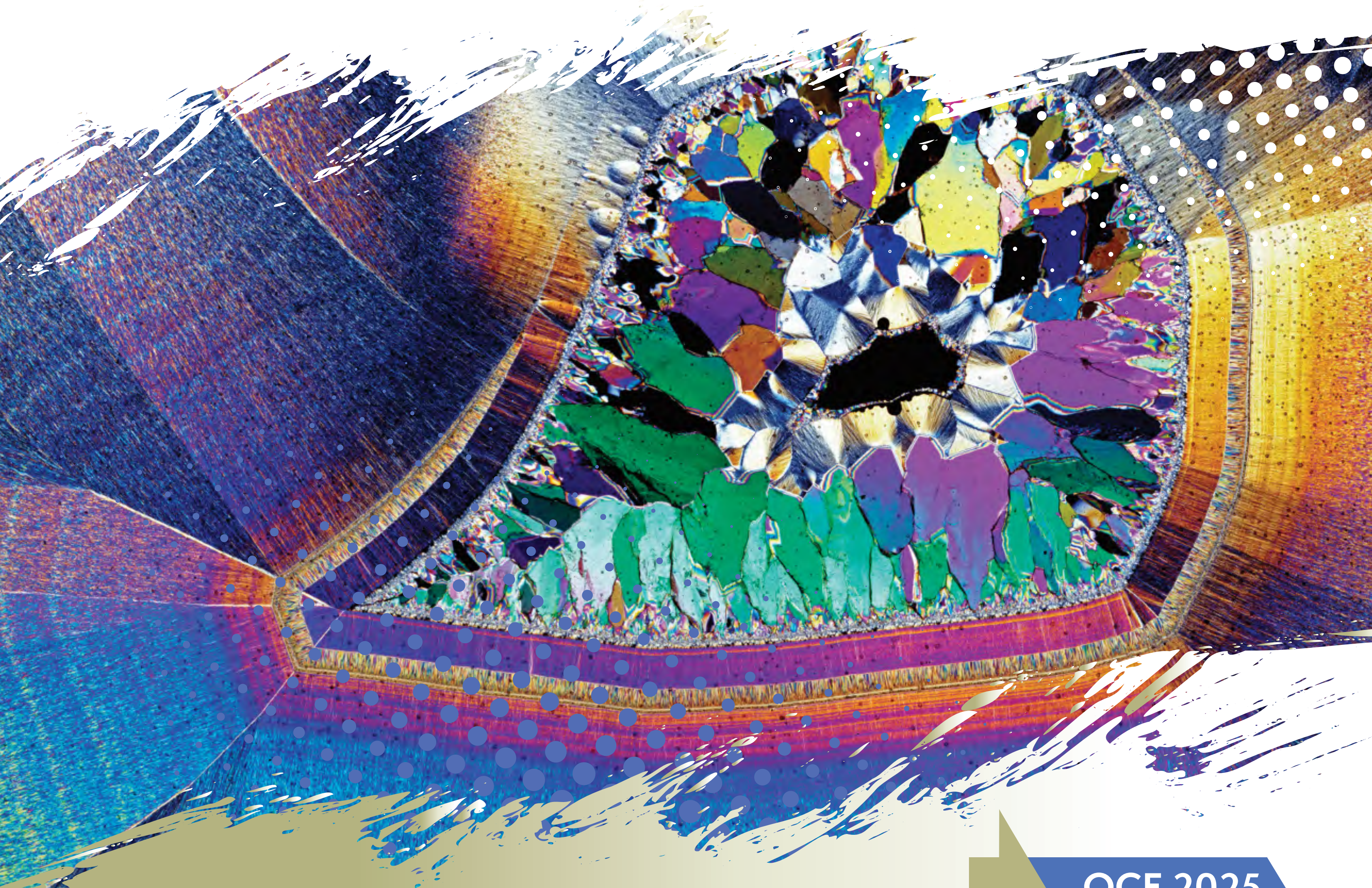
PEARSON CHEMISTRY QUEENSLAND

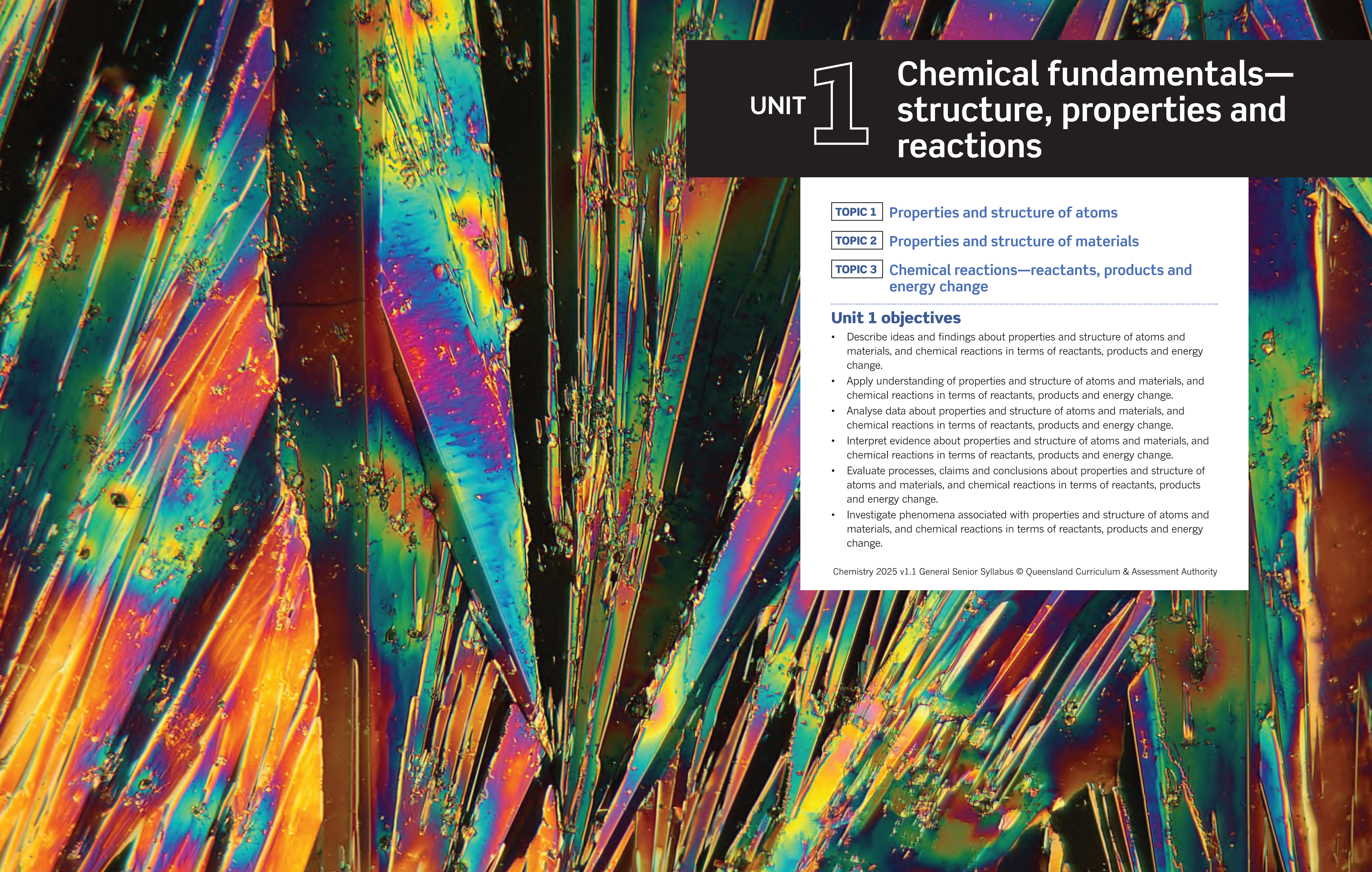
UNITS 1 & 2

2nd EDITION



Student Book

QCE 2025 Chemistry SYLLABUS



UNIT 1 Chemical fundamentals—structure, properties and reactions

TOPIC 1 Properties and structure of atoms

TOPIC 2 Properties and structure of materials

TOPIC 3 Chemical reactions—reactants, products and energy change

Unit 1 objectives

- Describe ideas and findings about properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.
- Apply understanding of properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.
- Analyse data about properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.
- Interpret evidence about properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.
- Evaluate processes, claims and conclusions about properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.
- Investigate phenomena associated with properties and structure of atoms and materials, and chemical reactions in terms of reactants, products and energy change.

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.

