PEARSON CHEMISTRY

QUEENSLAND

STUDENT BOOK

11

UNITS 1 & 2

Pearson

Contents

ONLINE CHAPTER

Chapter 1 Chemistry Skills and Assessment toolkit

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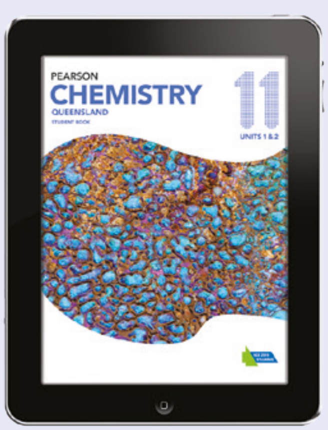


Unit 1 Chemical fundamentals—structure, properties and reactions

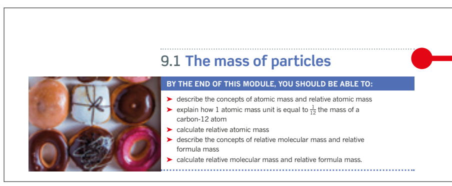
How to use this book

PEARSON CHEMISTRY 11 UNITS 1 & 2 QUEENSLAND

Pearson Chemistry 11 Queensland has been written to the new QCE Chemistry Syllabus. The book is an easy-to-use resource that covers Units 1 & 2 as well as comprehensively addresses the Skills and Assessment.
Explore how to use this book below.

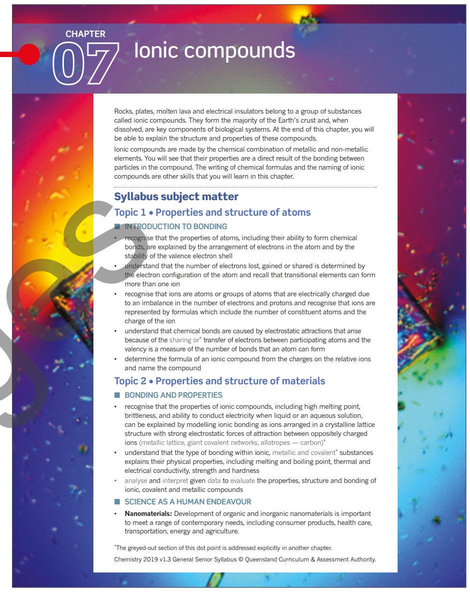
Design

Featuring best-practice literacy and instructional design, this series supports all learners with careful scaffolding of concepts and defined learning objectives.
A simple to navigate, predictable design enables ease of use. The high-quality, relevant photos and illustrations assist student understanding of concepts.



Chapter opener

The Syllabus subject matter addressed in each chapter is clearly listed, along with any Science as a Human Endeavour features and Mandatory Practicals.

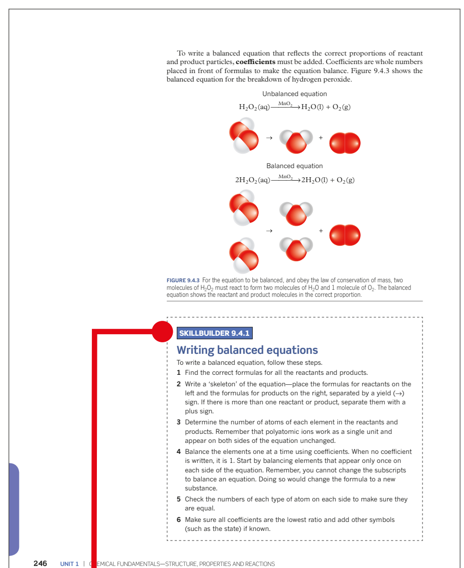


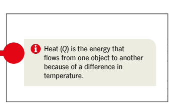
Module opener

Module openers outline the key concepts and skills developed and link to syllabus subject matter listed in the Chapter opener.

Science as a Human Endeavour

The SHE features provides an opportunity to appreciate the development of science and its use and influence on society.
The SHE features provide a segue into the development of claims and research questions for the Research Investigation. Questions are included to help students formulate ideas and delve more deeply into the concepts.





Highlight box

Highlight features focus students' attention on important information such as key definitions, formulas and salient points.

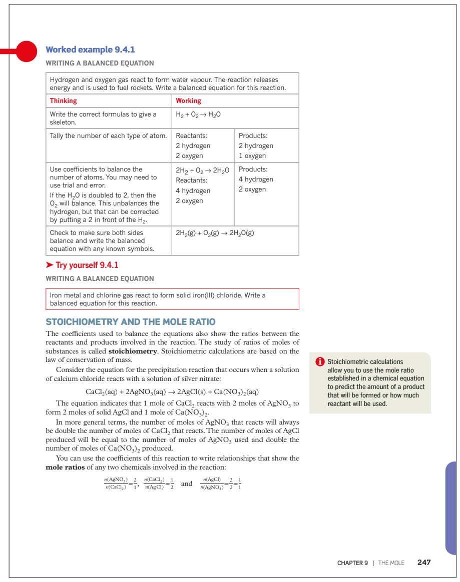
Skillbuilder

A Skillbuilder outlines a method or technique. Each is instructive and self-contained. Skillbuilders step students through the skills to support science application required when analysing or utilising knowledge.

Worked Examples

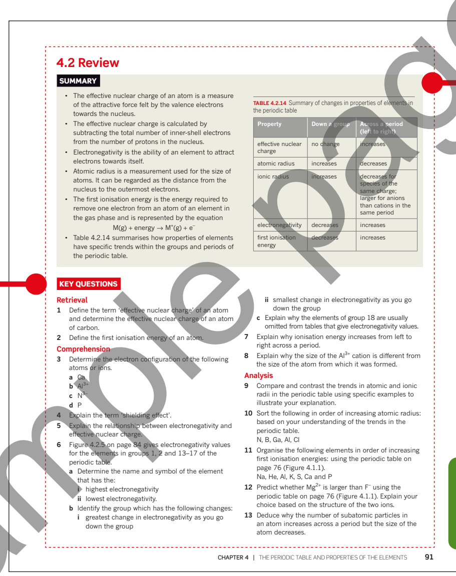
Worked Examples use sequential steps of thinking and working. This research-based approach greatly enhances student understanding and application of formulas to subject matter. Each Worked Example is followed by a Try Yourself task where students apply their learning to a mirrored problem to practise the skill.

Fully worked solutions to all Try Yourself problems are available on *Pearson Chemistry 11 Queensland* Teacher Support.



Module review

Each module finishes with key questions to test students' understanding and ability to recall the key concepts of the module. Questions are carefully categorised under the relevant cognitive level—Retrieval, Comprehension or Analysis—and are developed to assess the syllabus requirements.

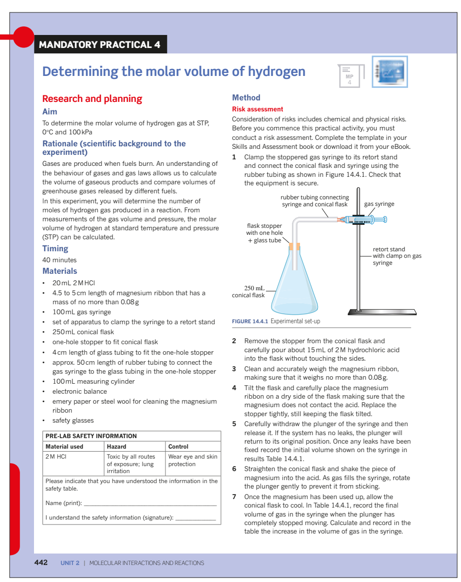


Module summary

Each module concludes with a summary to help students consolidate the key points and concepts.

Mandatory practicals

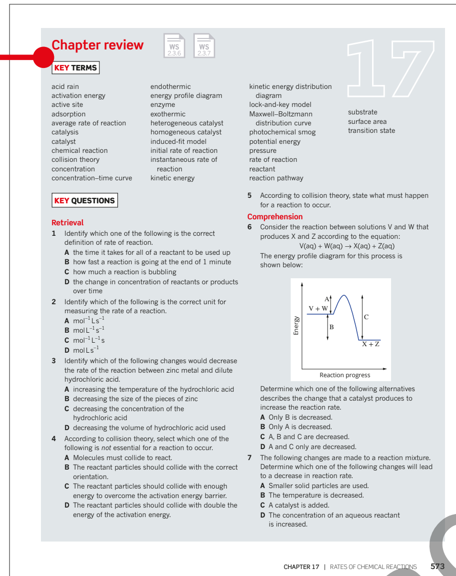
All Mandatory practicals are included in the Student Book and have been comprehensively developed to ensure they fully address the syllabus requirements. Each practical has been trialled and tested to ensure it can be safely performed and yields effective results, and includes a depth of questions and applications that enable students to develop and demonstrate required manipulative skills.



How to use this book

Chapter review

Each chapter finishes with a list of key terms covered in the chapter and a set of questions to test students' abilities to apply the knowledge gained from the chapter.



Icons

Go To icons make important links to relevant content within the student books in the course. The Go To icons indicate where to engage with Chapter 1 in your eBook.

Every Mandatory practical is supported by a complementary **SPARKlab** alternative practical.

The ***Pearson Chemistry 11 Skills and Assessment Book*** icons indicate the best time to engage with an activity for practice, application and revision. The type of activity is indicated as follows:

Worksheet (WS)

Practical Activity (PA)

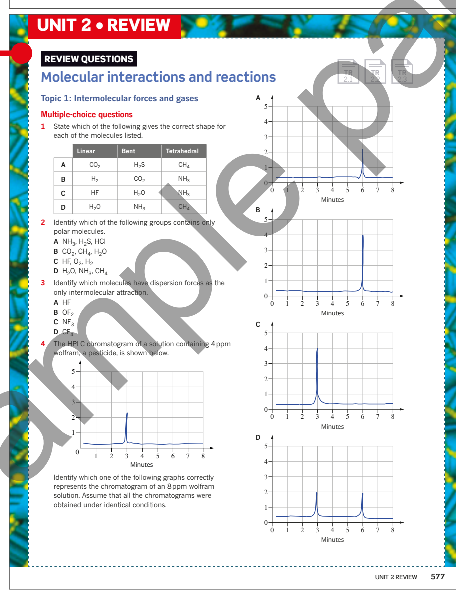
Mandatory Practical (MP)

Sample Assessment Task (SAT).

