WORKBOOK

FIRST EDITION
Rhys Lewis

SACE STAGE 2
Australian Curriculum

Chemistry

SASTA
South
Australian
Science
Teachers
Association

Publishing Information
This publication has been created to support the teaching and learning of SACE Stage 2 Chemistry in South Australia.

Published by the South Australian Science Teachers Association Inc.
249 Henley Beach Road, Torrensville SA 5031 AUSTRALIA
Telephone: +61 8 8354 0006
Fax: +61 8 8354 0008
Email: office@sasta.asn.au
Website: www.sasta.asn.au

ISBN 978-0-9953841-5-6

First Edition 2018

Cover Design: Jane McLean Design

Acknowledgements: Tanya Kalm (p6), Designua (p6, 364, 427), NASA/GSFC (p17), vladsilver (p21), udaix (p29), Dobermaraner (p32), Ethan Daniels (p32), Martyn Jandula (p35), tanewpix (p98), Laguna Design (p350), Dr Morley Read (p365), KYTan (p371), margouillat photo (p371), Smileus (p372), STUDIO M (p372), Stcokr (p373), lloyd thornton (p373), Juergen Faelchle (p383), petratrollgrafik (p383), NASA (p384), Igor Petrushenko (p419), Zern Liew (p426), Eye of Science (p496).

Copyright Information

Contents

Ocean acidification is caused by the ocean absorbing higher levels of carbon dioxide from the atmosphere.

- Describe and write equations to show how carbon dioxide lowers the pH of the oceans.

The world's oceans contain 50 times more carbon dioxide than the atmosphere. Carbon dioxide is cycled between oceans and the atmosphere of Earth (Figure 1.12).

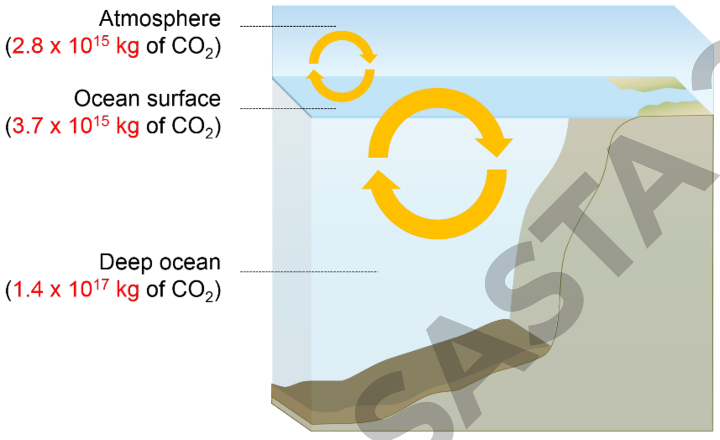


Figure 1.12: Cycling of carbon dioxide between the atmosphere and ocean.

Chemical reactions occur when carbon dioxide enters the oceans and is absorbed by seawater.

1. Carbonic acid (H_2CO_3) is formed when carbon dioxide reacts with seawater.

	CO_2	$+$	H_2O	$\rightleftharpoons$	H_2CO_3

2. Hydrogencarbonate ions (HCO_3^-) are formed when carbonic acid ionises in seawater.

	H_2CO_3	$+$	H_2O	$\rightleftharpoons$	HCO_3^-	$+$	H_3O^+

3. Carbonate ions (CO_3^{2-}) are formed when hydrogencarbonate ions undergo ionisation in seawater.

	HCO_3^-	$+$	H_2O	$\rightleftharpoons$	CO_3^{2-}	$+$	H_3O^+

Ocean acidification

The pH of the oceans decreases as hydronium ions (H_3O^+) are formed. A decrease in the pH of the oceans is called **ocean acidification**. Ocean acidification is occurring due to the increased emissions of carbon dioxide from anthropogenic sources. The hydronium ion concentration of the ocean has increased by 25-30% since the beginning of the Industrial Revolution (1750).

