04 Elements and Compounds

Introduction

In the previous chapter, matter was classified by state and the undifferentiated term 'particle' was used for the particles matter is made of. In this chapter, matter as elements and compounds is discussed together with the specific kinds of particles found in them, namely, atoms, molecules and ions. Physical models to represent these particles in elements and compounds are also used.

Chapter Opener (page 30)

1. To open the chapter, the following questions on this page could be discussed. Precise answers are not needed at this stage. This discussion could be combined with the 'Stimulation' on the next page.

   What are the names of some elements and some compounds?

   Answer: Accept all appropriate responses.

   Why are there are only a few elements but many compounds. What is the reason for this?

   Answer: The few elements can be combined in many different ways to form compounds.

   What kinds of particles make up matter in elements and compounds?

   Answer: Atoms, molecules and ions.

   What are the differences between elements, compounds and mixtures?

   Answer: Accept any appropriate (but probably tentative at this stage) responses.

2. Carry out an 'Inquiry Preview.'

Learning Outcomes

After completing this chapter, students should be able to:

- define an element, a compound and a mixture
- describe ways of classifying elements
- give the names and symbols of common elements
- describe the kind of particles in elements and compounds
- describe the differences between elements, compounds and mixtures

Teaching Notes for

4.1 Elements (page 48)

Stimulation

Bring a Lego set into the classroom. Use it to show that many objects ('compounds') can be made from a limited number of different types of building blocks (elements). Another analogy is that of using bricks to make a house. However, this analogy is not as good as the Lego analogy as there is only one kind of element (though different coloured bricks could represent different elements).

Teaching pointers

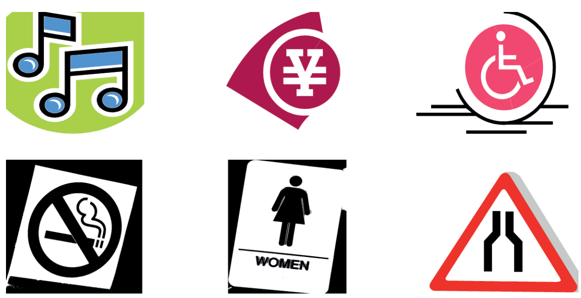
1. After introducing the topic, show the class some elements and compounds. For example, bring some sand and salt (sodium chloride) and the elements silicon, oxygen, sodium and chlorine that they are made of (where available). Samples of other elements should also be shown, such as those in Figure 4.2 on page 55 of the Textbook.

2. In the definition of an element, the words '*by chemical methods*' are included. These words are important as elements can be physically divided into smaller pieces.

3. Heat and electricity are used to decompose compounds. You may heat a sample of green copper(II) carbonate to show an example of a compound that breaks down into simpler substances. Ensure that students do not think that the products are necessarily elements. In the case of the electrolysis of sodium chloride, the products are elements. But in the case where copper(II) carbonate decomposes, the products are not. To be certain that a substance is an element, further tests have to be done to ensure that it cannot be broken down into anything simpler.

4. Ensure students appreciate that most of the elements occur in in the Earth's crust in the form of compounds and not as pure elements. For example, carbon and oxygen as carbonates in the Earth's crust and as carbohydrates, fats and proteins in the human body.

5. Symbols are widely used in everyday life. Ask students to give some examples. For example:



Get the class to suggest why symbols are used. Responses might include the idea of saving space, the ability to convey a message easier than by using words, are recognised quickly, are easier to understand (particularly those containing realistic images) and are international (as they often do not contain words). These are also the reasons why a chemist uses symbols.

6. You can show a sheet of music (of a familiar song) and a page with chemical symbols on it from a foreign-language Chemistry book. Discuss how both the symbols for musical notes and chemical symbols are part of international languages that people in all countries recognise and use. Get the class to identify the song and the chemical symbols. Mathematical symbols are also another example of an international language.
7. Students were introduced to classification in their Lower Secondary Science course and have learnt that things can be classified in different ways. The three ways of classifying elements given here are widely used in Chemistry. When we say an element is a gas, we understand that this refers to its state at room temperature and pressure (often taken to be 25 °C and 1 atmosphere).
8. The Periodic Table as a system of classification is introduced briefly here. No details need be given until Chapter 11.
9. The ability to conduct electricity is the easiest way to distinguish between metals and non-metals (except for graphite, a form of carbon, which conducts electricity).