The **Reader+** icon indicates when to engage with an asset via your reader+ eBook. Assets may include videos and interactive activities.

Unit review

Each Unit concludes with a comprehensive set of exam-style questions, including multiple choice and short answer, that assist students to draw together their knowledge and understanding of the whole Unit.



Glossary

Key terms are shown in **bold** throughout the Student Book and are listed at the end of each chapter. A comprehensive glossary at the end of the book defines all the key terms. The glossary aligns with the syllabus context and includes the QCAA defined terminology.

Answers

The Teacher Reader+ eBook provides comprehensive answers and fully worked solutions for all module reviews, Try yourself, Science as a Human Endeavour, chapter reviews and Unit reviews.

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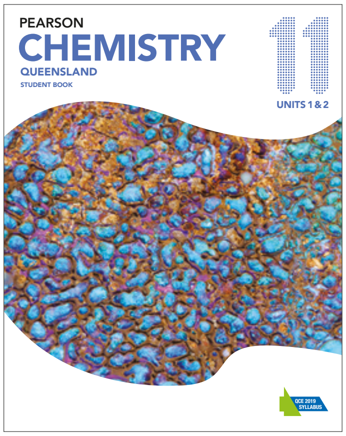


Student Book

Pearson Chemistry 11 Units 1 & 2 Queensland has been developed by experienced Queensland teachers to address all the requirements of the new QCE Chemistry 2019 Syllabus. The series features the very latest developments and applications of chemistry, literacy and instructional design to ensure the content and concepts are fully accessible to all students.

Skills and Assessment Book

The *Pearson Chemistry 11 Skills and Assessment Book* gives students the edge in preparing for all forms of assessment. Specifically prepared to provide opportunities to consolidate, develop and apply subject matter and science inquiry skills, this resource features a toolkit, key knowledge summaries, worksheets, practical activities and guidance, assessment practice and exam-style Topic Review sets.

Reader+ the next generation eBook

Pearson Reader+ lets you use your Student Book online or offline, anywhere and anytime, on any device. Pearson Reader+ retains the look and integrity of the printed book.

Teacher Support

Pearson Chemistry 11 Units 1 & 2 Queensland Teacher Support provides:

- complete answers, fully worked solutions or suggested answers to all *Student Book and Skills and Assessment Book* tasks
- mandatory practical expected results, common mistakes, suggested answers and full safety notes and risk assessments
- teaching, learning and assessment programs

CHAPTER

02 Elements, compounds and mixtures

Chemistry is the study of matter: its properties, composition and transformations; how certain types of matter interact with other types of matter; and how matter interacts with energy such as heat, visible light and ultraviolet radiation. In this chapter, you will learn what matter is, the different types of matter that exist and how matter changes from one type to another. You will also recognise that most matter actually exists in impure forms as mixtures of pure substances (elements and compounds) and that these mixtures can take the form of homogeneous mixtures or heterogeneous mixtures. Finally, you will examine how simple physical processes can be used to separate mixtures into their pure components.

WS 1.1.1

Syllabus subject matter

Topic 2 • Properties and structure of materials

COMPOUNDS AND MIXTURES

- recall that pure substances may be elements or compounds
- recognise that materials are either pure substances with distinct measurable properties (e.g. melting and boiling point, reactivity, strength, density) or mixtures with properties dependent on the identity and relative amounts of the substances that make up the mixture
- distinguish between heterogeneous and homogeneous mixtures
- analyse and interpret given data to evaluate the physical properties of pure substances and mixtures.

2.1 Characterising matter

BY THE END OF THIS MODULE, YOU SHOULD BE ABLE TO:

- understand that matter can be characterised by its purity
- understand that most matter you encounter in your everyday life is a mixture of pure substances
- recall that mixtures may be homogeneous or heterogeneous
- recognise that mixtures are materials where the properties are dependent on the identity and relative amounts of the substances that make up the mixture
- recall that pure substances are either elements or compounds
- recognise that pure substances have a definite and distinct set of physical and chemical properties.

Chemistry is the study of **matter**, so it is important to understand the different types of matter that exist. You know from everyday experience that a tree, a rock, a glass of water and a piece of gold are examples of matter. You also intuitively know that there are fundamental differences in the observable properties of trees, rocks, water and gold that tell us that they are different types of matter. However, you can identify some properties common to all types of matter. For example, you can see the effect of matter on other matter; think of the book you are reading or the screen you are viewing; think of the wind on your face, the sand between your toes or the water in your bath tub. All are examples of matter.

Another characteristic feature of matter is that you can measure it. Matter has **mass** and you can measure this **physical property**; matter also occupies space and you can measure its **volume**. The following statement is a good working definition of matter that will suit our purposes for studying chemistry.

> Matter can be described as anything that has mass, occupies space and can be perceived by our senses.

PURITY OF MATTER

Matter can be classified, or characterised, in different ways. One way is to look at the purity of matter. It turns out that most of the matter you encounter in your everyday life—including the food you eat, the air you breathe and the water you swim in—is not chemically pure. Most matter actually consists of **mixtures** or **pure substances**. For example, the air you breathe is a mixture of oxygen and nitrogen with trace amounts of other gases, including carbon dioxide, water vapour and argon. Even tap water may appear to be pure but it actually contains trace amounts of dissolved minerals.

The relationship between pure substances and mixtures is shown in Figure 2.1.1. It shows that the matter you observe in your everyday life is ultimately composed of either **elements** or **compounds**. Collectively, elements and compounds are known as pure substances. Pure substances can be physically combined to produce mixtures. Mixtures can either be **homogeneous mixtures** or **heterogeneous mixtures**. The differences between these two types of mixtures will be discussed in detail in Module 2.2 of this chapter.

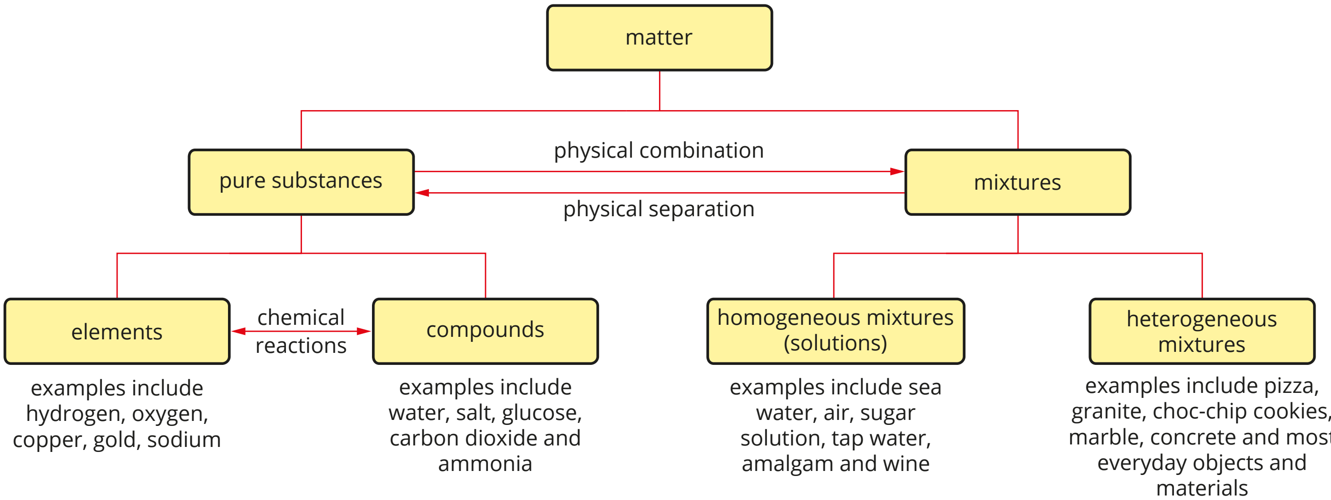


FIGURE 2.1.1 Classification of matter according to purity, showing the relationship between elements, compounds and mixtures

Figure 2.1.2 shows four examples of different types of matter.

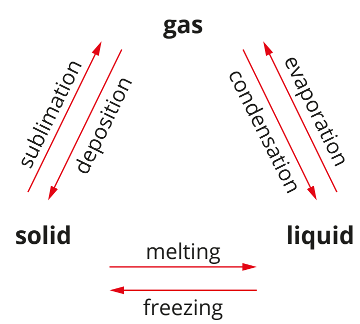
- A slice of pizza (Figure 2.1.2a) contains a mixture of carbohydrates, fats and oils, as well as water and dissolved minerals and nutrients. It is a physical mixture of a wide range of pure substances. It also contains visibly distinct 'chunks' that are different from other parts, such as the pepperoni slices. This gives us the hint that a slice of pizza is a heterogeneous mixture.
- Food colouring dissolved in water (Figure 2.1.2b) is also a physical combination of two or more pure substances and is, therefore, a mixture. In this case, however, there are no distinct 'chunks' of matter that are visibly different from the rest of the coloured solution. The homogeneous nature of a solution of food colouring gives us the hint that it is a homogeneous mixture. Homogeneous mixtures are also known as **solutions**.
- The salt crystal (Figure 2.1.2c) is a pure substance and is not a physical combination of different substances. It is the compound sodium chloride (NaCl) and consists of elements chemically combined in a fixed ratio (i.e. sodium and chlorine in a 1:1 ratio).
- The sample of copper wire (Figure 2.1.2d) is also a pure substance and is an example of an element.

FIGURE 2.1.2 Examples of different types of matter: (a) a slice of pizza (heterogeneous mixture), (b) food colouring dissolved in water (homogeneous mixture and also known as a solution), (c) a salt crystal, which is a pure substance composed of the compound sodium chloride (NaCl) and (d) copper metal, which is an example of an element

PHYSICAL AND CHEMICAL CHANGES IN MATTER

In chemistry, you need to understand how matter can change from one form to another. A change in the form of matter can occur via physical changes and/or chemical changes. Figure 2.1.1 shows that combining pure substances to create mixtures requires a physical change. Separating mixtures into their pure components also requires a physical change. Figure 2.1.1 further shows that to create compounds or to decompose them into their elemental components requires a chemical change or **chemical reaction**.

a



b $H_2O(s) \underset{-\Delta}{\overset{+\Delta}{\rightleftharpoons}} H_2O(l) \underset{-\Delta}{\overset{+\Delta}{\rightleftharpoons}} H_2O(g)$

FIGURE 2.1.3 (a) Processes describing the changes of state between solids, liquids and gases. (b) The melting, boiling, condensing and freezing of water can be represented using chemical formulas and chemical equations. The bracketed letters, (s), (l) and (g), represent the solid, liquid and gaseous states of water. The '+Δ' and '−Δ' symbols refer to the need to 'add heat' or 'subtract heat' to induce the changes of state indicated.

