

The background of the entire cover is a close-up photograph of a green printed circuit board (PCB) populated with various electronic components. These include numerous resistors with color-coded bands, several electrolytic capacitors of different sizes and colors (red, black, silver), and integrated circuits. The image is overlaid with a semi-transparent red and orange gradient. The 'SPOTLIGHT' logo is positioned at the top center, featuring the word in a bold, white, sans-serif font with a thick black outline. Each letter is contained within a colorful, multi-pointed starburst shape in shades of pink, yellow, green, and blue.

SPOTLIGHT

SENIOR SCIENCE

HSC

SECOND EDITION

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Science Press

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The Stage 6 Senior Science course is an interdisciplinary study that extends well beyond the knowledge range of most teachers. We would like to thank a number of people and organisations who have helped in the preparation of this text. However, in acknowledging their contributions the authors prepared the final text and must take responsibility for any errors that may appear in the text.

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SYLLABUS CROSS-REFERENCE

Chapter	Unit	Syllabus
1 LIFESTYLE CHEMISTRY	1.1 Physical and chemical properties of substances	1. The use of a substance depends on its physical and chemical properties
	1.2 Surfactant and colloid cleaning products	2. A wide range of cleaning products are made from colloids and surfactants
	1.3 Cleaning your body	3. Cleaning products used on the human body must be compatible with the physical and chemical properties of the skin
	1.4 Solvents	4. The nature of a solvent plays an important role in the application of a mixture
	1.5 Drugs	5. The solubility materials used in drugs has an effect on the way in which the body responds to them
2 MEDICAL TECHNOLOGY	2.1 Maintaining human function	1. Increases in scientific understanding and technological advances have broadened options for maintaining humans as functioning organisms
	2.2 The circulatory system and heart	2. The regular beating of the heart and continuity of the flow of blood through the heart and around the body is needed to maintain good health
	2.3 The skeletal system	3. The wide range of movements, continual absorption of shocks and diseases make the skeletal system vulnerable to damage but new technologies are allowing the replacement of some damaged structures
	2.4 The respiratory system	4. Life support systems can be used to sustain life during operations or while the body repairs itself
	2.5 Medical techniques	5. The use of non-invasive or minimally invasive medical techniques has greatly reduced risks to patients and has increased our understanding of how the body works

Chapter	Unit	Syllabus
3 INFORMATION SYSTEMS	3.1 Sending messages	1. Information systems are many and varied and depend on the transfer of energy from place to place
	3.2 Electromagnetic spectrum	2. Electromagnetic radiation can be modulated to carry different types of information 3. Electromagnetic waves have different properties which are utilised in a range of communication systems through air and space
	3.3 Modulation: AM and FM	1. Information systems are many and varied and depend on the transfer of energy from place to place 2. Electromagnetic radiation can be modulated to carry different types of information 3. Electromagnetic waves have different properties which are utilised in a range of communication systems through air and space
	3.4 Modulation: digital	5. Information can be transmitted in the form of electrical impulses
	3.5 Satellite communication	4. Geostationary satellites relay and transmit information from the other side of the world
	3.6 Digital images	5. Information can be transmitted in the form of electrical impulses
	3.7 Fibre optics	6. Electrical energy can be converted to light energy for use in optical fibre communication system
	3.8 Telephones	1. Information systems are many and varied and depend on the transfer of energy from place to place
	3.9 Mobile phones	1. Information systems are many and varied and depend on the transfer of energy from place to place
	3.10 Television systems	1. Information systems are many and varied and depend on the transfer of energy from place to place
	3.11 Compact discs	1. Information systems are many and varied and depend on the transfer of energy from place to place
4 POLYMERS	4.1 Natural polymers	1. A range of natural polymers has been cultivated and used by many cultures for many purposes including clothing and ropes
	4.2 Properties of synthetic polymers	2. Synthetic polymers have different uses based on their different properties
	4.3 Plastics	3. Plastics are synthetic polymers that can be moulded and coloured
	4.4 Polymers and the environment	4. As synthetic polymers are not natural substances they do not decompose but remain in the environment for a long time

