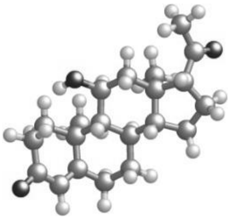
NANYANG GIRLS' HIGH



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<u>Chapter Three – Exploring the Diversity of Matter Based Upon Its Chemical Composition</u>

<u>Macroconcepts of Models, Systems and Scale</u>

Understanding the Essential Concepts:

- Scientist often use *models* to help them understand and explain phenomena in the natural world. In this chapter, we will use models to help us understand how the particles are arranged in elements, compounds and mixtures, which will lead to a deeper understand their properties. Suggest some ideas why Scientists use models to help them understand the natural world.
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- Scientists use *systems* to help them classify and organise living and non-living things based upon similarities and differences between them. In this chapter we will use a system to classify materials as either elements, compounds or mixtures based upon their chemical composition and properties.
  Provide some examples from your everyday life where you encounter systems. In what ways do these systems make your life more efficient?
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- Finally, Scientists use *scale* when they move from studying very small objects (*e.g.* the particles that make up matter) to studying very large objects (*e.g.* the solar system) – scale helps Scientist to put the phenomena in perspective.
  Provide some examples of objects or phenomena studied by Scientists – some of which are very big, and some of which are very small.

smaller than 1 mm	bigger than 1 km
←←← scale, over 1 000 000 times bigger or smaller →→→	
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Guiding questions.

- Why is it important for Scientists classify a substance based upon its chemical composition?
- What guiding principles or rules do Scientists use to classify a substance based upon its chemical composition?
- Can all substances be classified based upon their chemical composition? What are the consequences if a substance cannot be classified, or is classified incorrectly?
- What are the key characteristics that distinguish elements, compounds and mixtures?
- How is this chapter related to other chapters in Science (*e.g.* The Scientific Endeavour) and how does establishing these connections deepen my understanding of Science?
- How does understanding Science deepen my understanding of my other subjects and vice-versa?

- **Learning Outcomes:**

	Topic	**Yes, I understand**	**No, I need more help**
1.	State that elements are the basic building blocks of living and non-living matter.	☐	☐
2.	Recognise that there are different types of elements represented in the Periodic Table of Elements, *e.g.*, metals and non-metals.	☐	☐
3.	Show an understanding that compounds are substances consisting of two or more chemically combined elements.	☐	☐
4.	Show an understanding that compounds have different characteristics from their constituent elements.	☐	☐
5.	Show an understanding that mixtures are made up of two or more elements and / or compounds that are not chemically combined.	☐	☐
6.	Show an understanding that mixtures display characteristics of their original constituents.	☐	☐
7.	Classify matter as elements, compounds and mixtures based on their chemical composition.	☐	☐
8.	Distinguish between elements, compounds and mixtures.	☐	☐
9.	Distinguish between solute, solvent and solution.	☐	☐
10.	Show an understanding that solutions and suspensions are mixtures.	☐	☐
11.	Investigate the factors that affect the rate of dissolving and solubility of substances.	☐	☐
12.	Show an appreciation of how recycling and reuse of precious materials can be facilitated by the classification of waste products based on their chemical composition.	☐	☐
13.	Show an awareness of the importance of knowing the chemical composition of everyday items and how it can be beneficial (*e.g.*, melamine used for making plastic containers) or harmful (*e.g.*, melamine contamination in milk powder).	☐	☐

• **Introduction:**

There is an interesting variety of materials that make up our Earth. Humans have used the materials of the Earth to construct buildings and to make useful tools and devices.

• **Activity 1.**

What useful functions do the following materials have in our everyday lives?

(a) Gold – Au ……………………………………………………………………..

(b) Iron – Fe ……………………………………………………………………..

(c) Sodium chloride – $NaCl$ (table salt) ……………………………………………………………………..

(d) Octane – C_8H_{18} (a type of fuel) ……………………………………………………………………..

• **Activity 2.**

Knowing the chemical composition of everyday items such as food is important. At times, such knowledge can affect our daily lives.