Physical changes in matter

A **physical change** in matter is a process where the form of matter may be changed without changing its chemical identity or its chemical composition. No new substances are formed during physical changes. Cutting a piece of paper, grinding a tablet and bending an iron bar are examples of physical changes.

A change in **physical state** is one of the most important types of physical changes. The melting of ice to produce liquid water or the heating of water to produce gaseous steam are examples of physical changes of state. No new substances are formed in changes of state. The processes involved in changes of state are summarised in Figure 2.1.3a and represented using chemical equations in Figure 2.1.3b.

Chemical changes in matter

Chemical changes of matter (i.e. chemical reactions) involve a change in chemical composition where one or more kinds of matter are transformed into a new kind of matter (or several new kinds of matter). In other words, chemical reactions involve the production of new substances. You can see the results of chemical reactions around you every day. The burning of wood, the spoiling of milk, the digestion of food and the growth of plants via photosynthesis are all examples of chemical reactions.

In simple terms, a chemical reaction can be described as a rearrangement of **atoms**. The combustion of hydrogen (H_2) in the presence of oxygen (O_2) to produce water (H_2O) is one of the simplest chemical reactions. It can be represented using the balanced **chemical equation** below:

$$2H_2(g) + O_2(g) \xrightarrow{\text{heat}} 2H_2O(l)$$

Here two elements, hydrogen (H_2) and oxygen (O_2), chemically combine to produce the compound water (H_2O). The equation is balanced so the four hydrogen atoms and two oxygen atoms on the left-hand side of the equation are rearranged and incorporated into the two water molecules on the right-hand side of the equation.

MIXTURES

As Figure 2.1.1 on page 5 suggests, a mixture is a physical combination of two or more pure substances. This means there can be mixtures of:

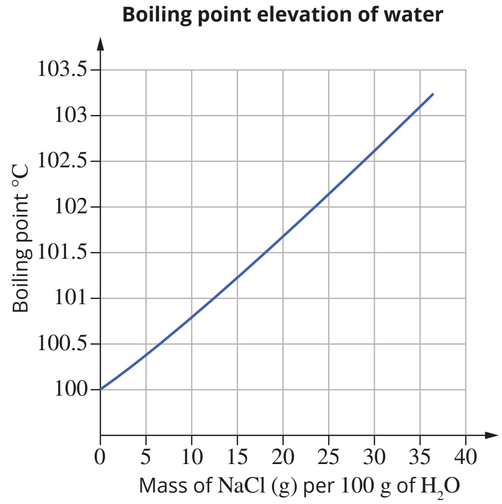
- two or more elements (such as mercury–gold **amalgam**)
- mixtures of two or more compounds (such as salt water)
- mixtures of elements and compounds (such as oxygen dissolved in water).

Figure 2.1.1 also suggests that mixtures such as these can be physically separated into their pure components by simple physical processes. Processes such as cutting, crushing, sieving, filtration, distillation or centrifugation can produce pure substances from complex mixtures. The ability to separate mixtures into their pure components is crucial in many industrial, environmental and biomedical applications. Different separation methods will be discussed in detail in Module 2.3.

Mixtures can vary in composition from sample to sample with different types and amounts of substances being present. Since the composition of mixtures can vary, it follows that the chemical and physical properties of mixtures can also vary depending on the type and amount of substances present.

Figure 2.1.4 shows how the **boiling point** and **freezing point** of water change with small additions of sodium chloride (NaCl). The boiling point of pure water is 100°C and the freezing point of pure water is 0°C. Both change when other substances are mixed with water. The increase in boiling point is known as **boiling point elevation**. The more salt dissolved, the greater the change in boiling point. Likewise, the decrease in freezing point is known as **freezing point depression** and, again, the more salt dissolved, the greater the change in freezing point.

a



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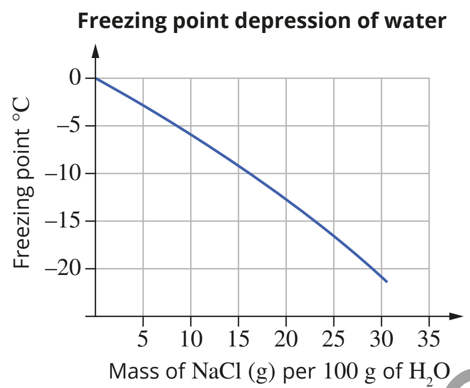


FIGURE 2.1.4 (a) Boiling point elevation—the boiling point of water increases with increasing amounts of NaCl. (b) Freezing point depression—the freezing point of water is lowered with increasing amounts of NaCl.

Changes in physical and chemical properties, like those shown in Figure 2.1.4, are useful for distinguishing between mixtures and pure substances. Mixtures will have different physical and chemical properties depending on the type and amount of substances present. Pure substances, on the other hand, do not vary in composition and therefore do not vary in chemical or physical properties. Some of the chemical and physical properties that can be used when characterising different types of matter are shown in Table 2.1.1.

TABLE 2.1.1 Examples of chemical and physical properties that can be used to characterise different types of matter. These properties can be used to distinguish mixtures from pure substances.

Chemical properties	Physical properties
combustibility/flammability	freezing point
reactivity in water	melting point
reactivity with acids	colour
reactivity with bases	viscosity
oxidisability	density
pH (specifically changes in pH)	solubility
toxicity	electrical conductivity
radioactivity	thermal conductivity
decomposition with heat	malleability/ductility

WS 1.2.2

PURE SUBSTANCES

A pure substance (or simply a substance) is matter that has a definite and distinct set of physical and chemical properties that do not vary in composition from sample to sample. In general, any two samples of matter that have identical chemical and physical properties are said to be the same substance. Therefore, chemical and physical properties (such as those outlined in Table 2.1.1 on page 7) can be used to identify a particular sample of matter. For example, a shiny, silver-coloured metal that has a melting point of 660.3°C, a **density** of 2.70 $g\,cm^{-3}$ and reacts with acid to produce hydrogen gas (H_2) can only be the element aluminium (Al). This is because only aluminium has this definite and distinct set of chemical and physical properties.

There are two types of substances: elements and compounds. As Figure 2.1.1 on page 5 shows, elements combine by chemical reactions to form compounds, while compounds can be decomposed into elements by chemical reactions. Unlike mixtures, substances cannot be separated into other kinds of matter by simple physical processes such as filtration, distillation and centrifugation.

ELEMENTS

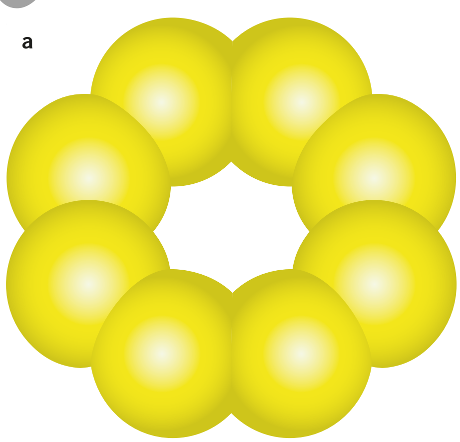
Elements are the simplest form of matter that exists. They cannot be broken down into other substances by simple physical processes, nor can they be broken down into other substances by chemical reactions. Elements are the building blocks of matter since they can combine chemically to form millions of different compounds. The defining feature of elements is that they are substances that contain only one type of atom. The monatomic gases helium (He), neon (Ne) and argon (Ar) are examples of elements; the diatomic **molecules** oxygen (O_2), nitrogen (N_2), hydrogen (H_2) and bromine (Br_2) are also examples of elements; so too are the metals sodium (Na), copper (Cu), aluminium (Al) and iron (Fe).

Most non-metallic elements form molecules with a definite number of atoms. Sulfur, for example, is composed of molecules with eight sulfur atoms (S_8). However, some non-metals form **covalent network lattices** or **giant molecules**. Carbon is an example of such a non-metallic element. Diamond and graphite are both examples of covalent network lattices formed by carbon. Graphene is a giant molecule formed by carbon. (You will learn more about covalent network lattices formed from carbon in Chapter 8.) Representations of the sulfur molecule and a carbon covalent network lattice are shown in Figure 2.1.5. Metallic elements form a different type of network lattice structure, which you will look at in detail in Chapter 6.

Monatomic elements are those made up of only one atom. Diatomic elements are comprised of two atoms. The prefixes *mon* (or *mono*) and *di* are frequently used in chemistry. They mean 'one' and 'two' respectively.

A molecule is a definite and discrete group of atoms chemically bonded together. The atoms in molecules are non-metallic atoms bonded to other non-metallic atoms.

a



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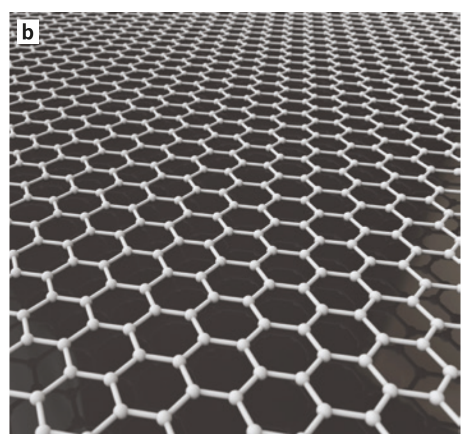


FIGURE 2.1.5 (a) Most non-metal elements, such as sulfur, form molecules. (b) Other elements, such as carbon, form covalent network lattices or giant molecules, given by the example here of graphene.

Element names, symbols and numbers

At present there are 118 known elements, 92 of them naturally occurring, while the other 26 have been synthesised in laboratories and are very unstable. Each element is assigned a unique name and **chemical symbol**. Chemical symbols are typically either a single capital letter (e.g. H for hydrogen) or a single capital letter followed by a lower-case letter (e.g. Ne for neon). Most chemical symbols make sense from their names (e.g. C for carbon or Mg for magnesium). Others symbols make less sense as their symbol may be derived from their Latin name (e.g. Au for gold, from the Latin *aurum*, or K for potassium, from the Latin *kalium*). Table 2.1.2 shows an alphabetical listing of some common elements along with their chemical symbols and some observable physical properties.