Chemistry in Society (page 50-51)

A Little History — Elements and Symbols

Answers to Questions

1. Man will discover more man-made elements in the future. This is because advances in technologies over the centuries had allowed the discovery of naturally-occurring elements.

Chemistry Inquiry (page 52)

Classifying Elements

Answers to Questions

1. Substances are either solids, liquids and gases and their properties do not overlap.
2. Metal-like: They can be shiny or dull, they are ductile and can be drawn into the shape of pipes, they are conductors of heat.
   Non-metal like: They are usually brittle, they are electrical insulators at room temperature.

Skills Practice (page 51)

1. E.g. **(a)** Carbon C, hydrogen H, boron B, silicon Si, magnesium Mg.
   (b) Gold Au, silver Ag, lead Pb, tin Sn, mercury Hg.
   (b) For example, differences in colour, heat/thermal conductivity, electrical conductivity, boiling points.
   (c) For example, differences in smell, colour, density, heat/thermal conductivity.
2. **(a)** There are 18 non-metals
   (b) There are 7 metalloids — boron, silicon, germanium, arsenic, antimony, tellurium and astatine.
   (c) Mercury is a liquid metal at room temperature.
3. O, Si, Al, Ca, Fe, Mg, K, Na. Teachers could link this question to Questions 1 and 2.

Notes for Teachers

Notes on the elements

- In 2002, 115 elements were known. However, those elements with proton number above 109 are highly unstable and have been made only in tiny quantities.
- The Romans used the metal lead to make water pipes. Its Latin name 'plumbum' gives, not only the symbol Pb, but also the English word 'plumbing.'
- The early 19^{th} Century symbols shown on page 57 of the Textbook were devised by John Dalton.
- The elements with proton number 110 or above have temporary names until permanent names can be found. The symbols have three letters, e.g. Uun. The names are derived from the three digits in the proton numbers. For example, element 110 is called Ununnilium from un = 1 + un = 1 + nil = 0 + the suffix -ium. Similarly, element 112, symbol Uub, is called Ununbium (bi = 2).

Element or compound?

Early chemists faced the problem of not being able to positively identity a substance as an element. They often thought a new substance was an element because they could not decompose it. However, later, others were able to decompose it. Positive tests for an element were not easy but became easier after the Periodic Table was devised and a new 'element' could be compared with other elements (refer to the discovery of germanium on page 168 of the Textbook).

Teaching pointers

4.2 What are Elements made of? (page 53)

1. Get students to repeat the thought exercise carried out by Democritus about 2500 years ago. Democritus imagined cutting up a piece of gold until it could not be divided any further. He believed he would end up with small indivisible particles which he called *atomos*, from which we got the word atoms. This led to the idea of the atom.
2. Atoms of each element are basically the same. Minor differences in the atoms of the same element (isotopes) are discussed in Chapter 5.
3. Emphasise that the symbol for a chemical element also represents the symbol for the atom. For example, Cu represents:
   - the chemical symbol for the element copper, and
   - the *symbol* for a copper atom.
4. *Size of atoms:* It is difficult for anyone to fully appreciate the size of an atom as we have no experience with objects of that small. To get some idea of their size, we can use analogies.
   One analogy is to look at a dot on a page. One dot (area about 1 mm^2) uses about 10^{16} atoms which is about two million times more atoms than there are people in the world.

   Another way is to imagine a ball magnified to the size of the Earth. The atoms in the ball would then be about the size of the original ball. (**Note:** Analogies are studied further in Chapter 6.) For a calculation on the size of an atom that could be given to students, see 'Notes for Teachers' on the next page.
5. The model of an atom as a solid ball is used here. Although this is a very simple model, it enables many ideas in Chemistry to be understood. In fact, apart from the structure of the atom itself, it is the main model of the atom used in the 'O' Level course.

