

## CHEMISTRY

### What the study of Chemistry involves

**Chemistry** is the branch of science concerned with substances of which matter is composed.

It investigates their properties, how they interact, combine, and change to form new substances.

It is central to our daily lives: cooking, cleaning, medicine, agriculture, environment, energy.

Chemistry links with biology (biochemistry), physics (physical chemistry), geology (geochemistry).

### BRANCHES OF CHEMISTRY

1. Pure Chemistry (fundamental study of principles and theories)

These focus on **understanding** matter and its properties, without always thinking of immediate use.

- **Organic Chemistry** – study of carbon compounds (fuels, plastics, medicines).
- **Inorganic Chemistry** – study of all other elements and compounds (metals, minerals, salts).
- **Physical Chemistry** – study of energy, forces, and how matter behaves (rates of reaction, thermodynamics).
- **Analytical Chemistry** – study of identifying and measuring substances (food testing, drug quality control).
- **Biochemistry** – study of chemical processes in living things (DNA, enzymes, metabolism).
- **Theoretical Chemistry** – use of mathematics and computer models to understand matter (quantum chemistry, molecular modeling).

2. Applied Chemistry (uses chemistry knowledge to solve real-world problems)

These focus on **practical applications** of chemical knowledge.

- **Medicinal / Pharmaceutical Chemistry** – design and production of drugs.
- **Agricultural Chemistry** – fertilizers, pesticides, soil treatment.
- **Industrial Chemistry** – large-scale production of materials (cement, plastics, paints, cosmetics).
- **Environmental Chemistry** – study of pollution, recycling, renewable energy.
- **Food Chemistry** – preservation, flavor, nutrition, food safety.
- **Petrochemistry** – refining oil, making fuels, and chemical products from petroleum.
- **Material Science** – developing new materials (nanomaterials, alloys, ceramics, semiconductors).

## CAREERS IN CHEMISTRY

### Pure Chemistry Careers

- **Chemist / Laboratory Scientist** – develops new substances, studies properties of materials.
- **Pharmaceutical Scientist** – designs and tests new medicines.
- **Analytical Chemist** – investigates composition of materials (e.g., food, drugs, water).
- **Industrial Chemist** – works in industries like plastics, cement, cosmetics, textiles.
- **Environmental Chemist** – studies pollution, waste management, and renewable energy.

### Interdisciplinary Careers

- **Biochemist** – studies chemical processes in living things.
- **Forensic Scientist** – applies chemistry in crime investigation (fingerprints, poisons, DNA).
- **Materials Scientist** – designs new materials (alloys, polymers, ceramics, nanomaterials).
- **Chemical Engineer** – applies chemistry in designing production plants for fuel, fertilizers, etc.
- **Food Scientist** – ensures safety and quality of food, develops preservation methods.

### Applied/Everyday Careers

- **Agricultural Scientist** – develops fertilizers, pesticides, and soil treatments.
- **Pharmacist** – dispenses medicines, understands drug chemistry.
- **Medical Laboratory Technologist** – runs diagnostic tests using chemical principles.
- **Teacher / Lecturer / Researcher** – educates and advances chemical knowledge.

### University Programmes that require Chemistry

Chemistry is a **core requirement** for many programmes. Without Chemistry, students cannot qualify for these fields:

### Health & Life Sciences

- Medicine (Doctors need strong chemistry background, especially organic/biochemistry).
- Pharmacy & Pharmacology.
- Nursing & Midwifery.

- Biomedical Science.
- Dentistry.
- Veterinary Medicine.

### **Pure & Applied Sciences**

- Chemistry (Pure, Applied, Analytical, Industrial).
- Biochemistry & Molecular Biology.
- Environmental Science.
- Forensic Science.
- Food Science & Nutrition.

### **Engineering & Technology**

- Chemical Engineering.
- Petroleum & Gas Engineering.
- Materials & Metallurgical Engineering.
- Agricultural Engineering.
- Environmental Engineering.

### **Agriculture & Related Fields**

- Agricultural Science.
- Soil Science.
- Crop & Horticultural Science.

## **Fundamentals of Chemistry – Unit 1: Matter**

### **(Expanded Notes)**

#### **Wave–Particle Classification**

Matter behaves like particles: small discrete units such as atoms and molecules.

Energy often behaves like waves: sound waves, light waves, water waves. Modern science shows duality – light can behave as both particle (photon) and wave (electromagnetic wave).

This concept is important in understanding quantum mechanics and atomic structure.

#### **Definition of Matter**

Matter is anything that has mass and occupies space.

