachelor of Science (Chemistry), followed by honours in chemistry then finished a PhD in chemical engineering. I am currently undertaking a Graduate Certificate in Research Commercialisation.
- 3. How did you get into science and particularly into chemistry?** I kept studying areas that were interesting to me and they happened to be chemistry based.
- 4. What is it that you do?** On a day-to-day basis, I design and undertake experiments with the aim of creating degradable plastics. I also consult fellow scientists and engineers in the team on how to develop the best materials for the application required.
- 5. What do you like most about your work? What do you like least?** I like the challenges associated with trying to find practical solutions to problems and issues in question. Sometimes it can be disheartening after days of hard work that the result is not what you were hoping for.
- 6. What do you see as your greatest achievement?** Finishing the PhD on time.
- 7. What has been your biggest challenge?** Finishing the honours degree was definitely a challenge.
- 8. What are you working on now?** I am primarily focused on developing plastic materials that are degradable and do not have long-term negative effects on the environment.
- 9. What advice would you give to a young person thinking about entering this field of science?** Find yourself a mentor in the field of science you are interested in and try and obtain as much experience as you can. This will help you decide which areas you like the most and where you are best suited.
- 10. If you were a chemical, which chemical would you be and why?** That's a tricky one, possibly Botulinum toxin or more commonly known as Botox to be forever young!



## JESSICA FERGUSON

### Laboratory Supervisor, Sirromet Wines Pty Ltd

- 1. Why did you choose a chemistry-related career?** Chemistry was the science that made the most sense to me; it seemed to underpin everything else. I feel it is the foundation science.
- 2. What subjects did you study at school and university?** The most advanced chemistry and physics classes I could, also extended mathematics. I balanced the sciences with visual arts, music, Japanese and English Literature. English and Chemistry were my best subjects. At university I did a 'double major' in Chemistry – I basically took every Chemistry course that was on offer. I also studied Physics, Maths (but not beyond 1st year!) and Environmental Science.
- 3. How did you get into science and particularly into chemistry?** I had an amazing Year 12 Chemistry teacher. We once spent half a lesson discussing the existential aspects of the 1st and 2nd laws of thermodynamics, and whether these could prove (or disprove!) the existence of God. I'm not sure a teacher would get away with that type of discussion these days! I also loved the hands-on aspect of bench chemistry. We extracted essential oils by distillation, it was my first experience of Quickfit glassware and I was hooked.
- 4. What is it that you do?** For the last 6 years I have worked as a chemist at a winery. I had no appreciation of how much chemistry and biochemistry there is in winemaking. Every year I understand more about flavour metabolism in fermentation. This makes the more mundane aspects of the job (like the endless testing of preservative levels!) seem ok. I also work very closely with the winemakers on wine trials and blending. There is a lot of QA/QC work involved in preparing wines for bottling, just like any food/beverage lab position.
- 5. What do you like most about your work? What do you like least?** I love the fact that every year is different, the fruit is different, and the wine is different. This makes it unlike most food/beverage production jobs, and very unlike pharmaceutical manufacture that I worked in before. I'm still learning so much and I still find wine and fermentation fascinating. My appreciation of wine has really increased, as I understand the technique and skill that goes into making a great wine. What I like least – well, like any food production QA/QC role there is a lot of repetitive, routine work. I have a pretty simple, basic lab at the winery and I do miss being able to run more complex instruments like GCs, HPLCs, AAS etc.
- 6. What do you see as your greatest achievement?** Hmm, it's a pretty tedious one but I think our QC/QA systems have come a long way since the winemaker and I have been 'continuously improving' them over the past few years.
- 7. What has been your biggest challenge?** Coming into winemaking with zero background of biochemistry and very little microbiology. I know much, much more about yeast than I did 6 years ago (and probably much more than most people ever need to know!)
- 8. What are you working on now?** We've been doing some brewing trials on a 'wine-infused' beer. Brewing fermentations are really different from wine fermentations, the sugars are different and the metabolic pathways are a bit different. I've had to buy a book on brewing.
- 9. What advice would you give to a young person thinking about entering this field of science?** With chemistry make sure you enjoy bench work and are prepared to work on your skills, good bench skills don't necessarily come naturally and often the student with the highest theory marks can be hopeless in the lab. Most chemistry jobs involve repetitive work – even high-tech research can involve repeating and fine-tuning experimental conditions over and over. Be the sort of person who cares about being meticulous and have a high attention to detail, as it is hard to practise any kind of chemistry otherwise. Keep your options open and be prepared to gain experience just about anywhere to start off – very few of us find our dream jobs straight off. A mundane lab tech job will really hone your skills and is a good starting point. Definitely try to get some casual lab experience while you are still studying to see if this type of career appeals to you. Future employers want solid bench skills and problem-solving abilities more than high university marks.
- 10. If you were a chemical, which chemical would you be and why?** Right now I'm really into wine flavour compounds and how they are 'unlocked' by yeast from the precursors in the grapes. My current favourite is (-)-cis-rose oxide (tetrahydro-4-methyl-2-(2-methyl-1-propenyl)-2,5-cis-2H-pyran), which is the compound in Gewurtztraminer, and Muscat wines that smells like lychees and roses – I'd be pretty happy to smell like that!



## AMANDA SAUNDERS

### Process Chemist, Product Development, CSBP Limited

- 1. Why did you choose a chemistry-related career?** To understand how the world works so that I can make good decisions and work on projects that are of benefit to the planet and all of its inhabitants.
- 2. What subjects did you study at school and university?** Chemistry, Mathematics, Physics, Biology...
- 3. How did you get into science and particularly into chemistry?** I had great science teachers and I loved the experiments!
- 4. What is it that you do?** I am an Industrial Chemist working in product development. I spend time in the production plant, analyzing experimental and process data and conducting laboratory scale and production scale experiments.
- 5. What do you like most about your work? What do you like least?** I like taking a concept and developing it until it becomes a practical tool or solution to a problem. I enjoy investigating problems in detail so that solutions to the root cause can be implemented in a way that suits all parties involved including operations, maintenance and technical teams.
- 6. What do you see as your greatest achievement?** Being involved with the Scientists in Schools Program.
- 7. What has been your biggest challenge?** Learning to run a manufacture plant.
- 8. What are you working on now?** I am developing a granulation binder that enhances product strength.
- 9. What advice would you give to a young person thinking about entering this field of science?** Work experience. If you are not sure about what you want to do, go and try it first and speak to people who work in the field.
- 10. If you were a chemical, which chemical would you be and why?** H<sub>2</sub>O because it is so versatile and has very unique properties.



Building Intelligently



Saving Energy

Science For A Better Life



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