2. For molecules, you may mention that in the early 19th Century, chemists such as Dalton believed that elements consisted of just atoms (as metals are). It was Avogadro who suggested the idea of the molecule. You may photocopy and distribute the notes on page 53 to the class for additional information.
7. Distinguish the terms *symbol*, used only for atoms (and metals), and formula, used for molecules (in non-metals and compounds). Match a symbol, such as Cl_2, to a model of the molecule.
8. In the particle model for chlorine in Figure 4.9 on page 54 of the Textbook, some students have the misconception that there is air between the molecules. Discuss this misconception with the class and emphasise that there is just empty space between the molecules.
9. Show space-filling models of the non-metals in Figure 4.10 on page 53 of the Textbook, but without giving any details on how the atoms combine (this will be investigated in Chapter 6). If possible, get students to assemble the models and work out the chemical formulae using the models.
10. Ensure students are aware that the macroscopic properties of a substance are not reflected in the properties of the atoms. Thus real elements may be coloured (e.g. sulfur) or shiny (e.g. metals). But the atoms and molecules making up the elements are *not coloured* or shiny.
11. Discuss the various types of molecules in Table 4.3 including the meanings of monatomic, diatomic, triatomic and polyatomic. The noble gases, such as helium (He) are a special case, as they are monatomic molecules but also just single atoms, i.e. molecules consisting of one atom.
12. Discuss with the class the colours chemists use to distinguish atoms. For example, hydrogen is white, oxygen is red and carbon is black. Point out that the colours are only used in diagrams and models in order to distinguish atoms; the atoms themselves do not have colours. The website in the IT link below also shows the colour code for common atoms.

Skills Practice (page 55)

1. The solid sulfur would consist of many S8 molecules packed close together in an orderly arrangement. The atoms in the molecules would not be coloured yellow. dispersed throughout the water. [See again the video animation above for this process.]

2. **(a)** A hydrogen molecule, represented by the formula H_2, is a distinct particle and the basic unit in hydrogen gas. The molecule consists of two hydrogen atoms joined together.
   (b) A molecule of oxygen consists of two oxygen atoms.

Notes for Teachers

Question on the size of an atom

It has been found that eight million atoms can fit side by side across a pin-head. If a pin-head is 2 mm across, what is the diameter of an iron atom?

Answer:

Pin-head diameter = 2 mm
Number of atoms across the pin-head $= 8 \times 10^6$
Therefore, diameter of one atom $= 2 \div (8 \times 10^6)$
$= 2.5 \times 10^{-7}$ mm (or 2.5×10^{-10} m)

IT Link

Colour code for common atoms:
http://cwx.prenhall.com/petrucci/medialib/media_portfolio/text_images/FG03_02-01UN.JPG

Teaching pointers

4.3 What are Compounds? (page 55)

1. Show samples of some compounds, such as common salt, chalk, water and sugar and discuss their constituent elements. Discuss also how the appearance of a substance often suggests whether it is an element or a compound. For example, metallic elements, but not compounds, are usually shiny. There are only two liquid elements (mercury and bromine), so any other liquid must be a compound. Gaseous elements and compounds are more difficult to distinguish based solely on appearance.
2. Point out that the name of a substance is usually a clue to whether it is an element or a compound. Thus nitrogen dioxide refers to the elements, nitrogen and oxygen and so is a compound. Substances that do not include the names of any elements, such as water and sand, must therefore be compounds.
3. Demonstrate the burning of magnesium in air and compare the appearance of magnesium oxide with magnesium and oxygen separately. Also, demonstrate and discuss the reaction of hydrogen in air, and compare the compound (water) formed with its constituent elements (hydrogen and oxygen). (The reaction of hydrogen in air is used as a test for hydrogen gas.)
4. As an additional example for the formation of a compound from its elements, you could demonstrate the burning of sodium in chlorine gas to form sodium chloride. Alternatively, the videos in 'IT Links' below could be used.
5. When discussing Table 4.4 and Table 4.5, give other examples of formulae and get students to state the name of the compounds and vice versa.

Notes for Teachers

Movies on the elements sodium and chlorine reacting to form the compound sodium chloride:
http://cwx.prenhall.com/petrucci/medialib/media_portfolio/text_images/021_SODIUMCHLOR.MOV
Many others are available on YouTube.