TABLE 2.1.2 Alphabetical listing of common elements including names (Latin name in brackets), symbols and physical properties

Element	Chemical symbol	Physical properties
aluminium	Al	silvery metal
barium	Ba	silvery metal
bromine	Br	reddish liquid
calcium	Ca	silvery metal
carbon	C	soft, black solid (graphite)
chlorine	Cl	greenish gas
chromium	Cr	silvery metal
cobalt	Co	silvery metal
copper (cuprum)	Cu	reddish metal
fluorine	F	pale yellow gas
gold (aurum)	Au	soft, yellow metal
helium	He	colourless gas
hydrogen	H	colourless gas
iodine	I	bluish-black solid
iron (ferrum)	Fe	silvery metal
lead (plumbum)	Pb	bluish metal
magnesium	Mg	silvery metal
manganese	Mn	grey metal
mercury (hydrargyrum)	Hg	silvery liquid
neon	Ne	colourless gas
nickel	Ni	silvery metal
nitrogen	N	colourless gas
oxygen	O	colourless gas
phosphorus	P	yellowish solid (white phosphorus)
potassium (kalium)	K	soft, silvery metal
silver (argentum)	Ag	silvery metal
sodium (natrium)	Na	soft, silvery metal
sulfur	S	yellow solid
zinc	Zn	bluish-white metal

Along with a name and chemical symbol, each element is also assigned a number, called the **atomic number**. The atomic number identifies the number of protons in the atom. For our purposes, atomic numbers range from 1 (for hydrogen) up to 92 (for uranium), i.e. the 92 naturally occurring elements. At this stage you should become familiar with the first 20 elements (Table 2.1.3 on page 10).

TABLE 2.1.3 The first 20 elements listed in order of increasing atomic number

Atomic number	Name	Symbol	Atomic number	Name	Symbol
1	hydrogen	H	11	sodium	Na
2	helium	He	12	magnesium	Mg
3	lithium	Li	13	aluminium	Al
4	beryllium	Be	14	silicon	Si
5	boron	B	15	phosphorus	P
6	carbon	C	16	sulfur	S
7	nitrogen	N	17	chlorine	Cl
8	oxygen	O	18	argon	Ar
9	fluorine	F	19	potassium	K
10	neon	Ne	20	calcium	Ca

The periodic table

Figure 2.1.6 shows that elements can be listed in a special way in the **periodic table of elements**. The periodic table groups elements with similar chemical and physical properties into vertical columns called **groups**. Most elements are metals, which appear on the left-hand side of the periodic table, while the non-metals appear towards the upper-right of the periodic table.

You will generally have a copy of the periodic table at hand during your chemistry studies so detailed memorisation is not normally required. However, being able to recall specific information about the first twenty elements or so will be very useful. It is very important to learn how to use the periodic table since it is the most useful tool in chemistry. There are many useful trends in the periodic table that you will learn more about in Chapter 4.

The periodic table is an arrangement of the elements in order of increasing atomic number in which elements of similar chemical and physical properties are placed in vertical columns known as groups.

KEY

Non-metals

Metals

Metalloids

atomic number: 13
symbol: Al
name: aluminium

1 H hydrogen																	2 He helium
3 Li lithium	4 Be beryllium											5 B boron	6 C carbon	7 N nitrogen	8 O oxygen	9 F fluorine	10 Ne neon
11 Na sodium	12 Mg magnesium											13 Al aluminium	14 Si silicon	15 P phosphorus	16 S sulfur	17 Cl chlorine	18 Ar argon
19 K potassium	20 Ca calcium	21 Sc scandium	22 Ti titanium	23 V vanadium	24 Cr chromium	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga gallium	32 Ge germanium	33 As arsenic	34 Se selenium	35 Br bromine	36 Kr krypton
37 Rb rubidium	38 Sr strontium	39 Y yttrium	40 Zr zirconium	41 Nb niobium	42 Mo molybdenum	43 Tc technetium	44 Ru ruthenium	45 Rh rhodium	46 Pd palladium	47 Ag silver	48 Cd cadmium	49 In indium	50 Sn tin	51 Sb antimony	52 Te tellurium	53 I iodine	54 Xe xenon
55 Cs caesium	56 Ba barium	57–71 lanthanoids	72 Hf hafnium	73 Ta tantalum	74 W tungsten	75 Re rhenium	76 Os osmium	77 Ir iridium	78 Pt platinum	79 Au gold	80 Hg mercury	81 Tl thallium	82 Pb lead	83 Bi bismuth	84 Po polonium	85 At astatine	86 Rn radon
87 Fr francium	88 Ra radium	89–103 actinoids	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadtium	111 Rg roentgenium	112 Cn copernicium	113 Nh nihonium	114 Fl flerovium	115 Mc moscovium	116 Lv livermorium	117 Ts tennessine	118 Og oganesson

Lanthanoids	57 La lanthanum	58 Ce cerium	59 Pr praseodymium	60 Nd neodymium	61 Pm promethium	62 Sm samarium	63 Eu europium	64 Gd gadolinium	65 Tb trebium	66 Dy dysprosium	67 Ho holmium	68 Er erbium	69 Tm thulium	70 Yb ytterbium	71 Lu lutetium
Actinoids	89 Ac actinium	90 Th thorium	91 Pa protactinium	92 U uranium	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fremium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium

FIGURE 2.1.6 The periodic table groups elements according to their chemical and physical properties.

COMPOUNDS

Compounds are substances formed from two or more elements in which the elements are always combined in the same fixed proportion. This means the composition of compounds does not vary, no matter how much of the compound there is. Water is a compound in which hydrogen and oxygen are always combined in the ratio of 2:1 and is represented by the **chemical formula** H_2O.

A chemical formula is a shorthand notation that uses elemental symbols from the periodic table, with numerical subscripts to convey the relative proportions of atoms of the different elements in the compound. You will note that the oxygen atom in the formula H_2O has no subscript. When an element in a chemical formula has no subscript, the subscript is presumed to be the number one.

Compounds are substances that can be broken down by chemical reactions to form other substances. To determine whether a pure substance is an element or a compound, you must determine if the substance can be broken down into elements. For example, when heated, mercury(II) oxide (HgO) decomposes to liquid mercury (Hg) and oxygen gas (O_2) (Figure 2.1.7). If it were not a compound, the mercury(II) oxide would not break down. As oxygen is a colourless gas, you cannot see it.

FIGURE 2.1.7 The red powder in this test-tube is mercury(II) oxide (HgO). If you look closely at the test-tube, you will see beads of liquid mercury forming from the decomposition of the compound.

Types of compounds

There are two major types of compounds: **molecular compounds** and **ionic compounds**. Molecular compounds are composed of molecules all of which are alike and have non-metallic elements chemically bonded to other non-metallic elements in a fixed ratio. They tend to have relatively low boiling points and melting points. Examples of common molecular compounds include water (H_2O), methane (CH_4), ammonia (NH_3), benzene (C_6H_6), ethanol (C_2H_6O) and carbon dioxide (CO_2). Note how each example contains only non-metallic elements.

Ionic compounds form when metallic elements bond to non-metallic elements. Ionic compounds are composed of **ions** arranged in a rigid three-dimensional lattice. They contain positively charged ions (called **cations**) and negatively charged ions (called **anions**), which are attracted to each other by the electrostatic attraction of charges of opposite sign. They tend to have relatively high melting points and boiling points compared to molecular compounds. Examples of common ionic compounds include sodium chloride (table salt, NaCl), calcium carbonate (limestone, $CaCO_3$) and calcium oxide (lime, CaO). Note how each example contains a metallic cation and a non-metallic anion.

You will look at ionic compounds and molecular compounds in more detail in Chapters 7 and 8.

2.1 Review

SUMMARY

- Matter can be characterised and classified according to its purity.
- Pure substances are materials with definite and distinct chemical and physical properties.
- Mixtures are physical combinations of pure substances whose properties are dependent on the identity and relative amounts of the substances that make up the mixture.
- Changes in matter are brought about by physical changes or chemical changes: physical changes do not produce new substances; chemical changes result in the formation of new substances.
- Pure substances may be elements or compounds.
- Every element has a unique name, atomic number and chemical symbol.
- Elements are organised into the periodic table.
- Compounds are formed from two or more elements combined in the same fixed proportion.
- Molecular compounds are composed of non-metals bonded to other non-metals.
- Ionic compounds are composed of metals bonded to non-metals.

KEY QUESTIONS

Retrieval

1 Define the term 'matter'.

2 Name two types of:

a mixtures

b pure substances.

3 Describe a physical change in matter.

4 Define a pure substance.

5 Identify the common name of each of the following elements from its Latin name.

a ferrum

b kalium

c argentum

d plumbum

e hydrargyrum

6 Define the term 'compound' and list the two major classes of compounds.

7 Select the correct terms to complete the following sentence.

Molecular compounds/ionic compounds are composed of non-metals bonded to non-metals, whereas *molecular compounds/ionic compounds* are composed of metals bonded to non-metals.

8 Name two physical properties that could be used to distinguish between these substances.

a water and methanol

b gold and copper

c oxygen gas and chlorine gas

Comprehension

9 Describe the change of state associated with each of the following processes.

a Water is made into ice cubes.

b The inside of your car window fogs up.

c Mothballs in the wardrobe disappear with time.

d Wet washing dries.

10 A certain substance is a silver-grey coloured metal that melts at 420°C. When it is placed in dilute sulfuric acid, hydrogen is given off and the metal dissolves. It has a density of $7.13\,g\,cm^{-3}$ at 25°C and reacts slowly with oxygen to form a metal oxide. Describe the physical and chemical properties of the substance referred to above.

11 Determine if the following is a physical or chemical change.

a A sample of mercury(II) oxide was heated in a reaction vessel to produce mercury metal and oxygen gas.

b A glowing wood splint was thrust into the reaction vessel and the splint burst into flame.

12 Explain the differences between an element, a compound and a mixture.

Analysis

13 The following are properties of a certain element. Classify them as physical or chemical.

a In powdered form, it burns brilliantly on ignition.

b Bulk metal does not react with steam even when red hot.

c It has a density of $1.85\,g\,cm^{-3}$ at 20°C.

d It is a relatively soft, silvery-white metal.