Syllabus subject matter

WS 1.1.1

COMPOUNDS AND MIXTURES

- State that pure substances may be elements or compounds. **2.1**
- Identify that pure substances have distinct measurable properties (e.g. melting and boiling point, reactivity, strength, density) and mixtures have properties dependent on the identity and relative amounts of the substances that make them up. **2.1**
- Discriminate between heterogeneous and homogeneous mixtures. **2.2**
- Analyse data to determine the physical properties of pure substances and mixtures. **2.1**

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
- state that pure substances are either elements or compounds
- identify 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** of **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. **Elements** contain only one type of **atom**, for example, oxygen (O_2) or carbon (C). **Compounds** contain two or more elements chemically bonded together, for example, carbon dioxide (CO_2) or sodium chloride (NaCl). 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. **Homogeneous mixtures** are uniform throughout, while **heterogeneous mixtures** are not uniform. The differences between these two types of mixtures will be discussed in detail in Module 2.2 of this chapter.

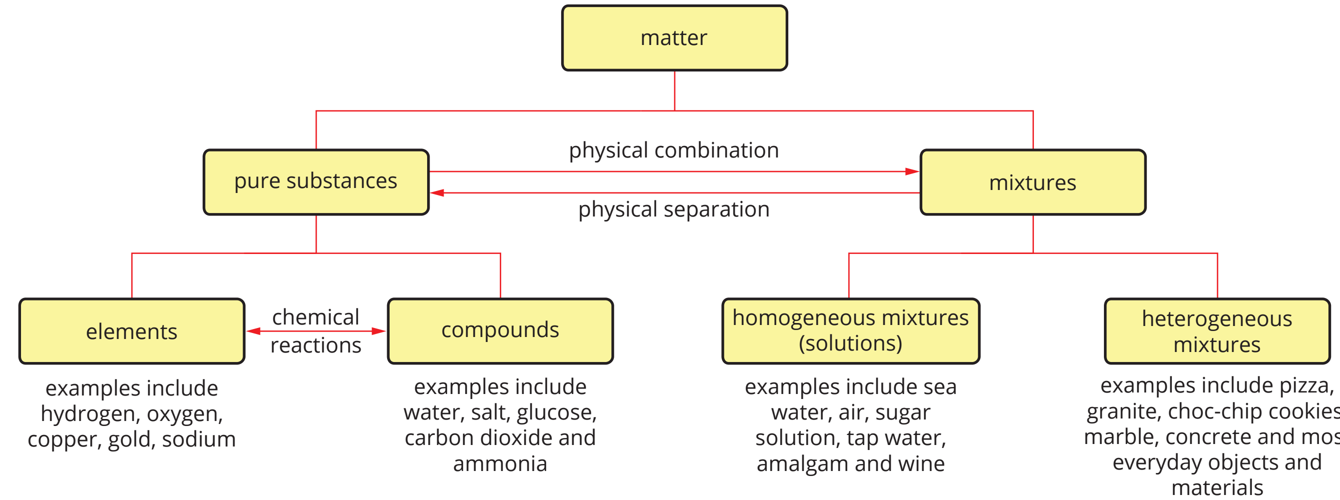


FIGURE 2.1.1 Classification of matter according to purity, showing the relationship between elements, compounds and mixtures

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 indicates 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 indicates that it is a homogeneous mixture. Many 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.

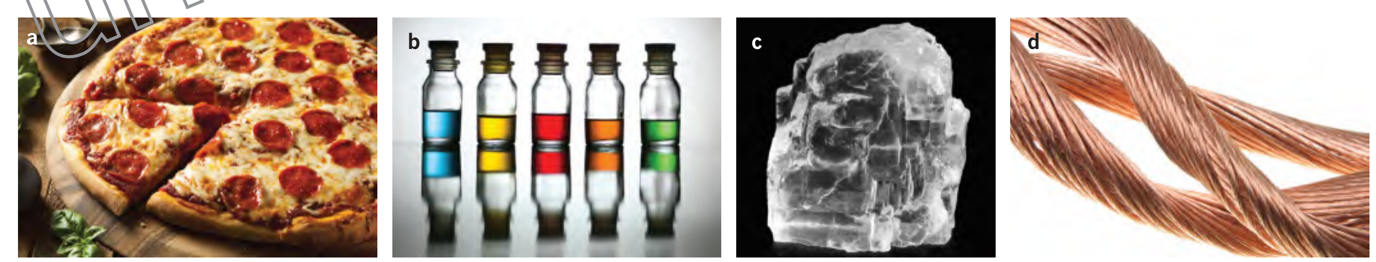
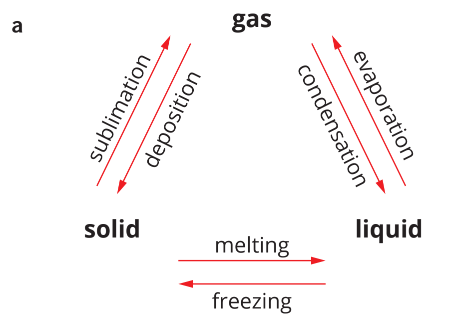


FIGURE 2.1.2 Examples of different types of matter: (a) a slice of pizza (heterogeneous mixture), (b) food colouring dissolved in water (homogeneous mixture; also a solution), (c) a salt crystal, which is a pure substance composed of the compound sodium chloride (NaCl) and (d) copper metal, which is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



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 for 'energy required' or 'energy released' to induce the changes of state indicated.