The skeletons and shells of many marine organisms are made of calcium carbonate and are vulnerable to dissolution at low pH.

- Write equations for carbonates reacting in acidic conditions.

Calcifying organisms are organisms that use calcium carbonate ($CaCO_3$) to construct shells and skeletons that are needed for survival. Examples of calcifying species in the oceans includes shellfish, pteropods, corals, coralline algae and calcareous plankton. Calcifying organisms obtain carbonate ions (CO_3^{2-}) from seawater to synthesise calcium carbonate.

$$Ca^{2+}_{(aq)} + CO^{2-}_{3\,(aq)} \rightarrow CaCO_{3(s)}$$

The concentration of carbonate ions in seawater decreases with pH (Figure 1.13).

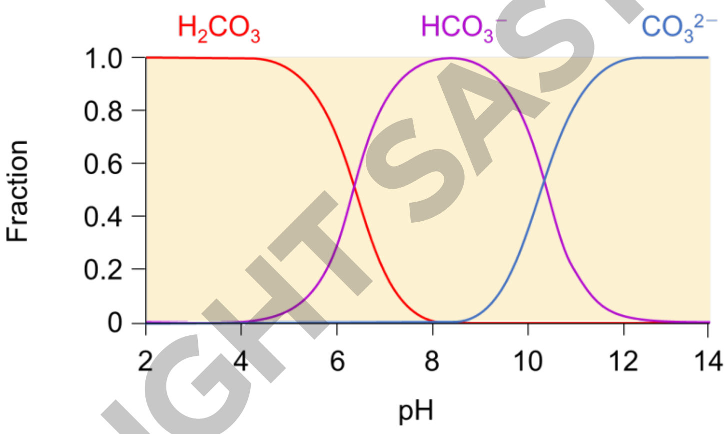


Figure 1.13: Fractions of carbon-containing species at varying pH.

A decrease in the growth rate of calcifying organisms will occur as fewer carbonate ions are available to synthesise calcium carbonate. Furthermore, calcium carbonate is dissolved by acidic species (denoted as H^+) in seawater.

$$CaCO_3 + 2H^+ \rightarrow Ca^{2+} + CO_2 + H_2O$$

Ocean acidification: Consequences

Calcifying organisms play an essential role in the oceanic ecosystem. Calcareous plankton are photosynthetic microorganisms that form the basis of the oceanic food web. A reduction in the population size of these essential microorganisms will destabilise the food web leading to a reduction in the population sizes of higher organisms such as fish and other forms of seafood.

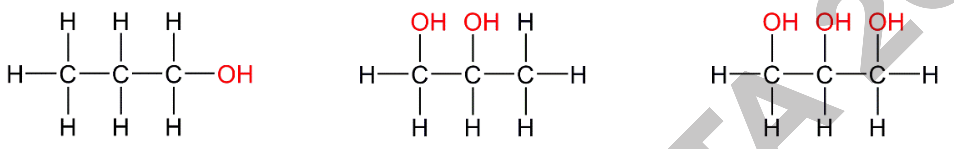
Corals are marine animals that build skeletons from calcium carbonate. Coral reefs are a habitat for 25% of all marine life on the planet. This marine life will be displaced as more coral is dissolved by rising concentrations of acidity in the oceans.

3.2: Alcohols

Identify, name systematically, and draw structural formulae of alcohols containing:

- up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms, and;
- one or more hydroxyl groups.

Alcohols are a homologous series of organic compounds. Alcohol molecules have one or more hydroxyl (OH) functional groups (Figure 3.13).



propan-1-ol propane-1,2-diol propane-1,2,3-triol

Figure 3.13: Simple alcohols.

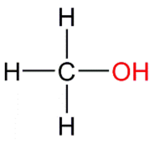
Systematic naming of alcohols

A simple method for naming saturated alcohols (single bonds between carbon atoms) is to firstly identify the alkane analogue* of the alcohol. The “e” is removed from the name of the alkane and the suffix *~ol* is added.