Teaching pointers

4.4 What are the Compounds Made of? (page 57)

1. In Section 4.3, students learnt that non-metals consist of molecules. Molecules in compounds usually consist of non-metals, e.g. water molecules consist of hydrogen and oxygen atoms.
2. Show a (space-filling) model of water and match it with its formula and with Figure 4.14 on page 57. Water consists of many identical H_2O molecules. Again, emphasise that in water, there is just empty space between the water molecules.
3. Point out that the writing of chemical formulae involves conventions. Some of these are involved in answering Question 2 of Skills Practice on page 58 for the formula of water.
4. Show space-filling models of the molecules in Figure 4.15. Get students to note difference in shapes but do not give any explanation. Look at molecule pictures on a CD-ROM, e.g. *Chemistry Set 2000*.

5. At this stage, the ion is introduced only as a particle. Leave out details about the formation of ions and the numbers of charges until Chapter 5. Evidence for ions comes from the electrolysis of compounds, but as students have not studied electrolysis, they will be unable to appreciate this yet.
6. Show the class a 3-D space-filling model of sodium chloride and point out the two types of ions present. Point out that the Cl^- ion is called the chlor*ide* ion and not the chlorine ion because of the naming convention of compounds with two elements (refer to the notes on the names and formulae of compounds in Table 4.5 on page 56). Also point out how the symbols for the ions are pronounced, e.g. Na^+ is "N-a-plus" and Cl^- is "C-*l*-minus".
7. Additional Exercise 1 found at the end of this chapter is a useful summary for the types of particles in elements and compounds. It also illustrates how a table can be used to organise information. The worksheet may be photocopied and distributed to students.

(page 57)

Mystery Clue

The water molecules vibrate rapidly and move randomly throughout the liquid. In doing so they collide with the much larger pollen grains causing them to move randomly.

Skills Practice (page 58)

1. **(a)** Carbon and oxygen
   (b) E.g. Carbon dioxide – colourless gas, turns limewater milky, extinguishes a burning splint. Carbon (graphite) – black solid. Oxygen – also a colourless, does not turn limewater milky, relights a glowing splint gas. (This question requires students to use previous knowledge.)
2. H_2O is correct. H_2O_1 – the 1 is unnecessary. H_2O_2 – has an extra O. H_3O – has an extra H. HO_2 – has an incorrect number of H and O atoms.
3. Both contain 2 H atoms. Water has an O atom. Hydrogen is an element, water a compound.
4. Sodium chloride is not made up of separate NaC*l* molecules. It is a giant structure made up of many sodium and chloride ions, represented as Na^+Cl^-.
5. **(a)** 2 N atoms. **(b)** 4 P atoms. **(c)** 1 S atom and 2 O atoms.
   (d) 2 C atoms, 6 H atoms and 1 O atom.
   (e) 6 C atoms, 12 H atoms, 6 O atoms.
6. **(a)** Sulfuric acid, glucose, methane.
   (b) Carbon monoxide: carbon, oxygen; Nitrogen dioxide: nitrogen, oxygen; Sodium carbonate: sodium, carbon, oxygen; Potassium chloride: potassium, chlorine; Hydrogen sulfide: hydrogen, sulfur; Aluminium silicate: aluminium, silicon, oxygen; Calcium hydroxide: calcium, oxygen, hydrogen

Teaching pointers

4.5 What are Mixtures? (page 58)

1. Mixtures are very common in everyday life. Get the class to suggest examples. Perhaps bring along food wrappers/boxes/soft drinks and get students to examine the ingredients on the labels and infer that most of these ingredients are mixtures. A discussion of mixtures as elements and compounds could follow.
2. Show mixtures of iron/sulfur and sand/salt to illustrate how some mixtures can be identified just by appearance. Show other mixtures, such as brass and seawater, where this identification is not possible.
3. The particle models of mixtures help students to visualise mixtures at the particle level. Get students to identify the different kinds of particles in these mixtures. At this stage, just treat alloys as mixtures; leave details about their structure and properties until Chapter 13.
4. Compare compounds and mixtures. Emphasise:
   - Mixtures are easily separated. (For example, water can be separated from seawater by distillation.)
   - Mixtures can be easily recognised as they melt and boil over a range of temperatures. (For example, butter and petrol.)