Nutrition Facts

48 servings per container

Serving size 1 cookie (25g)

Calories per serving 110

Amount/serving	% Daily Value*	Amount/serving	% Daily Value*
Total Fat 4.5g	**6%**	**Total Carbohydrate** 17g	**6%**
Saturated Fat 2.5g	**13%**	Dietary Fiber <1g	**3%**
Trans Fat 0g		Total Sugars 9g	
Cholesterol 20mg	**7%**	Includes 9g Added Sugars	**18%**
Sodium 80mg	**3%**	**Protein** 2g	

Vitamin D 0mcg 0% • Calcium 10mg 0% • Iron 0.4mg 2% • Potassium 40mg 0%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

INGREDIENTS: WHEAT FLOUR*, OAT, BUTTER* (CREAM, NATURAL FLAVORING), BROWN SUGAR, SUGAR, BANANA*, EGGS, SALTS, BAKING SODA, NATURAL FLAVOR, SPICE. * = ORGANIC

CONTAINS: MILK, EGG, WHEAT

Study the food label shown above. What useful information does it give the consumer, and how does this information allow the consumer to make informed choices about what they eat and drink?

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• **Case Study:**

Melamine is rich in nitrogen, a property that is similar to protein. Go to https://www.britannica.com/science/melamine to find out more about the uses of melamine and how it was misused by unethical manufacturers who wanted to mislead consumers into believing that their milk powder for babies contained higher levels of protein than they really did.

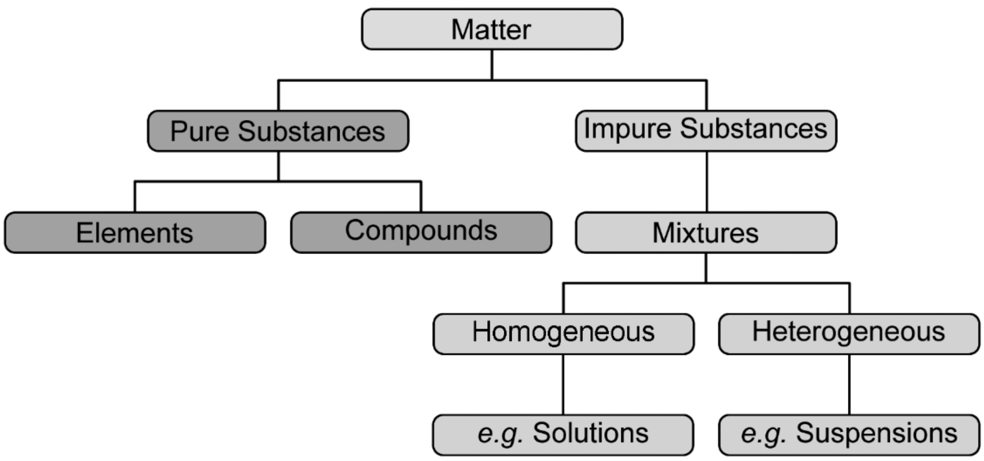
In the previous chapter, we classified matter using their physical properties. Another useful scheme is to classify matter as **pure** or **impure**. In everyday life, we use the term pure to describe things that are not contaminated or mixed with other substances. For example, pure water does not contain bacteria and substances such as salt, sand or mud.

In Science, scientists have developed more exact definitions of the terms 'pure' and 'impure'.

• **Pure and Impure Substances:**

A **pure substance** is a single substance not mixed with anything else. It has a fixed composition and fixed properties and cannot be decomposed by simple physical separation techniques, such as chromatography, distillation and filtration. Pure substances can be further classified into **elements** and **compounds**.

An **impure substance** is a **mixture**. It has variable composition and variable properties and can be separated into their components by various physical separation techniques. Mixtures can be either homogeneous or heterogeneous. A homogeneous mixture (from the Greek term *homo-* meaning the same or identical) has the same composition throughout, while a heterogeneous mixture (from the Greek term *hetero-* meaning different or other) varies in its composition.



• **Activity 3.**

Look around you. What are some examples of pure substances and impure substances?

Pure substances: ……………………………………………………………………………………

Impure substances ……………………………………………………………………………………

• **More About Elements:**

Elements are the simplest pure substances. They are the basic building blocks of living and non-living matter that cannot be broken down into simpler substances by chemical means.

All known elements have been arranged in the **Periodic Table** of the elements according to increasing atomic number. Elements in the Periodic Table are arranged into **Periods** and **Groups**. Horizontal rows are called **Periods** while vertical columns are known as **Groups**. Elements in the same Group usually have similar properties, *i.e.* they all react in a similar way to each other.