Examples: chair, stone, air, water.

Non-matter examples: heat, light, sound, emotions – these do not have mass or occupy space.

Matter exists in different forms (solid, liquid, gas, plasma).

#### **Mass and Volume**

Mass is the measure of the amount of matter in an object.

Measured using a balance; SI unit is kilogram (kg).

Volume is the amount of space an object occupies; SI unit is cubic metre ( $\text{m}^3$ ).

Other useful units:  $\text{cm}^3$ ,  $\text{dm}^3$ , litres (L).

Conversions:  $1 \text{ cm}^3 = 1 \text{ mL}$ ;  $1 \text{ dm}^3 = 1 \text{ L}$ .

#### **Density**

Density is the mass per unit volume of a substance (Density = Mass  $\div$  Volume).

It describes how tightly packed the particles of a substance are.

Unit:  $\text{kg/m}^3$  or  $\text{g/cm}^3$ .

Water's density =  $1000 \text{ kg/m}^3$  or  $1 \text{ g/cm}^3$  – this is the reference point.

If density  $<$  water, substance floats; if  $>$  water, substance sinks.

Experiment:

- Regular object: measure length  $\times$  width  $\times$  height for volume, weigh mass, calculate density.
- Irregular object: immerse in water, measure displaced water volume, then calculate density.

#### **Things to take note of when conducting experiments**

Meniscus (what it is, the factors that accounts for meniscus; parallax error)

Answering a “DESIGN an EXPERIMENT” question (Aim, Apparatus, Procedure, Results or Observation Conclusion)

#### **How Matter Adds Up & Mixes**

Law of Conservation of Matter: matter cannot be created or destroyed in ordinary processes.

When substances are combined, their masses add up to the total.

Mixtures: substances can combine physically without losing individual properties.

Experiments:

- Dissolving salt in water (mass remains constant).
- Mixing sand and iron filings (can still separate by magnet).

## **States of Matter**

Solid: definite shape and volume; particles closely packed; vibrate in place.

Liquid: definite volume, no definite shape; particles slide past one another.

Gas: neither definite shape nor volume; particles move freely and far apart.

Plasma: ionized gas with free electrons and ions; occurs in stars, neon signs, lightning.

## **Changes of State**

Melting: solid → liquid (heat absorbed).

Freezing: liquid → solid (heat released).

Evaporation: liquid → gas (heat absorbed at surface).

Deposition: gas → solid (heat released to the surrounding).

Condensation: gas → liquid (heat released).

Ionization: gas → plasma.

Deionization: plasma → gas.

All changes involve absorption or release of energy.

## **Matter and Temperature**

Temperature measures the average kinetic energy of particles.

Higher temperature = faster particle motion.

Melting point: temperature at which a solid turns to liquid.

Boiling point: temperature at which liquid turns to gas.

Different substances have different melting and boiling points – useful for identification.

## **Properties of Matter**

Physical properties: measurable without changing identity (color, odor, density, melting/boiling points).

Chemical properties: describe how a substance reacts to form new substances (flammability, reactivity).

Evidence of matter: it has weight (mass) and takes up space (volume).

## **Pure Substances and Mixtures**

Pure substances: fixed composition (elements and compounds).

Mixtures: combination of substances not chemically bonded.

Mixtures can be separated by physical methods: filtration, evaporation, distillation, chromatography etc.

## **Atoms – History & Scientists**

Empedocles & Plato: early theories (4 elements).

Alchemists: tried to turn base metals to gold; laid foundations for experimental chemistry.

Dalton's Atomic theory: matter is made of indivisible atoms.

Lavoisier: Law of Conservation of Matter.

J.J. Thompson: discovered electron (plum pudding model).

Rutherford: discovered nucleus and protons (gold foil experiment).

Bohr: electrons orbit nucleus in shells with fixed energy levels.

## **Subatomic Particles**

Proton: +1 charge, in nucleus.

Neutron: neutral, in nucleus.

Electron: -1 charge, orbiting nucleus.

Standard Model: includes quarks (make up protons and neutrons), leptons (electrons), and bosons (force carriers).

## **The Periodic Table (First 30 Elements)**

Students should memorize first 30 elements by name and symbol.

Arranged in increasing atomic number.

Elements in same group (vertical column) share similar chemical properties.

## **Mixtures**

Homogeneous mixtures: uniform composition (solutions like saltwater).

Heterogeneous mixtures: non-uniform.

Suspension: particles settle on standing (sand in water).

Colloid: particles remain dispersed and do not settle (milk, fog).