   Examples: Pure water boils at at 100 °C and as ice, melts at 0 °C. Butter (a mixture of compounds) melts over the range of 30 °C to 50 °C. Kerosene is a liquid mixture (of hydrocarbons) and boils over a range of about 170 °C to 250 °C.
5. Link this topic with the separation of mixtures in Chapter 2.

Experiment 4.1: Comparing a mixture and a compound (PWB page 53)

Mixture: The experiment is designed to show that a mixture (of elements) has the properties of its component parts, and can be easily separated into these parts (using a magnet and water). Warn students not to place the bar magnet directly into the iron-sulfur mixture as it is very difficult to remove all the iron filings from the magnet.

Compound: This experiment shows that the compound, iron sulfide cannot be separated into its component parts. The tin lid (or metal bottle cap) used in the experiment can be disposed of after use. As the reaction can produce toxic sulfur dioxide gas, the laboratory must be well-ventilated. Alternatively, you can carry out the reaction as a demonstration in a large test tube (so that the whole class can see what happens).

Note: Iron and sulfur are not normally heated in a test tube as the product is difficult to remove.

Skills Practice (page 60)

1. That a mixture has a variable composition / can be mixed in any proportion (Characteristic number 1 in Table 4.7).
2. E.g. Mixture can be separated by physical means, iron(II) sulfide cannot.
   Mixture has properties of its elements, e.g. differing density. Compound has its own properties, e.g. just one density.
   Mixture, unlike the compound, can have a variable composition by mass of iron and sulfur.
3. **(a)** Bronze is a mixture because it has a variable composition (the percentage of copper is not constant).
   (b) Heat the bronze to melt it. It should melt over a range of temperature and not at a fixed temperature.
4. **(a)** The (pure) compound has a single, sharp melting point. The mixture would melt over a temperature range.
   (b) Do a boiling point test. A (pure) compound has a single, sharp boiling point. The mixture would boil over a temperature range.

Notes for Teachers

IT Link

Video on the mixture of iron and sulfur and the formation of iron sulfide: http://cwx.prenhall.com/petrucci/medialib/media_portfolio/text_images/059_MixesandComp.MOV

Teaching Notes for

Solving the Mystery (page 61)

Why do pollen grains move about in water?

Brownian motion provided strong evidence for particles and the random movement of particles. It is interesting to note that something we find easy to explain today was very puzzling at the time Brown was making his observations in 1827. Brown, in fact, was not able to explain his observations. Although he knew about matter as particles, the idea of the random movement of particles was not suspected at that time. This idea was not proposed until more than 50 years later, much later than the idea of spaces between particles of matter. Hence, the particulate models of matter taught in schools today were actually built up over a period of time.

Infer
The mass of the water molecules is many times smaller that that of the pollen grains and specks of coal dust. The kinetic energy of each water molecule is small so that on collision with a larger particle, the larger particle moves only slightly.

Connect
In warm water, the water particles are move faster than in cold water. Therefore there will be more frequent and more energetic collisions with the smoke particles causing them to move faster.

Further Thought
The movement can be viewed at: http://mutuslab.cs.uwindsor.ca/schurko/animations/brownian/gas2d.htm

04 Chapter Review

Self-Management

Misconception Analysis (page 62)

1. **False** Graphite (carbon), a non-metal, conducts electricity.

2. **False** The products could be simpler compounds. For example, calcium carbonate decomposes when heated to give calcium oxide and carbon dioxide, which are compounds.

3. **True** Gases consist of molecules. For example, oxygen gas consists of many O_2 molecules with each molecule formed by two oxygen atoms joining together.

4. **False** 'H' is the symbol for an atom of hydrogen. The term formula can only be used for molecules; molecules of hydrogen gas have the formula H_2.

5. **False** Although a substance we observe may be coloured, its atoms are not coloured.

6. **True** All ionic compounds are solids at room temperature. Students will learn the reason for this in Chapter 7.

7. **False** With physical changes, substances do not change into other substances. This only happens with chemical changes. A compound can be separated into its elements only by chemical means.