The Periodic Table of the Chemical Elements

Key: atomic number / atomic symbol / name / relative atomic mass

Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3											13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	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 –		114 Fl flerovium –		116 Lv livermorium –		

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	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 –

Note: Metallic elements are to the left of the dividing line drawn around aluminium (symbol, A*l*) while the non-metallic elements are to the right of the dividing line. There are many more metallic elements compared to non-metallic elements.

Each element is identified by a unique symbol that consists of one or two letters. The first letter is always written in uppercase. If there is a second letter, it is always written in lowercase.

Elements are often named after mythological gods, countries, scientists, properties or astronomical objects. For example, vanadium (symbol, V) is named after the mythical Scandinavian goddess *Vanadis* – the goddess of beauty – because of the many beautifully coloured chemical compounds the element forms.

The symbols chosen for elements are not always related to their English names. The symbols for some elements are based on its Latin, Greek or German name. For example, the symbol for gold is Au which originates from the word *aurum*, the Latin name for gold. The word aurum itself originates from the Greek word Aurora – the name of the mythical golden goddess of the dawn.

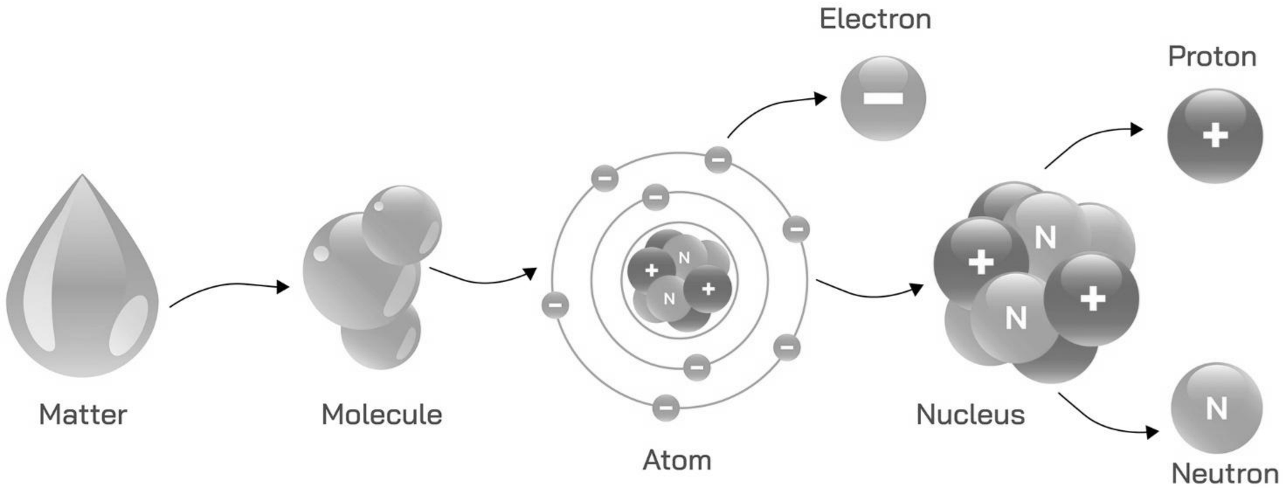
Element	Symbol	English name
oxygen	O	Oxygen
calcium	Ca	Calcium