Chapter	Unit	Syllabus
5 PRESERVATIVES AND ADDITIVES	5.1 Additives	<ol style="list-style-type: none"> Many consumer products, ranging from food through to cosmetics, have other substances added to improve the appearance, the shelf life, consistency or taste Food preservation techniques began with simple procedures and commonplace substances and developed to include a wider range of chemical substances and principles Government regulations, as part of food legislation which is published in the Australian Standards Food Code, permit the use of specified substances as part of food
	5.2 Food preservation	<ol style="list-style-type: none"> Food preservation techniques began with simple procedures and commonplace substances and developed to include a wider range of chemical substances and principles
	5.3 Growth of micro-organisms	<ol style="list-style-type: none"> Microbial activity is responsible for spoilage and the loss of appeal
	5.4 Natural preservatives	<ol style="list-style-type: none"> Food preservation techniques began with simple procedures and commonplace substances and developed to include a wider range of chemical substances and principles Natural preservatives are utilised in some food products in cheeses and yoghurt
	5.5 The role of the government in food manufacturing	<ol style="list-style-type: none"> Government regulations, as part of food legislation which is published in the Australian Standards Food Code, permit the use of specified substances as part of food
6 PHARMACEUTICALS	6.1 The central and peripheral nervous systems	<ol style="list-style-type: none"> The central nervous system and peripheral nervous system are responsible for the detection and interpretation of signals from outside and inside the body
	6.2 Transporting pharmaceuticals in the body	<ol style="list-style-type: none"> The circulatory system can be used to transport many pharmaceutical substances
	6.3 Pharmaceuticals to reduce pain and inflammation	<ol style="list-style-type: none"> When some pharmaceuticals are introduced into the circulatory system they can stop messages moving across the synapse or stop the inflammation response continuing
	6.4 Penicillin: a bacteria fighter	<ol style="list-style-type: none"> When penicillin is introduced into the circulatory system it can assist the body in fighting bacteria

Chapter	Unit	Syllabus
7 DISASTERS	7.1 Disasters may be natural or caused by human activity	1. Disasters may be natural or caused by human activity
	7.2 Monitoring and predicting the weather	2. Technological developments have improved our ability to monitor and predict weather patterns
	7.3 Earthquakes	3. Even with current technology disasters such as earthquakes and bushfires are not easy to predict
	7.4 Bushfires	3. Even with current technology disasters such as earthquakes and bushfires are not easy to predict
	7.5 Warning about disasters	4. Warning devices can also be used to detect disasters associated with human activity
	7.6 The role of emergency services	5. Emergency services also assist in the prevention or minimisation of disasters
8 SPACE SCIENCE	8.1 Earth in space	1. While the atmosphere has limits there is no such thing as 'empty' space
	8.2 The gravity of the situation	2. The strength of gravity varies at different points in space
	8.3 Getting into space	4. The components and materials used in the construction of rockets and shuttles must withstand launch and re-entry conditions
	8.4 Coming home	4. The components and materials used in the construction of rockets and shuttles must withstand launch and re-entry conditions
	8.5 Space flight: past and future	4. The components and materials used in the construction of rockets and shuttles must withstand launch and re-entry conditions
	8.6 Surviving in space	3. Reduced gravity in space can have short- and long-term effects on body functions 5. Space stations and probes provide information about our Solar System, galaxy and deep space 6. The technologies developed for space exploration have impacted on many different aspects of society
	8.7 Space research	5. Space stations and probes provide information about our Solar System, galaxy and deep space
	8.8 What have we learnt?	6. The technologies developed for space exploration have impacted on many different aspects of society

TO THE TEACHER

Teachers who have looked at the Stage 6 Science course are enthusiastic in their praise – it must be the best of the new Stage 6 courses. It provides students with a broad and contemporary understanding of Biology, Chemistry, Physics and Earth and Environmental Science and their application. It includes a major component of the sort of technology that many will use in work as well as life in general, plus a study of the impact of this science and technology on society.