14 Classify each of the following as a physical change or chemical change.
  - **a** the evaporation of water
  - **b** the rusting of iron
  - **c** the grinding of salt crystals into powder
  - **d** the burning of wood in a fireplace

15 Classify each of the following as an element, a compound or a mixture.
  - **a** copper
  - **b** sand
  - **c** water
  - **d** carbon dioxide
  - **e** muddy water
  - **f** sodium chloride
  - **g** gold
  - **h** lemonade

16 About 3.5% (3.5 g per 100 g) of the mass of sea water is the result of dissolved salts, mainly sodium chloride. Determine the freezing point of sea water using the graph in Figure 2.1.4b on page 7.

17 Classify each of the following elements on the periodic table on page 10 as a metal, metalloid or non-metal and represent each element using its chemical symbol.
  - **a** magnesium
  - **b** manganese
  - **c** silver
  - **d** mercury
  - **e** neon
  - **f** arsenic
  - **g** sulfur
  - **h** silicon

18 Classify the following as ionic compounds or molecular compounds using the periodic table on page 10.
  - **a** $NaCl$
  - **b** H_2S
  - **c** PF_3
  - **d** Fe_2O_3

19 Identify an element that has similar physical and chemical properties to potassium, K. Explain your reasoning.

2.2 Homogeneous and heterogeneous mixtures

BY THE END OF THIS MODULE, YOU SHOULD BE ABLE TO:

- distinguish between homogeneous mixtures and heterogeneous mixtures
- understand that the defining feature of a heterogeneous mixture is the presence of visually distinguishable phases that have different physical and chemical properties
- understand that liquid homogeneous mixtures, also known as solutions, are composed of solutes dissolved in a solvent.

You have already noted that most samples of matter are not chemically pure and consist of a physical combination of two or more pure substances called a mixture. You have also noted that there are two types of mixtures—homogeneous mixtures and heterogeneous mixtures.

> The terms **homogeneous** and **heterogeneous** have Greek origins: *homo*, meaning 'same', *hetero*, meaning 'different', and *genes*, meaning 'of a kind'. Homogeneous therefore translates to 'of the same kind' and heterogeneous translates to 'of a different kind'.

In some instances, mixtures are easily recognised. For example, consider a piece of granite, a choc-chip cookie and salad dressing (Figure 2.2.1). In these examples, you can see that different kinds of substances are present. In other cases, it is not so easy to recognise mixtures. For example, the air you breathe, sea water and sterling silver jewellery (Figure 2.2.2) may all appear to be pure but each consists of different substances. Air is a mixture of elements such as nitrogen (N_2) and oxygen (O_2) combined with compounds such as carbon dioxide (CO_2) and water vapour (H_2O); sea water is mostly a mixture of the compounds water (H_2O) and sodium chloride (NaCl); while sterling silver is a mixture of the elements silver (Ag) and copper (Cu). It is the uniformity of these mixtures and the lack of visibly different materials that makes it hard for us to recognise them as mixtures.

FIGURE 2.2.1 Some examples of mixtures: (a) This sample of granite shows at least three visibly distinct regions—white quartz, orange feldspar and black mica minerals. (b) A choc-chip cookie has at least two visibly distinct regions. (c) Some salad dressings are made from oil and water.

FIGURE 2.2.2 Examples of matter not easily recognised as mixtures. (a) Air is a colourless mixture of nitrogen, oxygen and some trace gases. (b) Sea water is a colourless mixture of salt and water. (c) Sterling silver is a mixture of silver and copper but appears to be a single lustrous silver-coloured metal.

HETEROGENEOUS MIXTURES

The piece of granite, the choc-chip cookie and the salad dressing shown in Figure 2.2.1 are examples of heterogeneous mixtures. These samples of matter are not uniform throughout and you can clearly observe the presence of different types of materials. You also know from experience that the different parts of each of these mixtures have different properties, such as colour, taste and hardness.

Heterogeneous mixtures consist of two or more substances that have visibly distinguishable regions, called **phases**, which have different physical and chemical properties. A heterogeneous mixture is not uniform throughout, so two small samples obtained from different parts of the mixture would be different in composition.

Heterogeneous mixtures may have phases in the same physical state or in different physical states. Granite is a heterogeneous mixture of three solid phases—the white quartz mineral (i.e. silica, SiO_2), the orange feldspar mineral and the black mica mineral. The oil and water phases of salad dressing are also both in the same physical state—the liquid state. On the other hand, a sample of muddy water consists of solid dirt particles physically mixed with liquid water.

You will see in Module 2.3 that the different phases in a heterogeneous mixture can be readily separated using simple mechanical separation techniques.

A phase is a region of matter that is physically and chemically uniform in composition and properties. It is physically distinct from other regions of matter and is mechanically separable from other phases.

HOMOGENEOUS MIXTURES

Homogeneous mixtures consist of a physical combination of two or more substances but have only one visibly distinct phase which has uniform properties. A homogeneous mixture is uniform throughout and samples taken from different parts of the mixture would be identical in composition. The air, sea water and sterling silver shown in Figure 2.2.2 are all examples of homogeneous mixtures where only one visibly distinct phase is observable.

Many homogeneous mixtures are also called solutions and have one substance dissolved in another. The substance present in the greatest amount is called the **solvent** and all other substances present in the mixture are called **solutes**. Solutes are said to be dissolved in the solvent.

The most common solutions you will encounter in your chemistry studies will be solid salts dissolved in liquid water (for example, sea water). The salts are the solutes and the water is the solvent. A solution in which water is the solvent is given the special name of an **aqueous solution**—the name being derived from the Latin *aqua*, meaning 'water'. Examples of some common solutions are shown in Table 2.2.1, which shows that solutions can involve mixtures across all three states of matter.

TABLE 2.2.1 Examples of common solutions

Example	States of matter involved	Solvent	Solute(s)	Physical appearance
air	gas–gas	nitrogen	oxygen, carbon dioxide, argon, water vapour	clear colourless gas
soft drinks	liquid–gas	water	carbon dioxide gas	coloured liquid
vinegar	liquid–liquid	water	ethanoic acid	clear colourless liquid (white vinegar)
sea water	liquid–solid	water	sodium chloride plus other trace salts	clear colourless liquid
sterling silver	solid–solid	silver	copper	lustrous silver-coloured solid metal

Even though any single sample of a homogeneous mixture will be uniform throughout, the composition may vary from sample to sample, depending on the relative ratio of the substances in the solution. For example, two samples of salt water may be prepared by dissolving, firstly, one gram of salt in a litre of water and then, secondly, 10 grams of salt in a litre of water. Both salt water samples will be homogeneous throughout but each sample will have different physical and chemical properties including density, electrical conductivity and boiling point.

You will see in Module 2.3 that the different components of a heterogeneous mixture are often separated using techniques that involve a change of state.

2.2 Review

SUMMARY

- Most matter is not chemically pure and consists of a physical combination of two or more pure substances that form a mixture.
- Mixtures can be classified as heterogeneous mixtures or homogeneous mixtures.
- Heterogeneous mixtures have two or more visibly distinguishable regions, called phases, which have different physical and chemical properties. They are not uniform throughout.
- Homogeneous mixtures may be known as solutions and have only one visibly distinct phase. They are uniform throughout.
- Many homogeneous mixtures are known as solutions.
- Solutions consist of solutes dissolved in a solvent. When the solvent is water, the solution is known as an aqueous solution.
- Both heterogeneous and homogeneous mixtures can vary in composition from sample to sample and therefore can vary in chemical and physical properties.

KEY QUESTIONS

Retrieval

1 **a** Define the term ‘phase’ with respect to heterogeneous and homogeneous mixtures.
  b State how many phases all solutions have.

2 Define the terms ‘solution’, ‘solvent’ and ‘solute’.

3 Indicate all possible answers that apply to each scenario from the list below.

compound	element
heterogeneous mixture	homogeneous mixture

  a a sample of matter that is not uniform throughout
  b a sample of matter that is uniform throughout
  c matter that can vary in composition

4 Name the two different types of mixtures that involve one substance being dissolved in another substance.

Comprehension

5 Explain the difference between a heterogeneous mixture and a homogeneous mixture using suitable examples.

Analysis

6 Classify each of the following as a homogeneous or heterogeneous mixture.
  a muesli
  b sand
  c wet sand
  d vinegar
  e an apple
  f sea water
  g a tree
  h air

7 Differentiate between a *state* of matter and a *phase* of matter.

8 Identify which of the following can have a varied composition. Explain your answer in each case.
  a element **b** compound
  c homogeneous mixture **d** heterogeneous mixture

9 Compare and contrast the variation in composition between a heterogeneous mixture and a homogeneous mixture.

10 Classify each of the following as an element, a compound, a heterogeneous mixture or a homogeneous mixture. For each, write down the different phases present.
  a printing ink solution with tiny particles of carbon black
  b iodine crystals and their vapour
  c a salt solution with salt crystals at the bottom of the flask
  d a blue solution of copper(II) sulfate
  e beach sand

11 Differentiate the following samples of matter containing sodium and/or chlorine by classifying them as elements, compounds, heterogeneous mixtures or homogeneous mixtures.
  a sodium metal
  b chlorine gas
  c sodium chloride crystals
  d sodium chloride dissolved in water
  e table salt (i.e. sodium chloride with added sodium iodide)

12 Identify the following metallic substances as elements or mixtures.
  a brass
  b sterling silver
  c bronze
  d mercury
  e gold
  f iron

2.3 Separating mixtures

BY THE END OF THIS MODULE, YOU SHOULD BE ABLE TO:

- recall separation techniques used to separate both heterogeneous and homogeneous mixtures
- understand that separation techniques use differences in the physical properties of the components to separate them from each other
- understand that separating phases of a heterogeneous mixture involves mechanical separation techniques
- understand that separating components of a homogeneous mixture typically involves a change of state.

Removing impurities from samples of matter or separating mixtures into pure components are crucial processes in many biomedical, environmental and industrial applications. For example, ensuring the purity of pharmaceutical drugs or removing impurities in drinking water supplies have significant health-related consequences.

If you want to separate mixtures, you can generally use the differences in the physical properties of the components of the mixture to separate the components from each other. Since mixtures are physical combinations of substances, relatively simple physical processes can be used to separate them.

SEPARATING HETEROGENEOUS MIXTURES

Heterogeneous mixtures have different phases that are physically distinct and mechanically separable from each other. Depending on the nature of the mixture, mechanical separation can take several forms.