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.

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 water vapour 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 XX 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 sterling silver—a mix of silver and copper)
- two or more compounds (such as salt water)
- 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 isolate pure substances from complex mixtures. The ability to separate mixtures into their pure components is crucial in many industrial, environmental and biomedical applications.

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.

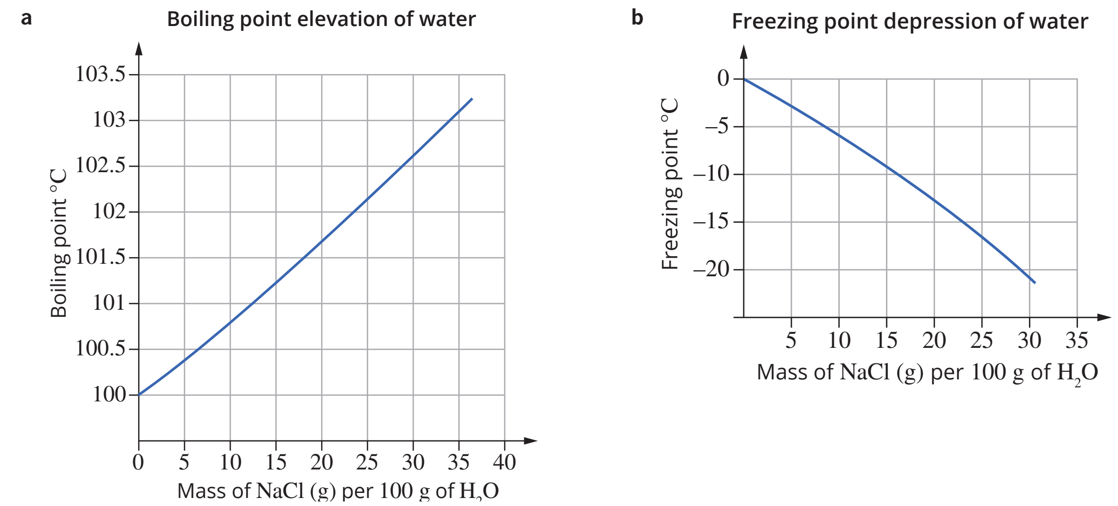


FIGURE 2.1.4 (a) Boiling point elevation—the boiling point of water increases with increasing amounts of NaCl. (b) Freezing point depression—the freezing point of water is lowered with increasing amounts of NaCl.

Changes in physical and chemical properties, like those shown in Figure 2.1.4, are useful for distinguishing between mixtures and pure substances. Mixtures 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/hardness/strength

Mixtures of metals are called **alloys**. An alloy might have more useful properties than the metals it is made of. An example is the 18-karat gold used in jewellery. The purity of gold is measured in karats (kt). When it is 99.9% pure (24-karat), gold has only moderate strength and hardness and scratches easily. 18-karat gold is 75% gold and has greater strength, so it makes more durable jewellery. Sporting medals do not require the same physical strength as jewellery and are often made in 24-karat gold. This gives the medal some softness. Figure 2.1.5 shows an athlete proudly 'testing' the softness of her medal.

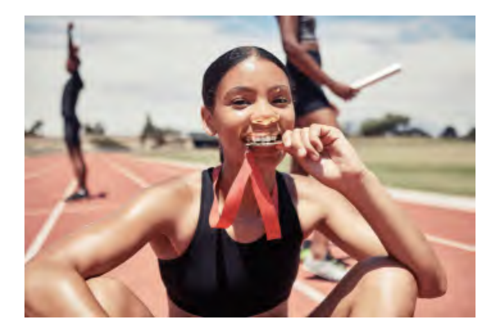


FIGURE 2.1.5 An athlete bites her gold medal to test its softness.

Many plastics are carefully designed mixtures of large molecules with specific physical properties. They are generally lightweight, durable, versatile, chemically resistant and quite cheap to produce. However, those plastics that are not biodegradable or recyclable can be an environmental problem.