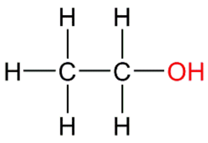
*The term alkane analogue refers to the alkane which has the same number of carbon atoms as the alcohol.

Examples

The alcohols below are present in the mixture known as methylated spirits.



(a)



(b)

Alcohols are named using the following steps.

1. State the name of the alkane that corresponds to the number of carbon atoms in the parent (longest) carbon chain.
2. Remove the “e” from the ending.
3. Conclude with the suffix *~ol.*

(a)	methanol	(b)	ethanol

Oxidation of alcohols

Primary and secondary alcohols are distinguished from tertiary alcohols by reaction with an acidified (H^+) solution containing dichromate ($Cr_2O_7^{2-}$) ions.

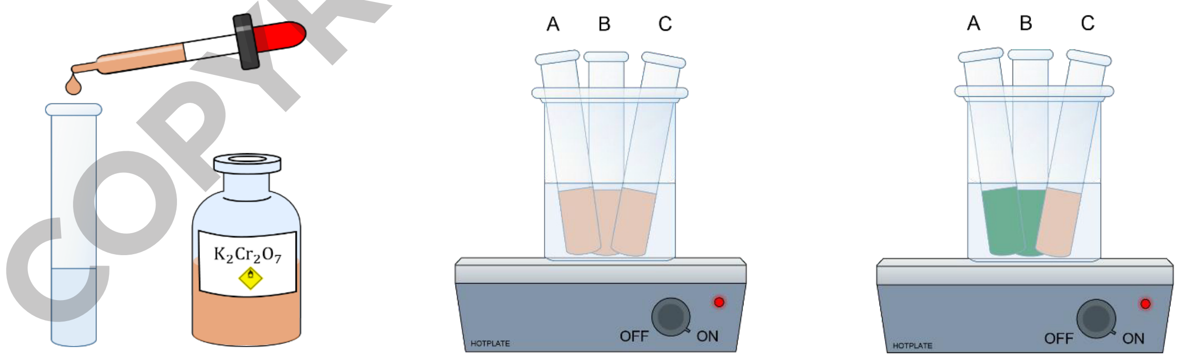
- Primary and secondary alcohols are reducing agents that undergo oxidation in an acidic solution containing dichromate ions.
- Electrons are transferred to dichromate ions in the acidic solution which reduces dichromate ions to chromium(III) ions.

$$Cr_2O_7^{2-} \quad + \quad 14H^+ \quad + \quad 6e^- \quad \rightarrow \quad 2Cr^{3+} \quad + \quad 7H_2O$$

The colour of an acidified dichromate solution changes from orange to green when reacted with a primary or secondary alcohol. The green colour is due to the presence of chromium(III) (Cr^{3+}) ions. No colour change is observed when acidified dichromate solution is reacted with a tertiary alcohol.

Organic compounds undergo oxidation through the loss of one or more hydrogen atoms. A hydrogen atom is removed from the alpha carbon when a primary and secondary alcohol undergo oxidation. Tertiary alcohols do not have a hydrogen atom attached to the alpha carbon and cannot undergo oxidation.

A simple laboratory test that is used to distinguish primary and secondary alcohols from tertiary alcohols is described in Figure 3.20.



Acidified dichromate solution is transferred to three separate test tubes, each containing a different alcohol (primary, secondary or tertiary).	The three test tubes are transferred to a beaker containing warm water. Test tube C contains a tertiary alcohol in this example.	The colour of the solutions in test tubes A and B changes from orange to green as the primary and secondary alcohols undergo oxidation.

Figure 3.20: Simple laboratory test to distinguish between alcohols.

Photovoltaic (solar) cells

A solar cell is a material that transforms (electromagnetic) energy from sunlight into electrical energy in the form of an electric current. Electrical energy is produced by the interaction between sunlight and electrons in the semiconductor material in a solar cell (Figure 4.16).