Hand sorting

Hand sorting is perhaps the simplest separation technique and can be used when there are relatively few objects to sort that have differing physical properties such as size, colour and texture. Separating seashells from sand would be a relatively straightforward process that could be done by hand. Similarly, if you needed to isolate the white quartz crystals from a sample of granite, you could use simple physical processes, such as cutting, grinding or crushing, followed by hand sorting—with the aid of a pair of tweezers if required.

FIGURE 2.3.1 Queensland beaches are cleaned by tractors dragging a rotating mesh drum to sieve large objects such as rocks, shells and other rubbish.

Sieving

Sieving can be used as a separation technique if there are many objects to sort and they are of different sizes. Beach-cleaning tractors are used daily on Queensland beaches to sift the sand to remove rocks, shells and rubbish, leaving behind clean sand (Figure 2.3.1). In a similar process, the primary treatment of sewage wastewater uses large rotating mesh screens to screen out (or sieve) large particles or objects, such as food scraps, that are part of the wastewater mixture.

Filtration

Fine grade separation of solids and liquids can be achieved in the laboratory using filter paper and a filter apparatus. In Figure 2.3.2, you can see the result of passing a muddy water sample through a filter apparatus. Muddy water consists of solid particles of dirt and clay suspended in water. During filtration, the solid particles are trapped by the filter paper while the clear liquid water easily passes through, resulting in the separation of the solid and liquid phases. This type of filtration technique is good for separating small samples of undissolved solids from a liquid.

FIGURE 2.3.2 Filtration of muddy water. Solid mud and clay particles suspended in water can be separated from the liquid water by the process of filtration.

PA 1.2.1

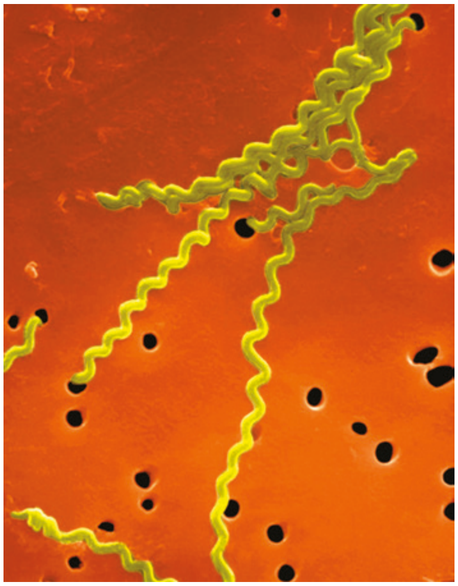


FIGURE 2.3.3 Polycarbonate filter membranes with well-defined pore size allow bacterial cells to be separated from water samples. The bacterial cells shown are the species *Leptospira interrogans*.

Different types of filter paper are used for different types of samples but most are manufactured from ashless paper, nitrocellulose or polycarbonate membranes. They can also be manufactured to separate particles of definite size. Figure 2.3.3 shows a close-up image of a polycarbonate filter membrane with pore sizes of the order of 0.2 μm. This filter membrane will block the passage of particles larger than this size and can effectively sterilise water by filtering bacterial cells from water samples.

Centrifugation

Another way to separate solid particles from liquids is to centrifuge them. **Centrifugation** is a separation technique that uses the centrifugal force of rotational motion to promote rapid settling of solid particles in a heterogeneous solid–liquid mixture. One of the most common uses of centrifugation involves the separation (or fractionation) of blood. Blood samples are placed into centrifuge tubes and rotated at very high speeds (Figure 2.3.4a). The solid components of the blood mixture are forced towards the bottom of the centrifuge tube. The end result is the separation of blood into different fractions with red blood cells settled at the bottom of the tube, white blood cells and platelets forming a layer above the red blood cells, and the liquid blood plasma sitting on top of the other layers (Figure 2.3.4b).

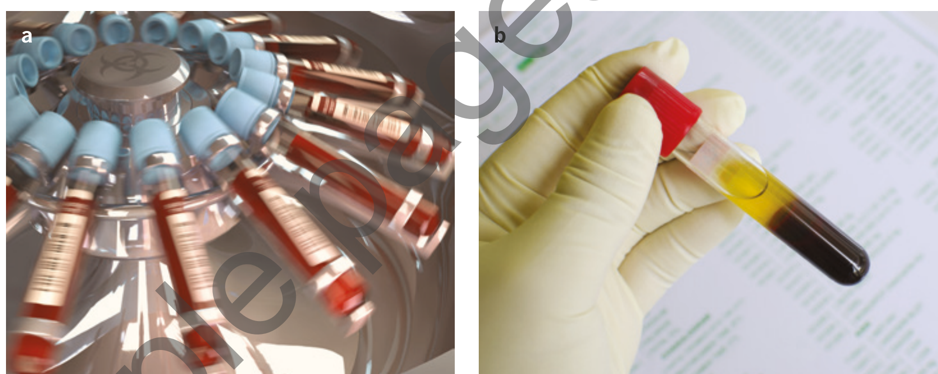


FIGURE 2.3.4 Centrifugation of whole blood is a common technique used in pathology laboratories. (a) Blood samples in centrifuge tubes are placed in a centrifuge and rotated at very high speeds. (b) Blood can be separated into different fractions: red blood cells, white blood cells, platelets and blood plasma.

Flotation

Flotation techniques take advantage of the differences in density of materials to separate heterogeneous mixtures. For example, a mixture of sawdust and sand can be easily separated by placing the mixture in water. The dense sand will sink to the bottom while the less dense sawdust will float on top, allowing it to be skimmed from the surface. This technique is used in the mining industry, in wastewater treatment plants and in paper recycling plants to separate complex mixtures.

Decantation

Decanting is another technique used for separating components of different densities. Decanting involves carefully pouring off the top liquid layer of a heterogeneous mixture. The mixture could be a liquid phase lying over a solid phase or it could be a liquid phase lying over another liquid phase. You can easily separate a mixture of sand and water by decanting the water, leaving behind the sand in the bottom of the container. Similarly, the liquid oil phase of salad dressing is easily decanted from the top of the more dense water layer underneath. Figure 2.3.5 shows that a separating funnel can also be used to separate two immiscible liquids, with the denser bottom layer being drained from the heterogeneous mixture.

FIGURE 2.3.5 A separating funnel is used to separate two immiscible liquids.

Magnetic separation

Magnetic separation can be used to separate heterogeneous mixtures where some components have magnetic properties. Figure 2.3.6 shows that a mixture of fine sand and iron filings can be readily separated using a magnet.

FIGURE 2.3.6 A magnet is used to separate iron filings from the non-magnetic sand particles.

SEPARATING HOMOGENEOUS MIXTURES

Homogeneous mixtures (or solutions) have one or more solutes dissolved in a solvent with only one visibly distinct phase that has uniform properties throughout. Separating solutions, therefore, requires more sophisticated techniques than the mechanical separation methods used for heterogeneous mixtures. One way to separate solutions is to employ changes of state to take advantage of the differences in boiling points or melting points of the components in the mixture.

Evaporation

As mentioned earlier, the most common examples of homogeneous solutions are solids dissolved in a liquid solvent. Evaporation of the solvent is the most convenient way of removing the liquid component and recovering the dissolved solid. Figure 2.3.7 shows that heating a salt solution will evaporate the water, leaving behind the solid salt. This process takes advantage of the differences in boiling points of the two substances involved.

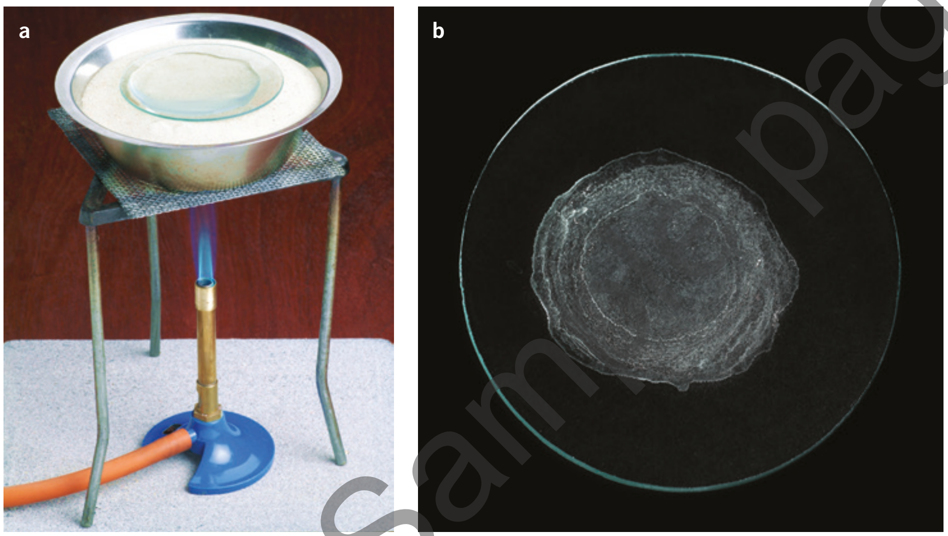


FIGURE 2.3.7 Evaporation of the solvent recovers the solid from a solid–liquid solution. (a) The salt solution is heated to drive off the water. (b) Solid salt residue remains after all of the water has evaporated.

Distillation

If both the solid solute and the liquid solvent need to be recovered then you need to use **distillation**. Distillation is a process of separating mixtures containing a liquid component by first evaporating the liquid to its gaseous state and then condensing it back to its liquid state. Figure 2.3.8 on page 20 shows a diagram of a typical distillation apparatus used in chemistry laboratories. This approach can be used to separate and recover both components of a salt water solution. A flask containing the salt solution is heated so liquid water evaporates. The water vapour is directed through a condensation tube, which is kept cool by a constant supply of cold water. The water vapour condenses to form pure liquid water, which is collected in the receiving flask. When all of the water has evaporated, a layer of pure salt will be retained on the inside surface of the distillation flask. In this way, both the pure salt and pure water are separated and recovered.

Volatility is a measure of how readily a substance will vaporise by going from its liquid state to its gaseous state. In general, substances with lower boiling points have higher volatility.

You can use the same distillation approach for separating a solution of two liquids by taking advantage of the difference in **volatility** and boiling points of the liquids. For example, a solution of ethanol and water could be separated via distillation by evaporating off the more volatile ethanol, leaving behind the higher boiling point water.