Practice

Structured Questions (page 63–64)

1. (a) Tin, mercury and iron
   (b) Neon and helium
   (c) Silicon
   (d) Water
   (e) Tin

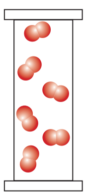
2. (a)

Elements	Compounds	Mixtures
carbon	ammonium chloride	bitumen (pitch)
zinc	manganese oxide	brass

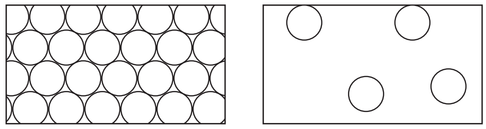
Table 4.9

   (b) Heat the bitumen to find its melting point. If it is a mixture, it will melt over a range of temperatures and not at a fixed temperature.

3. (a) A non-metal
   (b) Molecules
   (c) Each molecule of oxygen consists of two oxygen atoms.
   (d)



4. (a) Metal
   (b) Atoms
   (c) An atom of aluminium and the element, aluminium.
   (d)



5. (a) C represents a carbon atom and Cl represents a chlorine atom.
   (b) One carbon atom and four chlorine atoms
   (c) CCl4
   (d) A compound, as it is made up of more than one type of element.

6. (a) (i) Argon
   (ii) Carbon dioxide
   (iii) Oxygen/Nitrogen
   (b) Oxygen – O_2, argon – Ar, carbon dioxide – CO_2, nitrogen – N_2

7. 1 : neon, Ne
   2 : sulfur dioxide, SO_2
   3 : argon, Ar
   4 : hydrogen, H_2
   5 : nitrogen dioxide, NO_2
   6 : water, H_2O
   7 : nitrogen monoxide, NO
   8 : carbon dioxide, CO_2
   9 : hydrogen sulfide, H_2S
   10 : methane, CH_4
   11 : nitrogen, N_2
   12 : sulfur, S8
   13: carbon monoxide, CO

8.

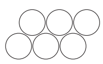
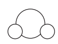
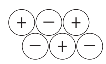
	Iron	Oxygen	Water	Sodium chloride
Element or compound?	element	element	compound	compound
State (solid, liquid, gas)	solid	gas	liquid	solid
Symbol/ Formula	Fe	O_2	H_2O	Na*Cl*
Particles (atoms, molecules, ions)	atoms	molecules	molecules	ions
Model (diagram)				

Table 4.10

9. (a) C and E. Metals conduct electricity and (usually) have high densities.
   (b) E. Mercury, like element E, is a metal with a silvery appearance.
   (c) A. Because of the very low density, element A is a gas. Neon, like element A, is a colourless gas.

10. (a) NO_2
    (b) $CaCO_3$
    (c) H_2
    (d) C_2H_5OH
    (e) CH_3COOH
    (f) H_2

11. (a) Seawater can be separated into different substances (water and salt) by distillation.
    (b) When sodium burns in chlorine, the elements combine to form salt. / Passing an electric current through molten salt decomposes it into sodium and chlorine.
    (c) Gold conducts electricity.

Free Response Question (page 64)

1. The response should include the following points:
    - Elements are classified into metals, non-metals, and metalloids. Noble gases are a subset of non-metals.
    - Appropriate examples for each of these four categories.
    - Any key differences, e.g. electrical or heat conductivity/appearance/ductility. (Metalloids normally do not conduct electricity.)

2. The response should include the following points:
    - Only two liquids are elements at room temperature and they are mercury and bromine but neither is colourless. Therefore, the colourless liquid must be a compound.
    - Obtain the boiling point of the unknown liquid and compare the value with the literature values to identify it.

Extension

1. The aims of this exercise are to familiarise students with the names and symbols of elements and to practice drawing charts.
   Most strange symbols are derived from the Latin names of the elements. The origins of the names and symbols can all be found from the IT Links given below and CD-ROMs such as World Book and Encarta.