## **Physical and Chemical Change**

Physical change: no new substance formed (melting, boiling, dissolving).

Reversible.

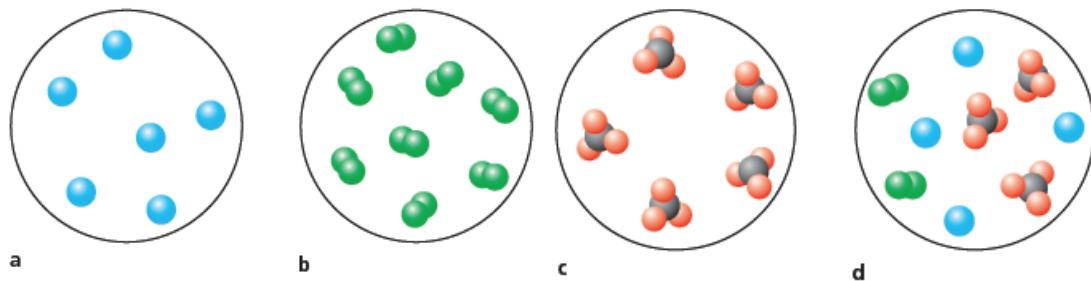
Chemical change: new substance formed with new properties (burning, rusting, reactions).

Irreversible.

Evidence of chemical change: color change, gas evolution, temperature change, precipitate formation.

## TRIAL QUESTIONS FOR SUMMATIVE

1. State what the following abbreviations mean:
  - a) SI
  - b) IUPAC
  - c) STP
2. Outline why your drink stays 'icy cold' when you add ice cubes.
3. Explain why a globally consistent approach to describing matter is important.
4. There is a fourth state of matter called plasma, found in extremely hot environments like the Sun. Suggest why Dalton did not include this form in his atomic theory.
5. The diagrams below use different coloured spheres to represent the atoms of different elements. Use these terms to describe what each of the diagrams represent these pure substances: **mixture, atom, molecule, element, compound**.



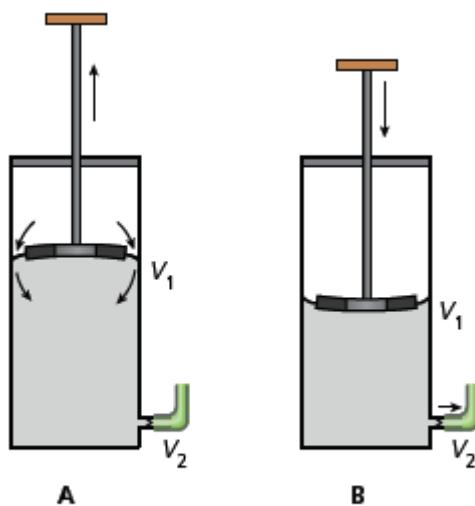
6. Sketch a similar diagram to show a mixture consisting of a combination of
  - a) two elements
  - b) a compound and an element.
7. Predict whether the matter of the familiar materials in the table is likely to be pure, and which are likely to be mixtures.

	Material	Pure matter?	Mixed matter?
a	PVC drink bottle		
b	Soup		
c	Ice cream		
d	Yoghurt		
e	Coffee		
f	Table salt		
g	Cake		

8. The matter in these common household materials is usually nearly pure. List some properties you associate with these materials. The first example is completed for you.

	Material	Properties
a	Iron nail	<i>solid, metallic, grey</i>
b	Water	
c	Sugar	
d	Ghee (clarified butter)	
e	'Methylated spirits' (cleaning alcohol)	

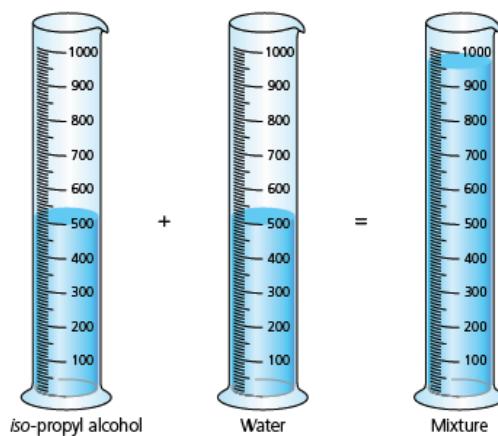
9. **State** one physical property that allows you to distinguish between the following paired examples of matter:
- soda water and tap water
  - sand and salt
  - gold and iron
  - ethanol and water.
10. **Apply** your knowledge about the attraction and kinetic energy of particles in a solid, liquid or gas to **suggest** the form of matter these groups of people could be modelling:
- students sitting at desks in the hall taking an external exam
  - a crowd leaving a movie theatre through a single door
  - all the students pushing up against the window of the canteen
  - recess, small children rushing around the play area
  - drama class, everyone walking randomly around, keeping a similar distance apart.
11. Your friend is staying overnight and you are pumping up an air mattress for her to sleep on. Figure 1.13 shows the pump at different positions. After the handle is pulled up (image A), no more air can enter. **Interpret** this information and judge:
- whether the mass of gas inside the pump has changed between position A and B
  - the position of the pump at which the gas it contains is at its most dense.