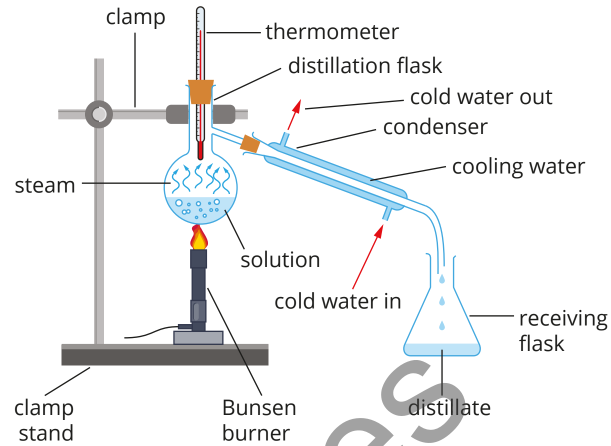


FIGURE 2.3.8 Typical distillation apparatus. A solution is vaporised by heating the distillation flask. Gaseous vapours are condensed in the condenser tube, which is kept cool by a constant supply of water. The pure liquid solvent is collected in the receiving flask and solutes remain in the distillation flask.

Fractional distillation of crude oil

Distillation is also used in one of the most important industrial processes of modern times—the production of petroleum products from crude oil. Crude oil is a complex mixture of different hydrocarbons with different boiling points. The differences in boiling points means that a process of **fractional distillation** can be used to separate and collect the different components (or fractions) of the mixture.

Fractional distillation of crude oil differs from 'normal' distillation in that a tall column, or tower, is situated above the liquid mixture with several condensers coming off at different heights. Figure 2.3.9a shows a typical distillation tower used in oil refineries, while Figure 2.3.9b shows a diagrammatic representation of the fractional distillation process used for crude oil. In this process, high temperature oil enters the distillation column at the bottom. As the mixture is vaporised it rises up the column and cools down with increasing height. Different components of the crude oil will condense at different temperatures, and therefore at different heights. Substances with high boiling points will condense at the high temperatures experienced at the bottom of the column; substances with low boiling points will condense at the lower temperatures experienced at the top of the column. Each of the different fractions is captured by condensers located at various heights.

The main fractions of crude oil that are collected include refinery gases (such as propane and butane), gasoline (i.e. petrol), naphtha, kerosene, diesel oil, fuel oil, and a residue containing paraffin wax, various oils and asphalt. Most of these fractions are used as fuels for heating or transport, while others are used as lubricants or in the manufacture of petroleum by-products such as plastics.

a

b

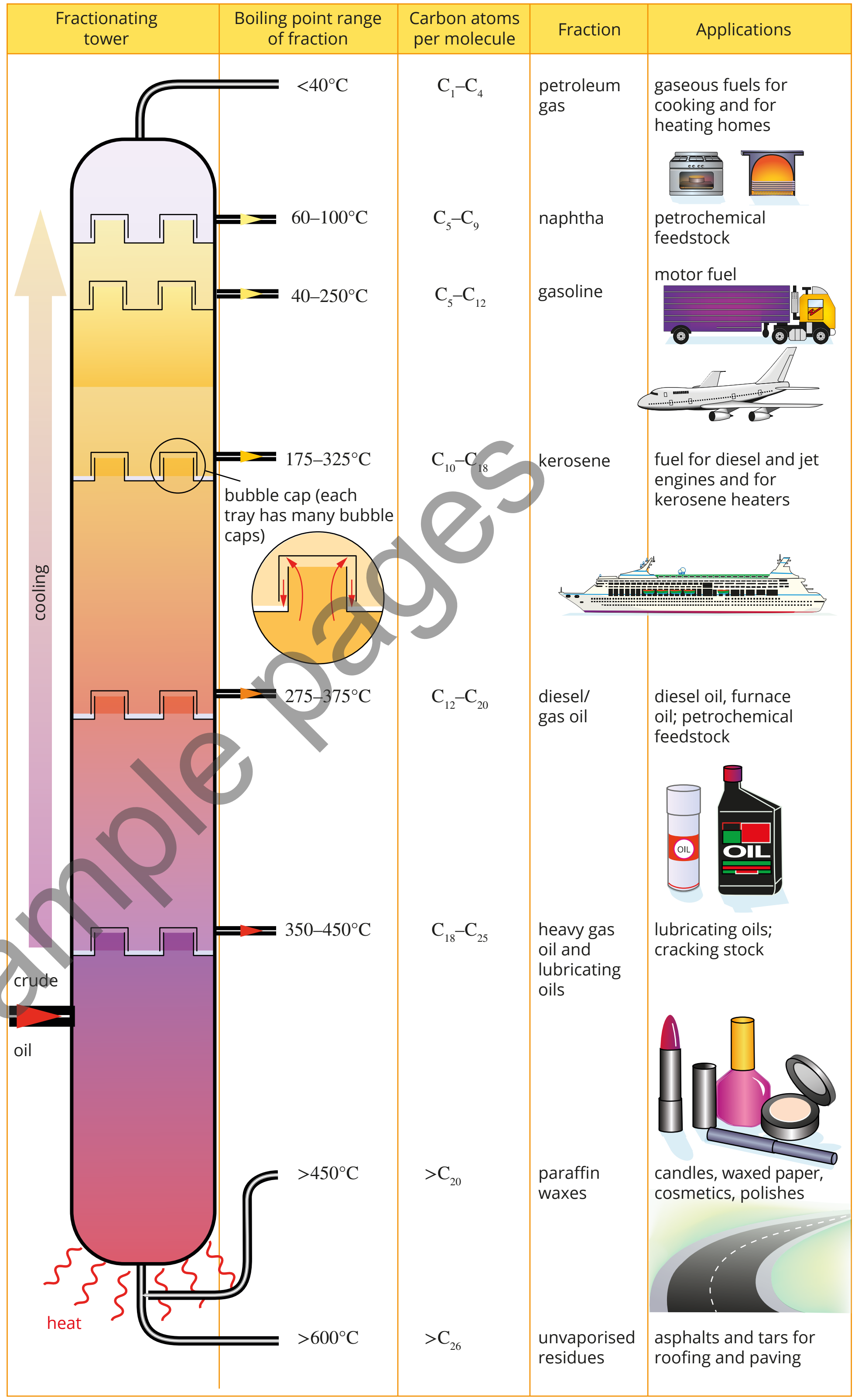


FIGURE 2.3.9 (a) A typical distillation tower used for the fractional distillation of crude oil in oil refineries. (b) A diagrammatic representation of the fractional distillation of crude oil. The crude oil is heated to around 400°C and piped into the bottom of the distillation tower. Different fractions are collected at different levels, depending on their boiling point.

2.3 Review

SUMMARY

- Separating mixtures uses relatively simple physical processes to take advantage of the differences in the physical properties of the components of the mixture.
- Hand sorting is a suitable separation method for mixtures containing a relatively small number of objects with visibly different properties.
- Sieving is a suitable separation method used for large numbers of different-sized particles.
- Filtration, centrifugation and decanting can all be used for separating undissolved solids from a liquid. Decanting can also be used for separating two immiscible liquids.
- Components of mixtures with differing magnetic properties can be separated using magnetic forces.
- Evaporation is a method for separating dissolved solids from the liquid solvent in a solid–liquid solution.
- Distillation is a suitable method for recovering both components of a liquid–solid solution.
- Distillation can also be used for separating two liquids with different boiling points.
- Fractional distillation is a method for separating complex mixtures of components with differing boiling points.

KEY QUESTIONS

Retrieval

1 Separating mixtures involves taking advantage of differences in the physical properties of the components that make up the mixture. Name one physical property that could be used to distinguish between the main components of these mixtures.
 a wine (main components are water and ethanol)
 b sterling silver (main components are silver and copper)
 c air (main components are oxygen gas and nitrogen gas)

2 Name the type of mixture that is separated into its constituent components by these processes.
 a sieving
 b filtration
 c flotation
 d distillation
 e evaporation

3 Recall the circumstances under which you would decant a mixture to separate its components.

4 Name the separation techniques that take advantage of differences in density.

Comprehension

5 Explain the physical properties you would take advantage of to separate the following mixtures. State the separation techniques you would employ.
 a iron filings and sand
 b salt and water
 c water and ethanol

6 Explain under what circumstances you would use distillation to separate an aqueous salt solution instead of simply evaporating the solvent.

7 Show your understanding of separation techniques by matching each scenario to the most appropriate technique.

Separation technique	Scenario
a sieving **b** filtration **c** evaporation **d** separating funnel **e** distillation **f** fractional distillation **g** centrifugation	**i** separation and recovery of each component in a complex aqueous solution of several different alcohols **ii** production of sea salt from salt water **iii** isolation of suspended solid particles from the Brisbane River water for laboratory analysis **iv** separation of the layers in an oil–water based salad dressing **v** separation of seashell fragments from sand **vi** separation and recovery of both components of a salt solution **vii** separation of the different fractions of whole blood

8 Explain the difference between distillation and fractional distillation when applied to the refining of crude oil.

Analysis

9 Identify the separation techniques that would be best used to separate and recover the following components within mixtures.
 a sand and gravel
 b boiled potatoes from the water they were cooked in
 c boiled rice from the water it was cooked in
 d silt particles from muddy water
 e hydrocarbon components in crude oil
 f salt and water from sea water

10 Compare and contrast the methods of evaporation and distillation for separating the components of a saltwater solution. Describe the advantages and disadvantages of each separation technique.

Chapter review

02

KEY TERMS

amalgam
anion
aqueous solution
atom
atomic number
boiling point
boiling point elevation
cation
centrifugation
chemical change
chemical equation
chemical formula
chemical reaction
chemical symbol
compound
covalent network lattice
decanting
density
distillation
element
fractional distillation
freezing point
freezing point depression
giant molecule
group
heterogeneous
heterogeneous mixture
homogeneous
homogeneous mixture
ion
ionic compound
mass
matter
mixture
molecular compound
molecule
periodic table of elements
phase
physical change
physical property
physical state
pure substance
sieving
solute
solution
solvent
volatility
volume

KEY QUESTIONS

Retrieval

1 Select the response that best describes a sample of matter that has these three characteristics.

- It is uniform throughout.
- It cannot be separated into other substances by physical processes.
- It can be decomposed into other substances by chemical processes.