Being such an interdisciplinary course it places high demands on teachers. It promotes science as a continually developing body of knowledge, emphasising the role of experimentation in deciding between competing theories and of the provisional nature of scientific explanations. Students studying Senior Science work individually and with others; they apply their investigative and problem-solving skills in the laboratory, the field and with interactive multimedia. They also learn to effectively communicate scientific information as well as understand and appreciate the contribution that a study of science makes to our understanding of the world.

This book seeks to assist the teacher in this task. On the one hand it provides all the necessary content for the course plus the many learning experiences specified in the syllabus.

In the textbook you will find:

- all the content needed for core and options
- all first-hand investigations
- all the specified activities
- homework questions
- exam-style questions
- detailed answers
- all the verbs modelled.

The accompanying Teachers CD also contains:

- worksheets for all activities
- supplementary worksheets for each chapter that can be used for homework or in class
- equipment lists and hints for all experimental activities and investigations
- some spreadsheets and animations
- some PowerPoint presentations at appropriate places in the course
- cross-references with the syllabus.

We feel sure that this text will provide a worthy supplement to your efforts as we educate students in the 21st century.

David Heffernan
Ruth Miller
Sandhya Ross
Vanessa Smith

TO THE STUDENT

Welcome to the second year of your study of science in the senior high school! You have chosen one of the most dynamic and interesting science courses in the world today. Everything you study will have relevance to your future roles in life – at work, at leisure and in the community.

Stage 6 Senior Science explores contemporary science and its applications. It includes a long look at technology and the impact of science and technology on society. Most future employment in science and technology will require you to have a wide, rather than a specialised knowledge. The breadth of this course also means that you will be introduced to a wide variety of science topics to help you in making decisions about a future career.

Some of the things you will be looking at this year are:

- the chemistry of cosmetics
- how the Internet works
- how artificial joints are designed
- what help you can receive if you have a serious accident
- how music is recorded on a CD.

You then have to choose an option:

- how does a plastic PET bottle differ from a polypropylene bottle
- why some foods never seem to go ‘off’
- why some pills are tablets and others are capsules
- what happens during a tsunami and other disasters
- what you have to survive to become an astronaut.

One of the main features of this course is the many hands-on activities. Other things that you will be doing include:

- undertaking laboratory experiments, including the use of appropriate use of electronic sensors and computers
- fieldwork when on excursions
- research using the library, Internet and CD encyclopedias
- using computer simulations for modelling or processing data
- using and reorganising data from a wide variety of sources
- extracting and reorganising information in the form of flow charts, tables, graphs, diagrams, prose and keys
- using animation, video and film resources to obtain information not available in other forms.

David Heffernan
Ruth Miller
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LIFESTYLE CHEMISTRY

Many consumer products have been developed because of increased understanding of chemical substances, chemical reactions and the biochemistry of human body surfaces. Some of these products are used as cleaning agents, while others have been developed to act as barriers against environmental factors like wind and heat. Some products are mixtures, used for medicinal purposes, and require a different understanding of body chemistry and chemical interaction. The production of these substances on a commercial scale resulted from developments in chemical technology and an understanding of the different properties of chemicals and of chemical interactions. These products include a range of different types of substances, mixtures and polymer molecules.

Many products are applied to the hair and skin, to keep them clean or offer some protection from the elements. These products are designed to take into account the properties of water and alcohol, as solvents, and numerous aspects of body chemistry. The different types of chemical substances and how they are combined to make mixtures depend upon their specific physical and chemical properties. The types of products used, and the ways in which they are used, have changed over time and are continuing to change as people become more aware of the environmental and health impacts of some of the synthetic substances produced.