Each type of plastic has particular uses, as outlined in Figure 2.1.6. Two key examples, which you will study in Unit 4, are high density polyethene (HDPE, recycle number 2) and low density polyethene (LDPE, recycle number 4). For low density polyethene, the decrease in density results in greater flexibility but a decrease in strength.

PETE	HDPE	PVC	LDPE	PP	PS	OTHER
Polyethene terephthalate	High density polyethene	Polyvinyl chloride	Low density polyethene	Polypropene	Polystyrene	Includes polycarbonates, ABS, Teflon, various copolymers, nylon and other condensation polymers
bottles for soft drinks, water, shampoo, takeaway food containers	garbage bins, fuel tanks, hard hats, banners, water pipes, food storage containers	plastic wrap, cordial bottles, electrical wire covers, water pipes, floor tiles	plastic wrap, squeeze bottles, plastic tubing, shopping bags	rope, clothing, ice-cream containers, flip-top bottle lids	yoghurt containers, fridge shelves, drink cups, insulating beads, packaging	

FIGURE 2.1.6 An international number code is used to identify each type of recyclable plastic.

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 XX) 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 pure substances: elements and compounds. As Figure 2.1.1 on page XX 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 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).

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.

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 covalent networks**. 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 covalent network 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 2.1.7. Metallic elements form a different type of network lattice structure, which you will look at in detail in Chapter 6.

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.

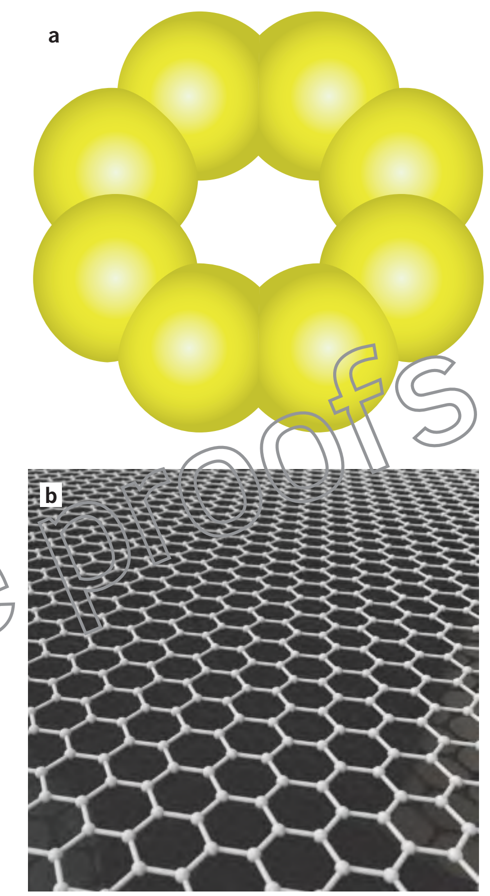


FIGURE 2.1.7 (a) Most non-metal elements, such as sulfur, form molecules. (b) Some elements, such as carbon, form covalent network lattices or giant covalent networks like the graphene shown here.

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). Other 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 some 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.

Other common physical properties used to describe pure substances are density, conductivity, tensile strength and expansion.

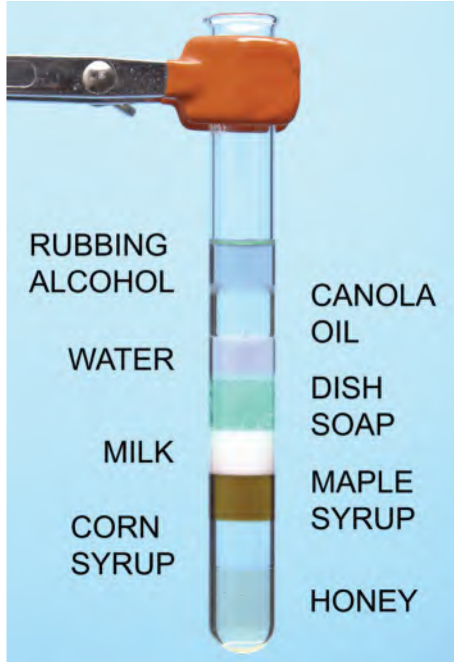


FIGURE 2.1.8 The relative density of some common liquids

> 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.

Density is measured as the mass per unit volume. You will have observed substances with different densities in your everyday life. For example, a salad dressing made of oil and vinegar will have the oil floating on top of the vinegar because oil is less dense. Figure 2.1.8 shows the density of some common liquids. The liquids form layers in order of their density, with the least dense at the top and the most dense at the bottom.