A a heterogeneous mixture
B a homogeneous mixture
C an element
D a compound

2 Identify the following as either a chemical property or physical property of matter.

a boiling point
b melting point
c combustibility
d toxicity
e density

3 Select the correct terms to complete the following sentence.
A *physical change/chemical change* involves the formation of new substances, whereas a *physical change/chemical change* does not.

4 Name the vertical columns of the periodic table. State their significance.

Comprehension

5 Explain whether the composition of each of the following can vary. Explain your answer in each case.

a element
b compound
c homogeneous mixture
d heterogeneous mixture

6 Determine whether each sample of matter listed is a heterogeneous mixture, a homogeneous mixture or a pure substance.

a iron ore
b copper wire
c wet sand
d distilled water

7 Determine which of the following are pure substances and which are mixtures. For each, list all of the different phases present.

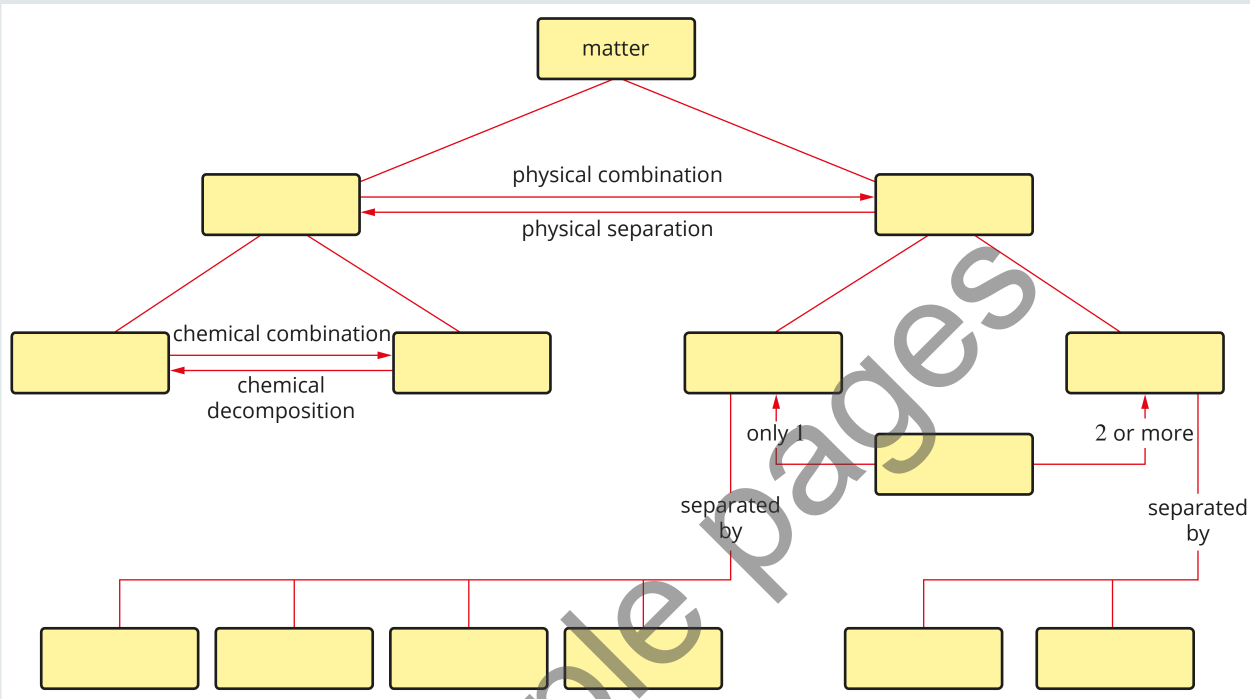
a alcohol and its vapour
b paint, containing a liquid solution and a dispersed solid pigment
c partially molten copper
d a sand containing quartz (silicon dioxide) and calcite (calcium carbonate)

8 The water in the Brisbane River is a mixture of water and suspended silt particles. A sample of Brisbane River water shows that the silt particles slowly settle to the bottom of a measuring cylinder under the action of gravity over a period of days. Describe two methods that could be used to rapidly separate the water and silt particles from the river water sample. Discuss the advantages and disadvantages of each method.

9 Describe the circumstances under which you would use distillation to separate an aqueous salt solution instead of simply evaporating the solvent.

10 Use the following list of terms and chart to complete a concept map that summarises the key ideas and their connections for this chapter.

centrifugation	compound	distillation	elements
evaporation	filtration	heterogeneous mixture	homogeneous mixture
mixture	phases	pure substance	sieving
sorting			



Analysis

11 Classify each of the following pure substances as elements or compounds, based on the information given, or indicate that no such classification is possible because of insufficient information.

a Analysis indicates that substance A contains two elements.

b Substance B decomposes upon heating.

c Heating substance C to 900°C causes no change.

d Heating substance D to 400°C causes it to melt.

12 The following is a description of the element cadmium (Cd). Classify each descriptor as either a physical property or a chemical property.

a It is a bluish-white coloured lustrous metal.

b It has a melting point of 321°C.

c When added to hydrochloric acid the metal dissolves and hydrogen gas is released.

d It is highly toxic and can adversely affect the kidneys, lungs and bones.

e It has a density of $8.65\,g\,cm^{-3}$.

f It has a hardness of 2.0 on the Moh hardness scale.

g If left in air it will form a layer of cadmium oxide (CdO) on its surface.

13 Classify each of the following changes as a physical change or chemical change.

a the evaporation of ethanol

b the rusting of steel

c the grinding of sugar crystals into powder

d the burning of coal in a fireplace

14 Classify each of the following changes as either a physical change or chemical change.

a corrosion of zinc anodes on boats

b the melting of iron in a blast furnace

c the pulverising of a granite sample

d digesting chocolate

e the growth of plants via photosynthesis

f explosion of TNT

15 Compare and contrast elements and compounds.

16 Identify the elements in the following molecular compounds, writing their name, symbol and atomic number.

a water (H_2O)

b ammonia (NH_3)

c benzene (C_6H_6)

d dinitrogen pentoxide (N_2O_5)

e sulfur hexafluoride (SF_6)

17 Identify what you note about the nature of the elements in the compounds listed in Question **16** and what type of compound they are.

18 Identify the elements in the following ionic compounds, writing their name, symbol and atomic number.

- **a** sodium chloride ($NaCl$)
- **b** calcium fluoride (CaF_2)
- **c** aluminium oxide (Al_2O_3)
- **d** copper(I) sulfate (Cu_2SO_4)
- **e** iron(III) carbonate ($Fe_2(CO_3)_3$)

19 Identify what you note about the nature of the elements in the compounds listed in Question **18** and what type of compounds they are.

20 If you light a match under a cold metal spoon you may observe one or more of the following. Classify each observation as a physical change or a chemical change.

- **a** The match burns.
- **b** Carbon soot is produced.
- **c** The metal spoon gets warmer.
- **d** Water condenses on the metal spoon.
- **e** Carbon soot is deposited on the metal spoon.

21 Determine all possible answers for each scenario from the list below.

compound
element
heterogeneous mixture
homogeneous mixture

- **a** matter that cannot be broken down to simpler substances by chemical or physical means
- **b** matter that can be separated into its constituent components by physical processes
- **c** matter that can be separated into its constituent components by chemical processes

22 Classify each of the following as a mixture or pure substance. If it is a mixture, indicate if it is heterogeneous or homogeneous.

- **a** tomato juice
- **b** a laptop
- **c** chocolate-chip ice cream
- **d** air
- **e** bromine liquid
- **f** calcium carbonate
- **g** vinegar

23 Identify the solvent and solute(s) in the following solutions.

- **a** air
- **b** sea water
- **c** vinegar
- **d** white wine
- **e** fish tank water

24 When small amounts of the following solids are mixed with water, determine which mixture is most easily separated into its constituent components. Explain your answer.

copper(II) sulfate, salt, sand, sugar

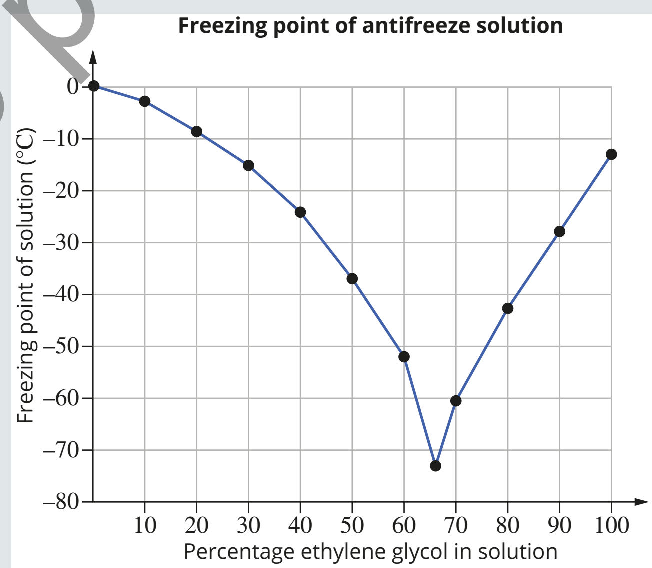
Knowledge utilisation

25 A glass contains a clear, colourless liquid that looks like water. Develop a test to describe how you can be sure that, if it is water, it is pure and does not contain any dissolved salts.

26 Propose how you could differentiate between a piece of pure silver jewellery and a piece of sterling silver jewellery.

27 Ethylene glycol is used as an antifreeze additive in vehicle radiators to stop the radiator water from freezing in cold weather. The lowest ever recorded temperature in Australia is –23.4°C recorded at Charlotte's Pass in the NSW Snowy Mountains on 29 June 1994.

- **a** Decide what percentage concentration of ethylene glycol would be required to be confident that a vehicle radiator would not freeze in Australia using the following graph.
- **b** The lowest recorded temperature in Canberra is –10°C. Determine what percentage concentration of ethylene glycol would be required to be confident that a vehicle radiator would not freeze in Canberra using the following graph.



28 Design a test that would enable you to separate:

- **a** oil and water layers in salad dressing
- **b** rocks from sand.

29 Develop a test that would enable you to separate a mixture of sand and sugar crystals, ensuring you recover both the sand and sugar in their solid states.

30 A bottle of white wine (a mixture of ethanol and water) has been contaminated by dissolved salt, sand and iron filings. Develop an experiment that would enable you to separate and recover all components of the mixture. Present your answer in a visual way such as a concept map or flow chart.