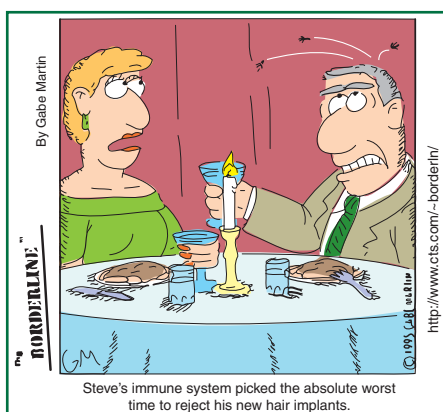


Figure 1.1 Lifestyle chemistry

OUTCOMES

By the end of this chapter, you should be able to:

- explain how the use of a substance depends on its physical and chemical properties
- describe a wide range of cleaning products that are made from colloids and surfactants
- explain how cleaning products used on the human body must be compatible with the physical and chemical properties of the skin
- describe how the nature of a solvent plays an important role in the application of a mixture
- explain how the solubility of drugs has an effect on the way in which the body responds to them.

You should also be able to:

- measure the pH of the skin and a range of products used on the skin
- identify what chemical and physical properties of a range of everyday products make them useful to people
- prepare suspension and colloid mixtures
- demonstrate the properties of surface tension in water
- use diagrams to demonstrate the effects of surfactants on the surface tension of water.

People use a wide variety of consumer products every day, but rarely think of the chemistry involved. In this chapter, you will learn about the physical and chemical properties of a variety of substances, such as surfactant cleaners, degreasers, lubricants, pesticides, solvents, metal cleaners, body hygiene chemicals, cosmetics and pharmaceuticals.

1.1 Physical and chemical properties of substances

Australian homes are full of chemicals (Figure 1.2). In the kitchen, bathroom, laundry and garden shed, a large range of chemical substances can be found, all of them designed to be used for specific purposes. Some of these chemicals are potentially dangerous. Every day we use chemicals to make cleaning jobs easier, to beautify our surroundings, to control dangerous pests and to maintain our homes. Although there are millions of chemical compounds, they can be broadly grouped according to their use and some of these groups include: surfactant cleaners, degreasers, lubricants, pesticides, solvents, metal cleaners, body hygiene chemicals and cosmetics. In this chapter we will look at why the physical and chemical properties of each of these groupings makes them so useful to people.



Figure 1.2 Chemicals at home Australian homes are full of chemicals.

Chemicals used in the home

Detergents Surfactants are the main ingredients in detergents. They are synthetic chemicals which help water to wet a dirty surface and lift dirt off it. Other ingredients soften water, break up fatty substances, prevent the redeposition of dirt and add fragrance. Common products made with detergents include washing powders, washing up detergents, shampoos, shower gels and surface-cleaning products.

Lubricants reduce friction and wear between moving surfaces. Lubricants are usually oil-based and are used in engines and other machines where moving parts rub together. They may be liquid (oil) or solid (grease).

Pesticides are materials that are able to selectively kill an animal considered to be a nuisance. They use varieties of complex chemicals and may be classified

by the type of animal killed, the way they act or the chemical group to which they belong. Table 1.1 shows some of the ways pesticides can be classified.

Table 1.1 Pesticides can be classified in a variety of ways

Group	Classification of pesticides
Type of animal killed	<ul style="list-style-type: none">• Insecticides (ants, cockroaches, aphids, flies)• Rodenticides (rats and mice)• Aracides (spiders, mites and ticks)
Method of working	<ul style="list-style-type: none">• Stomach poison (animal must eat it)• Contact poisons (absorbed through the cuticle)• Fumigants (gases – breathed in)
Chemical grouping	<ul style="list-style-type: none">• Inorganic chemicals (e.g. copper and arsenic compounds)• Chlorinated hydrocarbons (e.g. DDT, dieldrin)• Organophosphorus chemicals (e.g. malathion)• Nitrogenous chemicals• Plant based insecticides (e.g. pyrethrum, nicotine)

Many pesticides are accumulated in the food chain and thus cause environmental concern. Some insecticides, such as DDT, are less effective than when first introduced, because many species have developed greater resistance to them.