Metals and metal alloys (mixtures) are used widely in manufacturing and construction. For many situations, such as in aeronautical engineering, manufacturers must consider the weight versus the strength that the metal provides. Table 2.1.3 shows the properties of some metals; for example, aluminium is a lightweight metal with relatively good strength.

TABLE 2.1.3 Some physical properties of common metal elements

	Density (g/cm^3)	Thermal expansion (μm/m°C)	Electrical conductivity (MS/m)	Tensile strength (MPa)
gold	19.3	14.12	45.2	20
silver	10.5	18.9	63.0	170
copper	8.96	16.5	59.6	210
iron	7.87	11.8	10.4	300
aluminium	2.7	23.1	37.7	120
lead	11.3	29.1	4.81	17

The periodic table

Figure 2.1.9 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.

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 terbium	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 fermium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium

FIGURE 2.1.9 The periodic table groups elements according to their chemical and physical properties.

You will generally have a copy of the periodic table at hand during your chemistry studies so you don't need to memorise it in detail. However, being able to recall specific information about the first twenty elements or so is very useful. It is 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. For example, the atomic radius of each element in a period (row) decreases from left to right, and atomic radius increases down each group (column). You will learn more about periodic table trends in Chapter 4.

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 2.1.10). 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 2.1.10 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

Describe

1 Define the term 'matter'.

2 State two types of:
- a mixtures
- b pure substances.

3 Describe a physical change in matter.

4 Identify the common name of each of the following elements from its Latin name.
- a *ferrum*
- b *kalium*
- c *argentum*
- d *plumbum*
- e *hydrargyrum*

5 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.

6 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

Apply

7 Pure water can be obtained from many different sources: rainwater, sea water and underground aquifers. Does the composition of pure water from different sources vary? Explain your answer.

8 Can both elements and compounds be molecules? Use appropriate examples to explain your answer.

9 Name 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 Substance X 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 substance X.

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

Analyse

12 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

13 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

14 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 XX.

15 Classify each of the following elements on the periodic table on page XX 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

16 Classify the following as ionic compounds or molecular compounds using the periodic table on page XX.
- a NaCl
- b H_2S
- c PF_3
- d Fe_2O_3

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

18 Look at Table 2.1.3 (p. XXX), which shows some physical properties of common metal elements, and use this information to answer the following questions.
- a Determine a metal that would be suitable for electrical wiring. Consider both electrical conductivity and cost in your answer.
- b Research the metals used in steel, a common construction metal alloy, and use the data in Table 2.1.3 to justify its composition.
- c Traditionally, sinkers used in fishing were made of lead. Environmentalists have argued against their use, because lost sinkers can be eaten by animals, which could poison them. Consider cost and other properties of lead, as well as the information in Table 2.1.3, to explain the popularity of lead sinkers.

19 A student is heating a clear liquid, presumed to be water, and finds it has a boiling point of 101.5°C. As the student continues to boil the liquid, the temperature rises to 103°C. Is the clear liquid pure water? Explain your answer.

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2.2 Homogeneous and heterogeneous mixtures

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

- discriminate 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.

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.

Most samples of matter are not chemically pure and consist of a physical combination of two or more pure substances called a mixture. 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 2.2.2 Examples of matter that is 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.

> 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.

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.

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	solid–liquid–gas	water	sugar, 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.

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 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

Describe

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 Determine if the following statements about mixtures are true or false.
a Mixtures can be separated based on their physical properties.
b It is possible to see the individual components in a salt solution.
c Heterogeneous mixtures always have phases in the same physical state.
d In an aqueous solution, the solvent is water.

Apply

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

5 Describe the key components of a copper sulfate solution (shown below), and explain why it is uniform.

Analyse

6 Classify each of the following as a homogeneous or heterogeneous mixture.
a muesli
b sand
c wet sand
d vinegar

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

10 For each of the following solutions, identify the component as a solvent or solute.

Component in solution	Solvent or solute?
a oxygen in air	
b water in sea water	
c copper in sterling silver	

11 In the laboratory, a student compares the properties of two unknown mixtures. The results of the experiment are shown in the table below.

	Mixture A	Mixture B
Appearance	clear blue liquid	speckled grey/black solids
States of matter present	liquid only	solid only
Number of phases	one	two

Classify mixtures A and B as homogeneous or heterogeneous. Give evidence to support your answer.

