MahaScience9

CLASS 9 SCIENCE · MAHARASHTRA STATE BOARD

CHAPTER 13

Carbon: An Important Element

Chapter Notes

1. Carbon: a versatile element

Carbon (symbol **C**) is a non-metal with atomic number **6**. Its electronic configuration is **2, 4**, so it has 4 electrons in its outer shell and its valency is **4**.

- **Free state:** diamond, graphite and coal.
- **Combined state:** carbon dioxide in air; carbonates such as limestone, marble and chalk ($CaCO_3$); fossil fuels (coal, petroleum, natural gas); and all living things, whose carbohydrates, proteins, fats, vitamins and DNA are carbon compounds. Compounds of carbon found in living things are called **organic compounds**.

Why does carbon form so many compounds?

- **Tetravalency:** carbon can form 4 bonds with other carbon atoms or with atoms like H, O, N and Cl.
- **Covalent bonds:** carbon does not lose or gain electrons easily. It **shares electrons** with other atoms to form covalent bonds.
- **Catenation:** carbon atoms join with each other to form long **straight chains, branched chains** and **rings**. Carbon can also form single, double and triple bonds.
- **Solubility:** pure carbon (diamond, graphite, coal) is **insoluble in water** and common solvents.

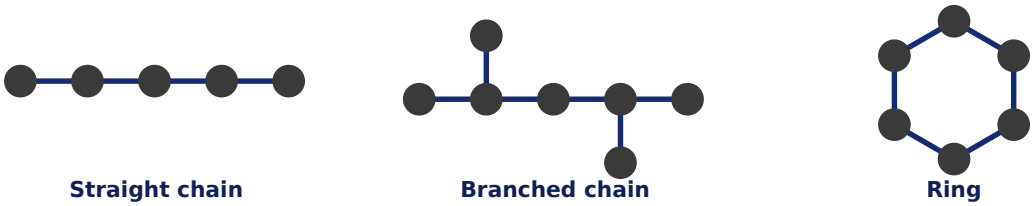


Fig. 13.1 Carbon atoms can join as chains, branches and rings

2. Allotropes of carbon

When an element exists in two or more forms with different **physical** properties but the same **chemical** properties, the forms are called **allotropes**, and this property is **allotropy**. All allotropes of carbon burn in oxygen to give only carbon dioxide, which proves they are all made of carbon.

Crystalline forms	Non-crystalline (amorphous) forms
Diamond, graphite, fullerene	Coal, charcoal, coke
Atoms arranged in a regular, definite pattern; sharp melting point.	No regular arrangement of atoms; no definite shape.

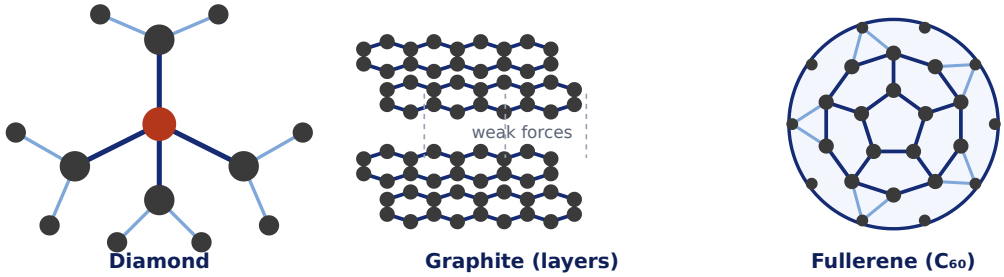


Fig. 13.2 Arrangement of carbon atoms in the crystalline allotropes

Property	Diamond	Graphite
Structure	Each C bonded to **4** C atoms in a rigid 3-D network	Each C bonded to **3** C atoms in flat hexagonal layers; layers held weakly
Hardness	**Hardest** natural substance	Soft and slippery (layers slide)
Appearance	Transparent, shining	Black, opaque, slightly shiny
Electricity	**Bad conductor** (no free electrons)	**Good conductor** (one free electron per atom)
Density	About 3.5 g/cm³	About 2.2 g/cm³
Uses	Jewellery; cutting glass and drilling rocks; polishing; tools for eye surgery	Pencil lead; electrodes; lubricant in machines; in nuclear reactors

FULLERENE

Fullerenes are cage-shaped molecules. The best known, **C_{60} (buckminsterfullerene)**, has 60 carbon atoms arranged like a **football**, in 20 hexagons and 12 pentagons. Discovered in **1985**, fullerenes are found in soot and in outer space. They are studied for use in nanotechnology, electronics and carrying medicines in the body.

SCIENTIFIC REASONS

Graphite conducts electricity: each carbon uses only 3 of its 4 electrons in bonding, so the fourth electron is free to move.
Graphite is not used in ornaments: it is soft, black, opaque and does not shine like diamond.
Diamond, graphite and fullerene are crystalline: their atoms are arranged in a definite, regular pattern.

Experiment: graphite conducts electricity

Make a circuit with a cell, a bulb and wires. Connect the ends of the wires to the two ends of a **pencil lead** (graphite). The bulb glows, which shows that graphite conducts electricity. A piece of diamond in its place would not light the bulb.