Element	Symbol	Latin name
tin	Sn	Stannum
iron	Fe	Ferrum

• **Composition of Matter – the Chemistry Perspective:**

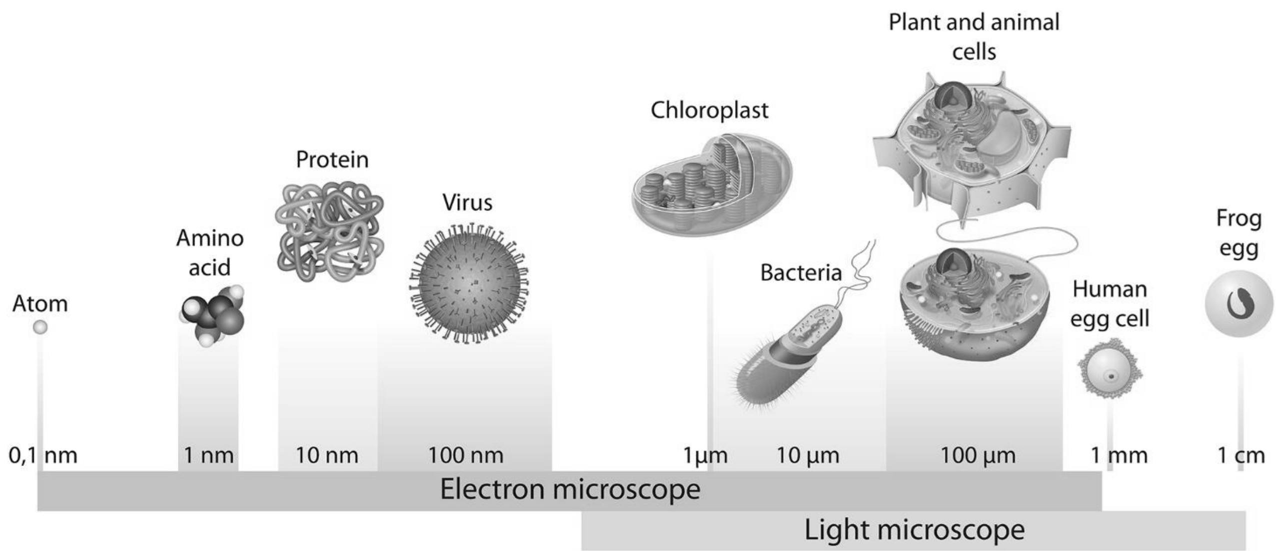
Scientists use **models** to visualize the components of matter in terms of different types of particles. **Atoms** are considered to be the basic building blocks of matter as they are smallest possible units of an element that retain all of the element's chemical properties.

Atoms are made of even smaller particles called **protons**, **neutrons** and **electrons**. The number of protons in the nucleus of an atom defines which element the atom belongs to. For example, an atom with **79 protons** in its nucleus is an atom of the elements **gold**.



• Models help scientists understand complex phenomena.

In addition to models, another concept that is often used in science is the concept of **scale**. Scale helps scientists organise and understand phenomena from the extremely small, *e.g.* atoms, to the extremely large, *e.g.* the Milky Way galaxy.

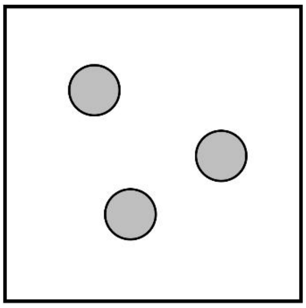


• The concept of scale helps scientists to arrange phenomena from the extremely small to much larger objects.

Sometimes, atoms of the same element or different elements combine to form more complex particles called **molecules**. A **molecule** is formed when 2 or more atoms chemically combine together, or bond together.

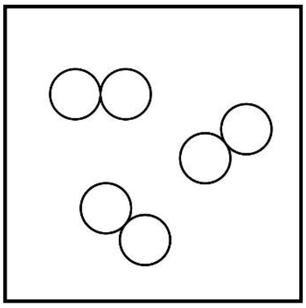
Some elements are made of individual atoms while other elements are made of molecules of the same type of atoms. The diagram below shows examples of particles present in certain elements.

Elements made-up of individual atoms



Examples: helium (He), neon (Ne), argon (Ar)

Elements made-up of two atoms of the same type chemically combined together (diatomic molecules)



Examples: oxygen (O_2), nitrogen (N_2), chlorine (Cl_2)

Elements are made up of only one type of atom. This is shown clearly in the examples of the models of particles shown above as only one type of particle, *e.g.*  is used. An element cannot be converted into a more simple substance by either a chemical or physical process.

Elements can be classified according to their physical properties, *e.g.* their states at room temperature. For example, iron is a solid, mercury is a liquid and oxygen is a gas. Elements can also be classified as **metals** and **non-metals**.

- **Activity 4.**

Write down some physical properties of metals and non-metals.

Properties of Metals	Properties of Non-metals

• **More About Compounds:**

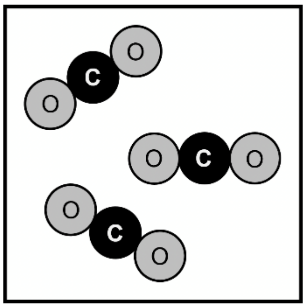
Compounds are also pure substances and are made up of two or more elements that are chemically combined (or chemically bonded) together. The table below shows examples of compounds and their constituent elements.

Compound	Elements in the Compound
Common table salt (sodium chloride)	Sodium and chlorine
Water	Oxygen and hydrogen
Sand (silicon dioxide)	Silicon and oxygen

Compounds are composed of fixed numbers of atoms of different elements bonded together. Compounds can be broken down into their component elements by a chemical process. The elements in compound cannot be separated from each other by simple physical methods such as chromatography, distillation or filtration.