- Photons in sunlight transfer energy to electrons in a semiconductor material such as silicon.
- The electrons transition to an excited state and are removed from the material, creating an electric current (electricity).
- No greenhouse gases are produced during the operation of a solar cell.

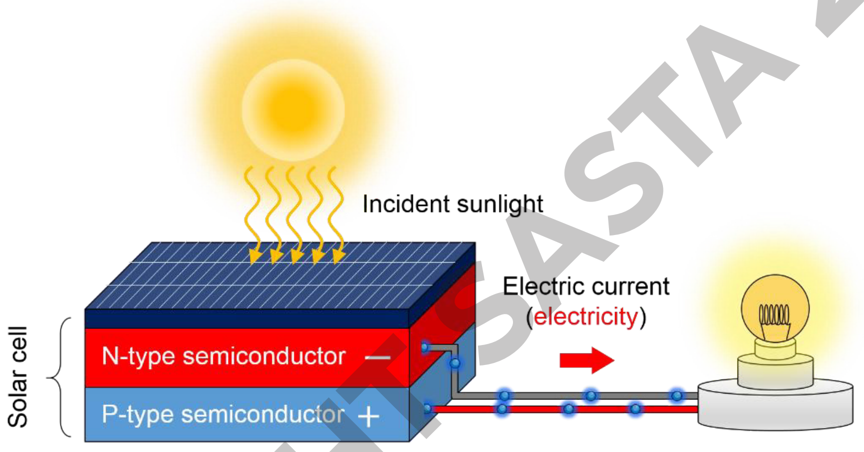


Diagram not to scale

Figure 4.16: Basic design of a photovoltaic (solar) cell.

Galvanic cells

Galvanic cells (Figure 4.17) are electrochemical cells that transform chemical energy into electrical energy by simultaneous redox reactions occurring at different electrodes.

- Electrons are removed from a reducing agent at the anode (oxidation).
- The electrons travel to the cathode and are gained by an oxidising agent (reduction).
- The flow of electrons from anode to cathode through an external circuit is an electric current.

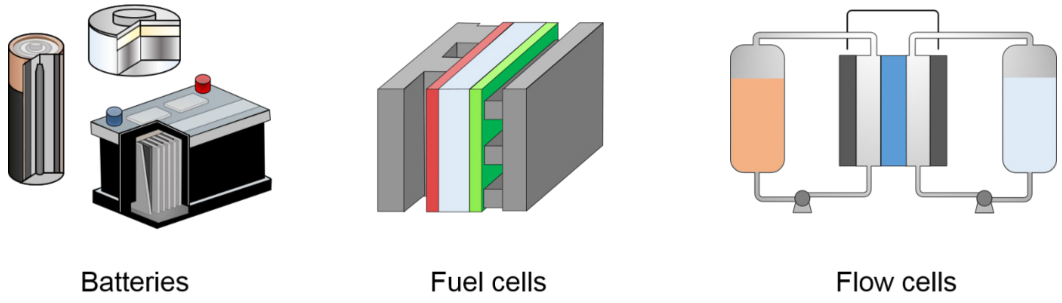

Batteries Fuel cells Flow cells

Figure 4.17: Galvanic cell types.

Conventional water treatment

Conventional water treatment involves many stages that are carried out in a water treatment facility. A brief description of each stage is provided in the table below.

Stage	Process	Description
1	Coagulation	A process used to neutralise charges on silicate particles forming larger particles that will settle or be filtered.
2	Flocculation	The process of agitation that encourages the larger particles to flocculate into masses large enough to settle or be filtered from solution.
3	Sedimentation	Sediments in water are left to settle for several hours before transferring the water to a filtration tank. Sediments are treated before disposal.
4	Filtration	Water passes through several filters that remove impurities.
5	Disinfection	Water is treated with a disinfectant to kill microorganisms. The disinfectant may be a chemical agent or UV radiation.
6	Storage	Treated drinking water is stored in tanks to deliver water effectively during periods of increased domestic or rural consumption.