Solvents are liquids in which we can dissolve another substance, which is then called the **solute**. The resulting mixture is a **solution**. The solvent molecules are able to surround the solute molecules and prevent them from rejoining. Ordinarily, when we say a substance is soluble, we are referring to its ability to dissolve in water. In fact, water is often referred to as the universal solvent because so many substances dissolve in it. However, there are many other solvents we use everyday – mineral turpentine (turps) to dissolve paints and dry-cleaning spirit and pre-wash stain removers to remove oil and grease stains from clothing.



Figure 1.3 Tarnish Metal cleaners remove corrosion.

Being able to dissolve one substance in another is an important factor in the use of pesticides, drugs and cleaning products. The general rule that chemists use to predict solubility is that like dissolves like. Ionic substances (where a positive ion is bonded with a negative ion) and polar substances dissolve in polar solvents like water and alcohol. Non-polar substances dissolve in non-polar solvents such as mineral turpentine, petrol, carbon tetrachloride and hexane.

Metal cleaners are used to remove tarnish from metals such as stainless steel, copper, brass and silver (Figure 1.3). Tarnish dulls the surface of metals and makes them less attractive. It results from the reaction of the metal substances, such as oxygen, in the air. This type of chemical reaction is called corrosion. Copper forms a layer of greenish copper carbonate (CuCO_3), and silver tarnish is silver sulfide (Ag_2S). Some metal cleaners contain chemicals such as phosphoric acid and thiourea which dissolve the metal oxide, exposing fresh, shiny metal underneath. Other metal cleaners contain abrasives, which remove the tarnished layer using small particles of grit. These products are not suitable for use on plated items such as silverware, which contain only a thin layer of silver on a base metal. Metal cleaners also contain detergents and corrosion inhibitors to slow further tarnishing.

Body hygiene chemicals and cosmetics is a term which covers a large range of products including skin-care products, fragrances and aftershave lotions, hair-care products, nail-care products, toothpastes and mouthwashes, soaps and sunscreens. These products are often solutions or suspensions, but colloid mixtures are the most common. Many of these products clean oil and dirt from the body and therefore contain surfactants. These substances are discussed in more detail in Units 1.3 and 1.4.

Pharmaceuticals are chemical substances which alter the biochemical processes in our bodies in ways which lead to an improvement in health. These substances cover an enormous range of chemicals, and their chemical properties influence the wide variety of methods used to administer them. These substances are discussed in more detail in Unit 1.5.



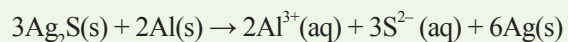
Activity Cleaning silver



Silver tarnish forms when sulfur in the air reacts with silver to form black silver sulfide. This compound discolours silver objects and reduces their attractiveness. Since the layer of silver on most silver-plated objects is very thin, it is best not to polish off the silver sulfide, as eventually no silver plate will remain. The chemical reaction that formed the tarnish can be reversed, turning the silver sulfide back into silver and sulfur.

1. Line the base of a ceramic or plastic container with aluminium foil. Cover the foil with boiling water to a depth of about 3 cm.
2. Add three teaspoons of sodium hydrogen carbonate (NaHCO_3 – baking soda).
3. Lay the silver to be cleaned in the container so it is touching the foil. The silver will be clean in several hours.

The reaction involved is:



Safe use and handling of chemicals

Most of the chemicals used in products around the home are safe as long as the product is used correctly. Some of the chemicals involved, such as solvents or propellants, may be dangerous if misused while others, such as enzymes may cause skin or eye irritation. Manufacturers' instructions may include warnings about the safe use of the product around flames, that the product should not make contact with the skin or eyes, that the product should be used in a well-ventilated area and not inhaled, or any special instructions regarding disposal.

Many cleaning agents are toxic to people and the environment. The majority of household poisonings are due to the inhalation of cleaning products. Most of these problems could be avoided if the instructions and warning labels were read before use.