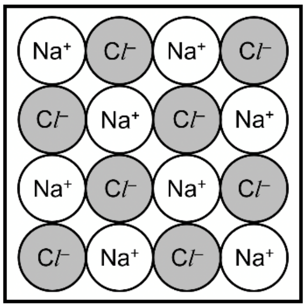
Each compound may be made up of **molecules** or another type of particles called **ions** (ions are electrically charged particles – ions are studied in more detail under the topic of Chemical Bonding in Secondary 2). The table below shows examples of two compounds and their particles. From these examples, you should notice that there are at least **two different** symbols used, indicating that there are **two different chemical elements** bonded together to make-up the compound.

Compound One – carbon dioxide



This compound consists of carbon dioxide molecules, which are composed of one atom of carbon (symbol, C) bonded to two atoms of oxygen (symbol, O).

Compound Two – sodium chloride



This compound consists of positive sodium ions (symbol, Na^+) and negative chloride ions (symbol Cl^-).

• **Characteristics of compounds:**

1. The composition of a compound does not vary. Constituent elements are present in fixed proportion by mass. For example, the proportion by mass of hydrogen and oxygen present in water is 11.1% and 88.9% respectively and will always have this fixed value.

2. Compounds have different properties from their constituent elements. For example, when we compare water with its constituent elements of hydrogen and oxygen, we will notice that water is a **liquid** at room temperature and pressure, unlike oxygen and hydrogen which are **gases** at room temperature and pressure.

3. Compounds can only be separated into the constituents by chemical methods (*e.g.* using heat, light or electricity to cause a chemical change) but not by simple physical methods.

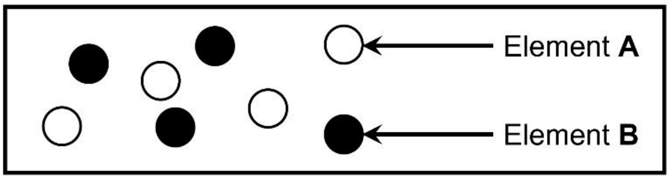
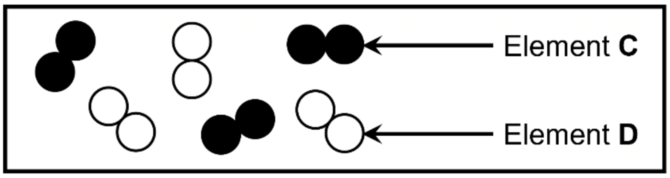
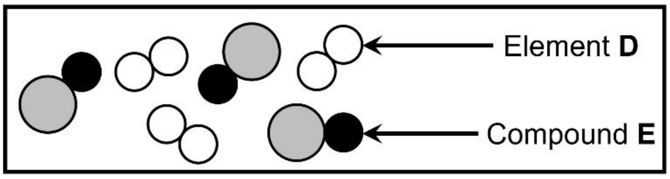
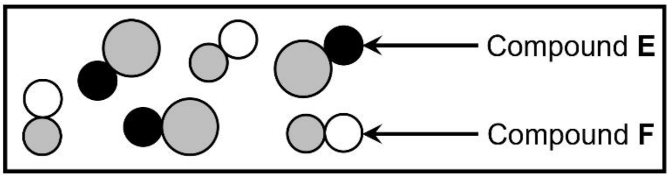
• **More About Mixtures:**

A **mixture** contains two or more substances physically mixed together (**not** chemically combined together). The table below shows examples of mixtures and their constituents.

Mixture	Constituents in the Mixture
Steel	Iron and carbon
Seawater	Water, sodium chloride (plus various other substances)
Air	Nitrogen, oxygen, argon, carbon dioxide, water vapour

Since constituents in a mixture are only physically mixed and are not chemically combined, the mixture will show characteristics of its original constituents.

Mixtures have various particle types and compositions. The table below shows examples of mixtures and their particles.

Type of Mixture	Composition of Mixture
	A mixture of two different elements (which are both monatomic).
	A mixture of two different elements (which are both diatomic).
	A mixture of an element and a compound.
	A mixture of two different compounds.