Figure 4.21 shows the steps described in the table above.

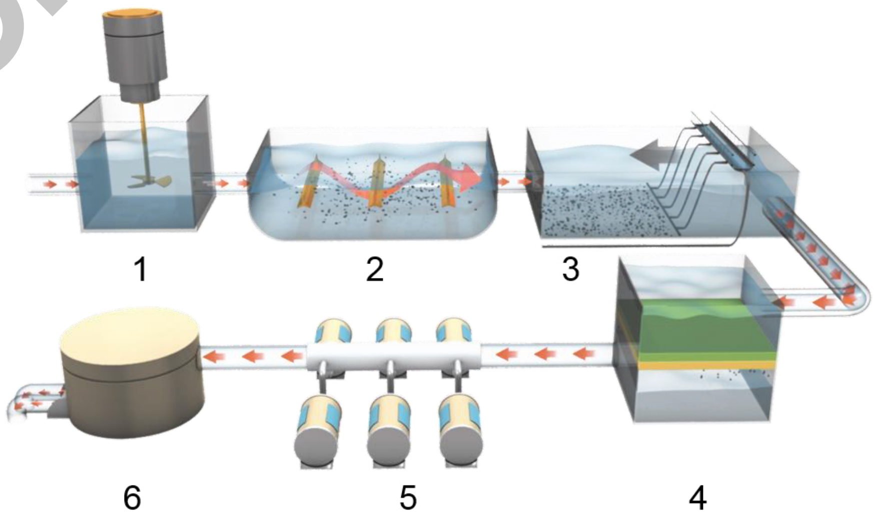


Figure 4.21: Treatment of raw water.

Composite materials comprise two or more constituent materials to produce a material with properties different from the individual components.

- Explain the advantages using of composite materials.
- Explain the difficulties associated with recycling materials and objects comprising two or more different materials with different properties.

A composite material is prepared by combining (physically) two or more materials that have different properties. The properties of the composite material are unique and are not present in any individual component.

Composite materials may be **natural** or **synthetic**.

Composite	Examples	Composition
Natural	Wood	Lignin and cellulose
	Bone	Calcium hydroxyapatite and collagen
Synthetic	Concrete	Cement, gravel, and sand
	Brick	Silica and alumina

Structure of composites

Most composites are a combination of two materials: **matrix** and **reinforcement**.

- The matrix (binder) is the central material that gives bulk to the composite. The matrix may be a metal, ceramic or polymer.
- The reinforcement is the material that is embedded in the matrix. The reinforcement material (particles or fibres) is distributed throughout the matrix material (Figure 4.50).

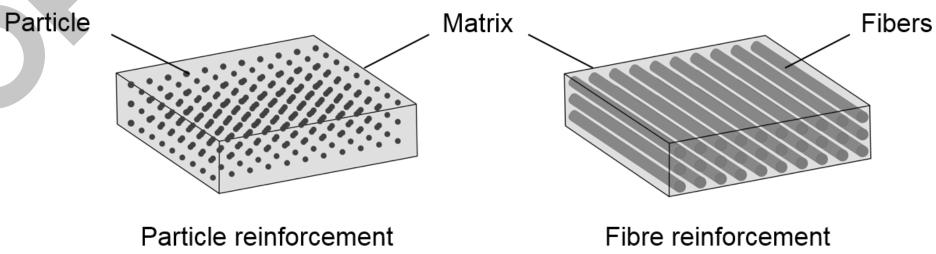


Figure 4.50: Composite materials with different reinforcements.

Reinforcement	Description
Particles	Particles of the reinforcement are distributed randomly in the matrix.
Fibre	Thin fibres of reinforcement material are woven into or distributed randomly in the matrix.