IT Link

http://www.chemicalelements.com
http://www.webelements.com
http://www.seds.org (Io and Triton)

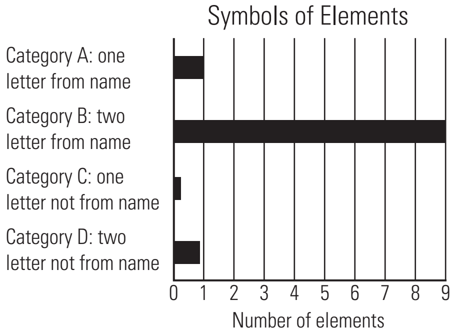


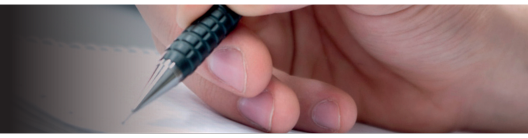
Figure 4.1

2. (a) Polonium (after Poland), francium (after France), germanium (after Germany)
       Note: There are others named after the names of countries in different languages e.g. Gallium is named after the ancient Latin name for France.
   (b) Helium (from the Greek word helios), gold (believed to be named after the shiny yellow Sun, the symbol Au is derived from Aurora, the goddess of dawn)
   (c) Curium (after Madame Curie), einsteinium (after Albert Einstein)
       Note: There are many others, especially the more recently discovered elements.
   (d) Plutonium (after Pluto), uranium (after Uranus), mercury (after Mercury)

3. An example of a good poster would be a striking picture accompanied by a few words. A picture of a molecule can be drawn using a program such as Microsoft Word or imported from a CD-ROM or the Internet. An attractive design can be produced using a program such as Microsoft Publisher.

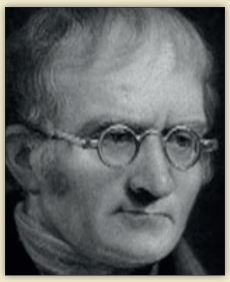
   Pictures of molecules could be obtained from the following CD-ROMs:
   - Chemistry Set 2000
   - World Book Encyclopaedia
   - Encarta Encyclopaedia

Additional Teaching Material



Chemistry in Society

A Little History — Atoms, Molecules and Ions



John Dalton (1766–1844)

Dalton and the Atomic Theory

The atomic theory, which holds that matter is composed of tiny, indivisible particles, was proposed in the 5th Century B.C. by the Greek philosophers Leucippus and Democritus. However, Aristotle did not accept the theory, and so it was ignored for many centuries. Modern atomic theory begins with the work of John Dalton (1766–1844), published in 1808. This theory rests on the following postulates:

1. *All matter consists of small particles.*
   Interest in the idea of the atom was revived during the 18th Century following work on the nature and behaviour of gases. In 1687, Isaac Newton used arguments based on atoms to explain the behaviour of gases. (Newton's speculations about atoms in his Principia were carefully copied by hand into Dalton's notebooks.)
2. *Atoms are indestructible and unchangeable.*
   Atoms of an element cannot be created, destroyed, broken into smaller parts or transformed into atoms of another element. Dalton based this hypothesis on the law of conservation of mass and on experimental evidence. With the discovery of subatomic particles after Dalton's time, it became apparent that atoms could be broken into smaller parts. The discovery of nuclear processes showed that it was even possible to change atoms from one element into atoms of another. But we do not consider processes that affect the nucleus to be chemical processes. The postulate is still useful in explaining the law of conservation of mass in Chemistry. However, it was amended to the following "Atoms cannot be created, destroyed, or transformed into other atoms in a chemical change".
3. *Elements are characterised by the mass of their atoms.*
   Dalton asserted that all atoms of the same element have identical masses. With the discovery of isotopes, however, the postulate was amended to read, "Elements are characterised by their atomic number".
4. *When elements react, their atoms combine in simple, whole-number ratios.*
   This postulate suggested a practical strategy for determining relative atomic masses from elemental percentages in compounds. Experimental atomic masses could then be used to explain the fixed mass percentages of elements in all compounds of those elements. This effectively explained both the law of definite proportions and the law of multiple proportions.

   Although some of the details of Dalton's original atomic theory are now known to be incorrect, the core concepts of the theory (that chemical reactions can be explained by the union and separation of atoms and that these atoms have characteristic properties) are the foundations of modern physical science.

Who thought of molecules?