- **Characteristics of mixtures:**
  1. The composition of a mixture varies. They have a variable proportion of elements and / or compounds.
  2. The elements and / or compounds found in a mixture retain their respective properties.
  3. The constituents in mixtures can be separated by physical methods (*e.g.* filtration, distillation, magnets) but not by chemical methods.

There are 2 main types of mixtures:

1. **Homogeneous mixtures:**
   The particles of each component in homogeneous mixtures are distributed uniformly. For example, a sugar solution in water is a homogeneous mixture as the sugar particles are uniformly mixed with the water particles (*i.e.* colour, density, other properties are the same in every part of the mixture).

2. **Heterogeneous mixtures:**
   The particles of each component in heterogeneous mixtures are not uniformly distributed. For example, muddy water is a heterogeneous mixture as the heavier mud particles settle under gravity to form a sediment.

- **Comparing Compounds and Mixtures:**

Mixture	Compound
It can be separated by a physical means, *e.g.* filtration.	It cannot be separated by a physical means. Can only be separated by a chemical process.
Its physical properties are the same as the substances that make-up the mixture.	Its physical properties are different from those of the substances in it.
The composition of a mixture can vary.	The composition of a compound cannot vary. Constituent elements are present in fixed proportions by mass.
Its chemical properties are the same as the substances that make-up the mixture.	Its chemical properties are different from those of its component elements.

- **Activity 5.**

Classify the following substances as either elements, compounds or mixtures.

Substance	Classification
carbon dioxide	
iron	
sugar	
coffee	

Substance	Classification
milk	
bronze	
concrete	
silver	

• **Activity 6.**

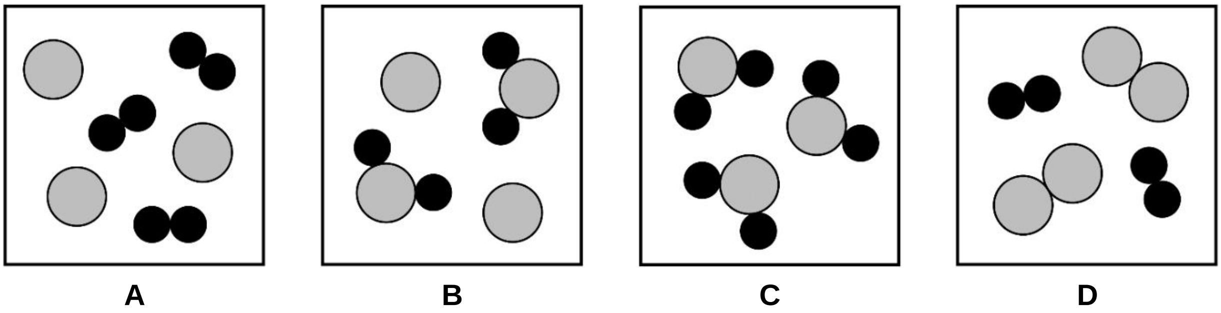
The diagrams below show four different substances; **A**, **B**, **C** and **D**.

Choose from the list the term which correctly describes the particles for substances **A**, **B**, **C** and **D**.