Table 1.2 shows some common chemicals used in household products which require particular care when handling.

Table 1.2 Precautions with household products

Type of chemical	Precautions needed
Ammonia	Is a common ingredient in many cleaning products. People with chronic respiratory problems should not expose themselves to ammonia as it causes irritation to the eyes, nose and lung membranes. Adequate ventilation is required when using cleaning products containing ammonia.
Bleach	Contains sodium hypochlorite and is not a dangerous chemical if used appropriately with skin protection and adequate ventilation. Problems arise when people do not read the warning labels and mix bleach with other cleaning products, especially those containing ammonia. The reaction produces toxic fumes which are readily inhaled.
Disinfectants	Kill bacteria which may be pathogenic (disease-causing). The problem is that harmless and useful 'good' bacteria are also killed. Humans need to be exposed to a large range of bacteria in order to develop healthy immune systems. Householders should not aim to create a germ-free environment, so many 'antibacterial' products are unnecessary.
Enzymes	Are used in laundry powders to assist in the breakdown of stains. Enzymes can trigger asthma or allergic reactions in some people. Products containing enzymes are often labelled 'biological detergents'. Wear gloves to avoid skin contact if sensitive to these chemicals.
Lubricants	Mostly found in the garage or garden shed. Generally flammable to some degree. They may also be poisonous, especially to children. They can also cause eye irritation. As such they should be out of reach of children, and preferably under lock and key. Wash hands after use.
Pesticides	Found in the garage, garden shed and kitchen. Toxic so avoid inhaling and wash hands after use. Keep out of reach from children. If in a spray-can, hydrocarbon propellants can be flammable.
Phosphates	Are found in detergents and washing powders. If too many phosphates enter the waterways then pollution occurs. The excess phosphates add nutrients to the water and this can lead to algal blooms and eutrophication. Substitutes for phosphates can be used. Look for labelling on detergent products indicating that the product is low phosphate or phosphate free.
Sodium hydroxide (caustic soda)	Is found in drain and oven cleaners. Sodium hydroxide is an extremely dangerous eye and skin irritant. Gloves, eye protection and good ventilation must be used when using products containing this chemical.
Solvents	Are present in most household products. Many solvents, such as those found in pre-wash stain removers, nail polish and paint products, are volatile. Volatile solvents are absorbed through the skin or can be inhaled and can be harmful in large quantities. They can also be highly flammable. Skin protection and adequate ventilation are required when using volatile solvents.

Poisons are toxic substances that have an effect on the body, either by impairing normal senses or by injuring body organs. Many household chemicals are poisons and children aged under four are the group at most risk from accidental poisoning. Poisons may include prescription or over-the-counter medicines, household cleaning products, solvents such as petrol or kerosene, perfumes and aftershaves, insecticides and weedkillers, paints, plants, and car products. Each of these different types of poisons has different effects on the body, and so the treatment required in each case can vary. This makes it difficult to give general advice on treatment, so the first course of action should always be to call for advice from a doctor or the Poisons Information Centre.

Poisons may be inhaled, injected (in the case of insect stings), or absorbed through the skin. Most commonly, poisoning in the home is caused by a toxic substance

being swallowed. Symptoms of poisoning include vomiting, convulsions, drowsiness, unconsciousness or stomach pains. If a soluble poison has been ingested, the patient should not be given Ipecac or any liquids before advice has been sought and must not be made to vomit as patients often choke on the vomit. If the poison swallowed was acidic or alkaline (caustic), then the patient should be made to swallow a small amount of water to dilute the poison. Vomiting acids and alkalis can cause severe chemical burns and too much water can induce vomiting. If the poison swallowed was an organic solvent like petrol, kerosene or mineral turpentine, then vomiting can cause the poison to enter the lungs. Milk can settle the stomach and help keep the poison down if it was a shampoo or detergent.

The Poisons Information Centre gives first aid information over the telephone when poisoning has