Dalton thought that the simplest particles in all elements were atoms. For metals, he was correct. For example, an object made of iron consists of many iron atoms packed close together. However, for non-metals, Dalton was wrong. For example, the simplest particles in chlorine gas are not atoms but molecules. The person who first thought of molecules was an Italian chemist called Amadeo Avogadro (1776–1856).

Amadeo Avogadro (1776–1856)

Avogadro hypothesised the idea of the molecule in 1811, but it was not until 1858 (nearly 50 years later) that other chemists accepted it as correct. This was because Avogadro did not provide experimental evidence for his hypothesis. It was just an intelligent guess, which later turned out to be correct. Once accepted, however, it allowed chemists to determine accurate masses of atoms.

Who thought of ions?

The idea of the ion was first proposed by the English scientist Michael Faraday (1791–1867), who made a detailed study of electrolysis. He used the idea of ions to explain observations made during the electrolysis of molten compounds and aqueous solutions of compounds. Faraday had to look for new words to explain his discoveries about electrolysis. To do this, he consulted Greek scholars and together they decided on the terms ion (from the Greek word 'ion', meaning 'something that goes'), electrode, anode and cathode.

Michael Faraday (1791–1867)

The concept and the term ion were used before electrons were discovered, so how the charge on an ion arose was not understood. This again illustrates that even with incomplete knowledge or models, progress in science can still be made in explaining the observations we make.

Additional Teaching Material

Additional Exercise 1: Particles in Elements and Compounds

Objective

To identify the kinds of particles that make up elements and compounds

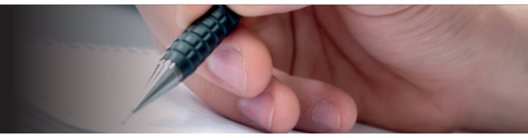
Competencies

CIT: inferring, organising; **ICS**: communicating (table, diagrams)

Scientists need to organise and present data in a neat fashion. One way to do this is by using tables. Complete the following table to show the different kinds of particles that make up elements and compounds.

Type of particle	Present in elements (✔ or ✘)		Example of diagram	Present in compound (✔ or ✘)	Example of diagram
	metals	non-metals			
Atoms					

Additional Teaching Material



Additional Exercise 2: Classifying Substances

Objective

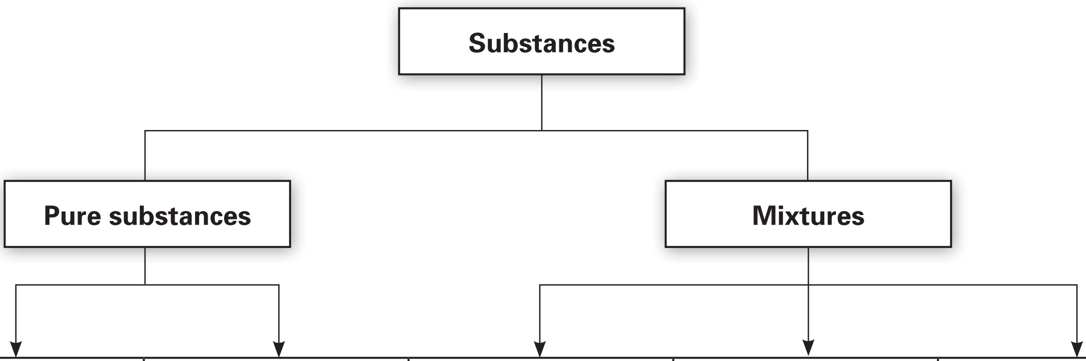
To classify substances such as elements, compounds and mixtures

Competencies

CIT: inferring, classifying; **ICS**: communicating (classification key)

aspirin	air	propane	butter	brass
cement	diamond	diesel	granite	charcoal
kerosene	magnesium	margarine	milk	perspex
paracetamol	pewter	poly(ethene)	soy sauce	steel
water	wine	vinegar	18-carat gold	chromium

A list of common substances is given above. Use the Internet or a reference CD-ROM to find out what these substances are made of. Then classify them into one of the following types in the table below.



Elements	Compounds	Mixture of Elements	Mixture of compounds	Mixture of elements and compounds
metals: **non-metals:**				

Write the address of the website or the title of the CD-ROM that you have used to obtain your information.

Website: ____

CD-ROM: ____

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