An Element | **A Compound**

A Mixture of Elements | **A Mixture of Compounds**

A Mixture of an Element and a Compound

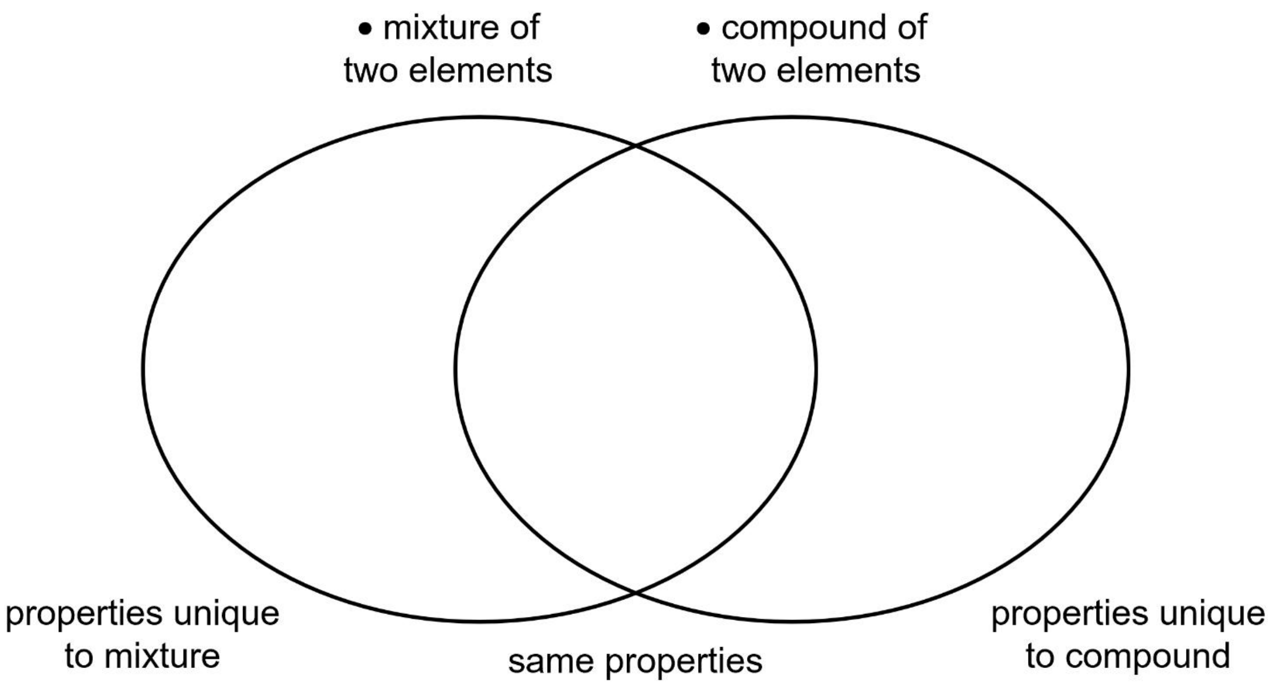


Substance **A** ………………………………………. Substance **B** ……………………………………….

Substance **C** ………………………………………. Substance **D** ……………………………………….

• **Activity 7.** Summarise your understanding:

Compare and contrast their properties of mixtures and compounds by completing the Venn Diagram given below.



- **Types of Mixtures – Solutions and Suspensions:**

1. **Solutions:**

   A **solution** is a **homogeneous mixture** of two or more substances. In a solution, a **solute** dissolves into a **solvent** and they stay mixed together.

   Example: Salt dissolves in water to form salt solution.
   Salt is the solute and water is the solvent.

   A **solute** is a substance which dissolves in another substance (and often present in a smaller amount). A **solvent** is a substance which can dissolve other substances (and often present in a larger amount). Some examples of solvents are water and ethanol (alcohol). Water is widely used as a solvent and solutions made with water as the solvent are known as **aqueous solutions**. The table below shows more examples of different types of solutions.

- **Activity 8.**

Provide examples of the different types of solutions by completing the table below.
Solid – solid has already been given as an example.

Type of Solution	Example
liquid – liquid	
gas – liquid	
solid – liquid	
solid – solid	Alloys (bronze is a mixture of copper and tin)
gas – gas	

2. **Suspensions:**

   A **suspension** is a **heterogeneous mixture** that contains substances that do not dissolve and the different parts will separate. The insoluble particles in a suspension will settle to the bottom when the suspension is left to stand for some time.
   Significant differences between a solution and a suspension are given in the table below.

Solution	Suspension
Solute particles are smaller.	Particles of the insoluble substance are bigger.
Clear, homogeneous mixture.	Not clear, heterogeneous mixture.
Particles do not settle on standing.	Particles settle on standing.
Particles are small enough to pass through filter paper, *i.e.* leaves no residue when filtered.	Particles are too large to pass through filter paper, so insoluble solid particles can be removed by filtration.

• **Activity 9.**

Explain why some bottles of liquid medication and cartons of fruit juice have labels on them advising the consumer to ***Shake Well*** before drinking its contents.

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• **Solubility:**

Solubility is the maximum mass of a solute that can dissolve in a fixed volume of a particular solvent at a certain temperature. It is often expressed in units of grams (mass of solute) per 100 cm^3 (volume of solvent) or g / 100 cm^3.