Chapter review

02

KEY TERMS

alloy
anion
aqueous solution
atom
atomic number
boiling point
boiling point elevation
cation
chemical change
chemical equation
chemical formula
chemical reaction
chemical symbol
compound
covalent network lattice
density
element
freezing point
freezing point depression
giant covalent network
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
solute
solution
solvent
volume

KEY QUESTIONS

Describe

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

4 Select the list below that contains only pure substances.
A tap water, air, ammonia
B air, hydrogen gas, glucose
C distilled water, glucose, sand
D ammonia, glucose, distilled water

5 Select the list below that contains only homogeneous mixtures.
A air, amalgam, seawater
B air, tap water, pizza
C copper, gold, oxygen
D choc-chip cookies, concrete, wine

6 Which of the following is an indicator of a chemical change?
A A solid dissolves in water.
B A precipitate is formed.
C There is a change in state.
D There is a change in viscosity when heated.

Apply

7 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

8 Below are four samples of different matter. Which of the samples are heterogeneous mixtures?
I iron ore
II copper wire
III wet sand
IV distilled water
A I and II only
B II and III only
C III only
D I and III only

9 Determine which of the following are pure substances and which are mixtures. For each, list all of the different phases present.
a paint, containing a liquid solution and a dispersed solid pigment
b partially molten copper

10 Describe the key difference between a physical and a chemical change.

11 There is a range of liquid metal alloys containing gallium, indium, tin, zinc and silver. In their elemental state, all of these metals are solid. Explain why the alloy has different properties to the individual elements.

12 Natural gas used in the home for heating and cooling is composed mainly of methane CH_4 and ethane C_2H_6. It can have small traces of other gaseous substances present. Both methane and ethane are odourless and colourless gases, but when a gas tap is left on there is a distinct odour present. This is due to the addition of warning agents, which have distinct odours. Ethanethiol (CH_3CH_2SH), a liquid at room temperature, is one such warning agent.

a Are methane and ethane elements or compounds? Explain your answer.
b State three physical properties of ethane.
c State one chemical property of methane.
d Is natural gas a homogeneous or heterogeneous mixture?
e State two physical properties of ethanethiol.

13 Draw particle diagrams to explain the difference between a diatomic element and a monatomic element.

Analyse

14 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.

15 The following is a description of the element cadmium (Cd).

I It is a bluish-white coloured lustrous metal.
II It has a melting point of 321°C.
III When added to hydrochloric acid, the metal dissolves and hydrogen gas is released.
IV It is highly toxic and can adversely affect the kidneys, lungs and bones.
V It has a density of $8.65\,g\,cm^{-3}$.
VI It has a hardness of 2.0 on the Moh hardness scale.
VII If left in air, it will form a layer of cadmium oxide (CdO) on its surface.

Which of the following are chemical properties of cadmium?

A I, III, and IV
B III, IV and VII
C III, IV and VI
D IV, VI and VII

16 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

17 Below is a list of changes.

I corrosion of zinc anodes on boats
II melting of iron in a blast furnace
III pulverising of a granite sample
IV digesting chocolate
V growth of plants via photosynthesis
VI explosion of TNT

Which of the following are physical changes?

A I, II and III
B II, III and IV
C II and III
D III and V

18 Compare and contrast elements and compounds.

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

a ammonia (NH_3)
b benzene (C_6H_6)
c dinitrogen pentoxide (N_2O_5)

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

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

a calcium fluoride (CaF_2)
b aluminium oxide (Al_2O_3)
c copper(I) sulfate (Cu_2SO_4)

22 Identify what you note about the nature of the elements in the compounds listed in Question **21** and what type of compounds they are.

23 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.