■ **Figure 1.13** A diagram showing how an air pump between 'strokes'

12. **Outline** reasons for standardizing conditions in which chemists describe matter.
13. In an experiment similar to the Activity: How does matter mix?, a student mixed 500 cm<sup>3</sup> each of two pure liquids, *iso*-propyl alcohol (propan-2-ol) and water.

**Apply** your knowledge and understanding about matter to explain why the total volume of the mixed liquids is less than 1000 cm<sup>3</sup>.



■ **Figure 1.14** Apparatus for experiment

14. Your little sister left her balloon in the back seat of a hot car. You return to the car with her after visiting a shopping mall for a few hours and notice the balloon seems a lot bigger. **Interpret** this observation with a scientifically supported judgment about how this may have been caused.

**THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 5–6**

15. Dalton's atomic theory included (a) elements, (b) atoms, (c) compounds and ideas about (d) states of matter: solids, liquids and gases.

16. Briefly **describe** these terms, using diagrams if necessary.

17. Recycling waste is a solution for improving the use of matter. In most urban environments, consumers are asked to sort their household waste to improve the efficiency of their community's recycling programmes. Properties for different categories of waste matter are summarized in the table below.

Category	Source category	Typical amounts/ 4 person household/ week (kg)	Average density (kg/1000 cm <sup>3</sup> )
Clean, used paper	Plants, renewable	5	0.5
Metals	Minerals, non-renewable	1.0	2.70 (aluminium) 7.87 (steel)
Plastics	Fossil fuels, non-renewable	0.5	1.1 (PVC) 0.9 (polystyrene)

- Calculate** the volume of each of the waste categories. Assume each type of material contributes equally, in categories that are mixtures. Express your answers using scientific notation.
- In the event of limited transport being available, **suggest** the waste category likely to deliver the best economic returns to the city, if recycled, and why.

18. A grain of sand can be assumed to be a sphere of diameter 10–4 m. It can be assumed that the particles making the sand grain are 10–10 m in diameter. **Estimate** the number of atoms in the grain of sand. Express your answer using scientific notation.

19. The table below shows some physical properties of familiar, everyday substances.

	<b>Material</b>	<b>Boiling point/°C</b>	<b>Melting point/°C</b>	<b>Density/kg/1000cm<sup>3</sup></b>
a	PVC drink bottle)	–	100–260	1.3–1.45
b	Table salt	1465	801	2.17
c	Gasoline (petrol)	23.5–190.2	–	0.71–0.77
d	Cane sugar (sucrose)	–	186	1.59

**Analyse** the information to make scientifically supported judgments about which of these materials is likely to be chemically pure.

### THESE PROBLEMS CAN BE USED TO EVALUATE YOUR LEARNING IN CRITERION A TO LEVEL 7–8

20. **Explain**, using examples about the nature of matter, the limitations of developing scientific knowledge by argument and discussion alone.
  
21. Consider the following two situations involving the storage of gases:
  - Cooking gas is often stored and delivered in steel bottles. Over a period of time, the pressure of the gas in the steel bottle does not change.
  - Air and helium are gases that are often used to fill rubber balloons. Over a period of time, the balloons gradually shrink.
    - a. **Explain** these observations, using your scientific understanding about the nature of matter.
    - b. **Suggest** how your ideas might be tested.
  
22. **Analyse** and **evaluate** the observations below, to determine whether the changes described are likely to involve the formation of new combinations of matter, or are physical changes.

	Observation	Chemical or physical?	Scientifically supported judgment
a	The edge of a towel hanging in a wet bath draws up water, wetting the entire towel		
b	A firecracker explodes, producing noise, smells and smoke		
c	Copper is a pink-coloured metal that is often used as cladding (covering) on roofs and domes of important buildings. After a few years, it goes bright green		
d	When a clean, dry, very cold glass is placed on a table at room temperature, it quickly becomes covered with small droplets of water		