The mass of solute that can dissolve in a fixed volume of solvent depends on the following factors:

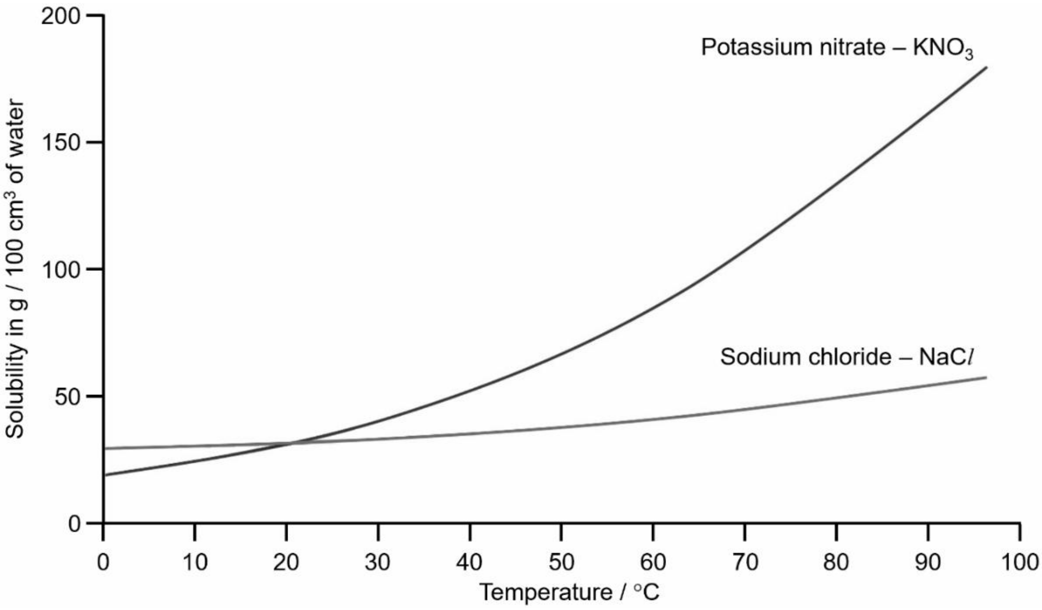
1. **Type of solute**. Different solutes dissolve to different extent in the same amount of solvent. For example, table salt can dissolve in water but pepper cannot.
2. **Type of solvent.** Different amount of the same solute dissolves in different solvents. For example, table salt can dissolve in water but not in cooking oil.
3. **Temperature**. At different temperatures, different amounts of solute dissolves in a given amount of solvent. Generally, solubility increases with increase in temperature.

A **dilute** solution is one with small amount of solute in large amount of solvent.

A **concentrated** solution is one with large amount of solute in small amount of solvent.

A **saturated** solution is one which contains the greatest mass of solute that can be dissolved in a fixed volume of solvent at a given temperature.

The change in solubility of a solute in a certain solvent as temperature changes can be shown in a **solubility curve**. The graph below shows the solubility curves of potassium nitrate and sodium chloride.



• **Rate of Dissolving:**

The **rate of dissolving** is the mass of a solute that can dissolve in a fixed volume of solvent, in a fixed amount of time.

• **Activity 10.** Factors that affect the rate of dissolving:

Temperature of solvent – higher temperature, ………………………… the rate of dissolving.

Size of solute particles – smaller solute particles, ………………………… the rate of dissolving.

Rate of stirring – higher the rate of stirring, ………………………… the rate of dissolving.

• **Recycling of Waste Based Upon its Chemical Properties:**

It is important to adopt a sustainable lifestyle in order to reduce consumption of the Earth's limited resources as well as save energy and reduce pollution. Household and industrial waste can be recycled, a process during which it is often broken down into a more simple form and then converted into a new object that can be put to another use. An example is extracting the precious **metallic elements gold** and **silver** from electronic waste, such as laptop computers.

Precious metals, such as **platinum**, **palladium** and **rhodium** are used in the catalytic converters of motor cars to convert gases that are harmful to health and the environment into products that are less harmful. When cars are sent to be scrapped, these metals are extracted and recycled due to their high value and scarcity.

Precious Metal	Price per *Troy Ounce
Gold – Au	$2930
Silver – Ag	$33
Platinum – Pt	$985
Palladium – Pd	$985
Rhodium – Rh	$5350

*The troy ounce is the unit of measure used in the trading of precious metals.

1 troy ounce = 31.1 g

• **Activity 11.**

Use Artificial Intelligence (*e.g.* ChatGPT or Google Gemini) to generate a song or poem to help you remember the similarities and difference between elements, compounds and mixtures. Experiment with different prompts and see how this affects the system's output.

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- Scan the QR Code for the answers to this assignment.

https://www.chemist.sg/elements_compounds_mixtures/elements_compounds_mixtures_ans.pdf