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

- compound
- element
- heterogeneous mixture
- homogeneous mixture

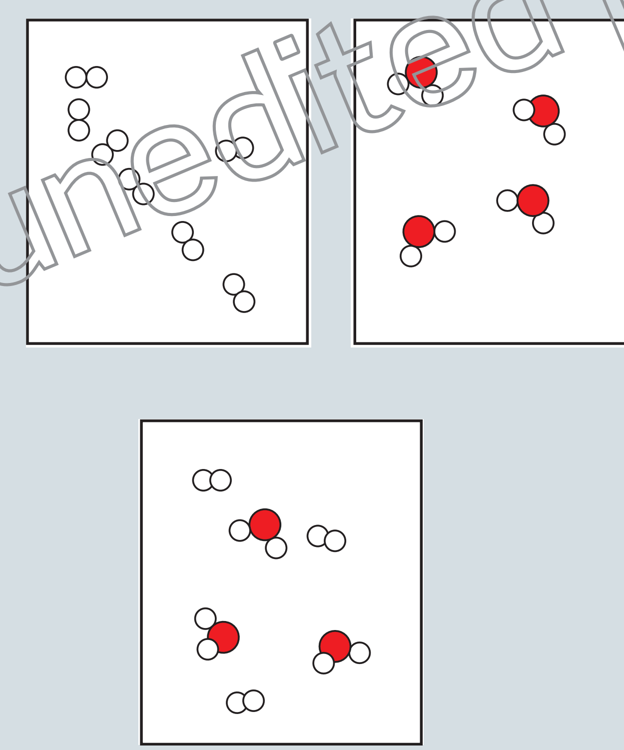
a matter that cannot be broken down to simpler substances by chemical or physical means
b matter that can be separated into its constituent components by physical processes
c matter that can be separated into its constituent components by chemical processes

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

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

26 A student is investigating an unknown grey solid and begins by testing its melting point. They find the solid has a melting point range of 189–193°C. What conclusions can be drawn about the purity of the solid?

27 The diagram below shows molecules of two different elements. Classify A, B and C as element, compound or mixture.

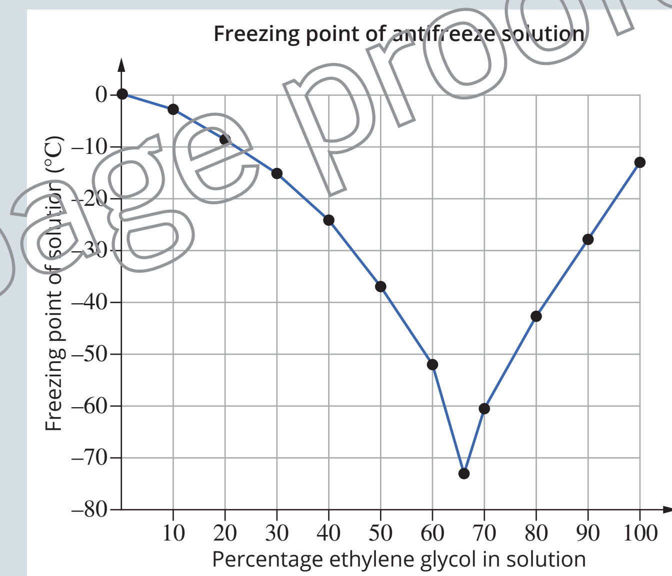


Interpret

28 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.

29 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. Use the following graph to answer these questions.

a Decide what percentage concentration of ethylene glycol would be required to be confident that a vehicle radiator would not freeze in Australia.
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.



30 Two students are investigating mixtures. They have access to water, table salt (sodium chloride), sand, glass beads and sugar. They are told that each mixture must contain a minimum of three of the substances.

a Student 1 is tasked with making a heterogeneous mixture. They add a small quantity of table salt, sand and several glass beads to a beaker and label it mixture 1. Have they succeeded in their task? Explain your answer.
b Student 2 is tasked with making a homogeneous mixture. They add some water to mixture 1, and claim it is a solution. Have they succeeded in their task? Explain your answer.
c Propose a method to satisfy the task of making a homogeneous mixture with three of the substances.

Data analysis

DATA SET 1

The information below applies to Questions 1–5.

Solder is an alloy most often made from tin and lead in different ratios. One of its common uses is to hold components in place in electric circuits. The advantage of solder is that it has a lower melting point than either of its component metals. This means that it will melt easily when it comes into contact with a soldering iron, then solidify quickly to hold components in place.

FIGURE 1 A soldering iron used to melt solder

A student investigated the change in the melting point as the percentage of tin is increased in the tin/lead alloy. Table 1 shows the data the student collected for the melting point of alloys made with varying percentages of tin.

TABLE 1 Melting point of alloys

Percentage of tin by mass	Melting point (°C)
10	302
20	280
30	258
40	238
50	214
60	190
70	192
80	202
90	216

Question 1 (2 marks)

Name the independent variable and the dependent variable for this investigation.

Question 2 (4 marks)

Plot the data in Table 1 in an appropriate graph.

Question 3 (2 marks)

Describe the trend shown by the data.

Question 4 (1 mark)

Identify the percentage of tin that provides the lowest melting point.

Question 5 (2 marks)

Examining the data, does it verify that mixtures have varying properties dependent on the identity and relative amounts of the substances that make up the mixture? Explain your answer.