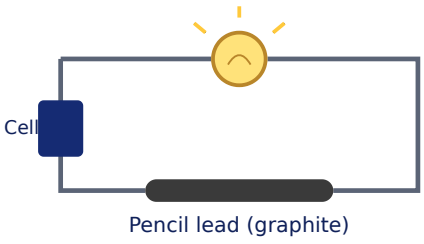


Fig. 13.3 Bulb glows: graphite conducts

Non-crystalline forms of carbon

Form	How it is formed	Properties and uses
Coal	Plants buried deep under the earth millions of years ago were changed by heat and pressure into coal.	Black, hard. Used as fuel, to make coke and coal gas, and in thermal power stations.
Charcoal	**Wood charcoal:** heating wood in a limited supply of air. **Animal (bone) charcoal:** heating bones.	Light, porous, black. Fuel; it **adsorbs** gases and colours, so it is used in water filters, gas masks and to decolourize sugar.
Coke	Heating coal strongly **without air**.	Almost pure carbon. Smokeless fuel; reducing agent in extracting iron from its ore.

Types of coal (increasing carbon content and quality): **peat** (about 60%) → **lignite** (60–70%) → **bituminous** (70–90%) → **anthracite** (about 95%). Anthracite is the best quality and gives the most heat.

3. Hydrocarbons

Compounds made of **only carbon and hydrogen** are called **hydrocarbons**. Petroleum, natural gas, LPG and CNG are mixtures of hydrocarbons.

SATURATED HYDROCARBONS

All carbon atoms are joined by **single bonds**. Examples: methane (CH_4), ethane (C_2H_6), propane (C_3H_8).

UNSATURATED HYDROCARBONS

At least one **double or triple bond** between carbon atoms.
Examples: ethene (C_2H_4, C=C), ethyne (C_2H_2, C≡C).

4. Methane (CH_4)

Methane is the **simplest hydrocarbon**. One carbon atom shares its 4 electrons with 4 hydrogen atoms, forming 4 single covalent bonds.

- **Occurrence:** the main part of natural gas and biogas; also found in coal mines and marshes.
- **Why "marsh gas":** in marshy (swampy) land, bacteria decompose dead plants without oxygen and produce methane, which bubbles up from the water.
- **Properties:** colourless, odourless gas, lighter than air, burns with a **blue flame** giving a lot of heat.
- **Uses:** fuel for homes and vehicles (CNG), in industries, and for making hydrogen and other chemicals.

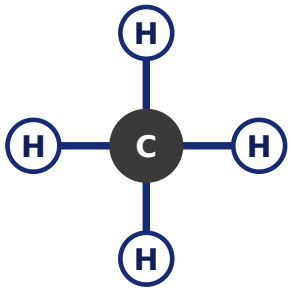


Fig. 13.4 Structure of methane

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + heat | $CH_4 + Cl_2 \xrightarrow{\text{sunlight}} CH_3Cl + HCl$

The second reaction is a **substitution reaction**: one hydrogen atom of methane is replaced by a chlorine atom.

Biogas plant

In a biogas plant, cow dung, plant waste and kitchen waste are mixed with water and put into a closed tank called a **digester**. Bacteria break down the waste **without oxygen** and produce **biogas**, which contains mainly **methane (about 55–75%)** with carbon dioxide and traces of other gases.

Why biogas is eco-friendly: it is made from waste, is renewable, burns without smoke, gives good heat, and the leftover slurry is a rich **manure**. It also reduces the cutting of trees for firewood.

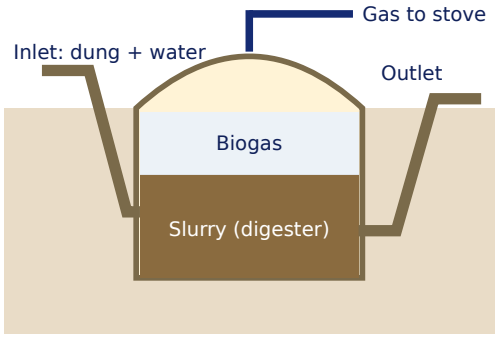


Fig. 13.5 A simple biogas plant

5. Carbon dioxide (CO_2)

Air contains about **0.03–0.04%** carbon dioxide. It is released by respiration, burning of fuels, fermentation and volcanoes, and taken in by plants for **photosynthesis**.

Laboratory preparation

Marble chips (calcium carbonate) are placed in a flask and dilute hydrochloric acid is added through a thistle funnel. The gas is collected by upward displacement of air, because CO_2 is heavier than air.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2\uparrow$$

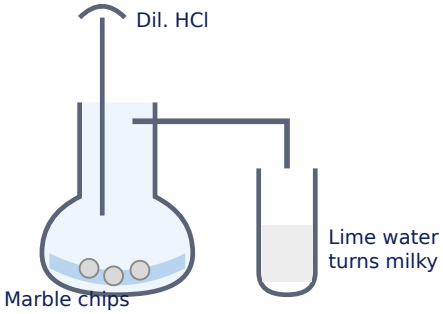


Fig. 13.6 Preparing CO_2 and testing it with lime water

Properties of CO_2 and how to verify them

Property	Test / reaction
Colourless, odourless, heavier than air	It can be poured from one jar into another like water, and it puts out a candle in the lower jar.
Turns lime water milky	$Ca(OH)_2 + CO_2 \rightarrow CaCO_3\downarrow$ (white, insoluble) + H_2O. Too much CO_2 makes it clear again (soluble calcium bicarbonate forms).
Does not burn or support burning	A burning candle or matchstick goes out in a jar of CO_2.
Dissolves in water, forming a weak acid	$CO_2 + H_2O \rightarrow H_2CO_3$ (carbonic acid); it turns blue litmus slightly red.
Reacts with bases	$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

Uses of carbon dioxide

- **Fire extinguishers**
- **Soda water and cold drinks** (CO_2 dissolved under pressure gives fizz)
- **Dry ice** (solid CO_2) to keep food, medicines and ice-cream cold; also for stage fog effects
- Photosynthesis; making washing soda and baking soda

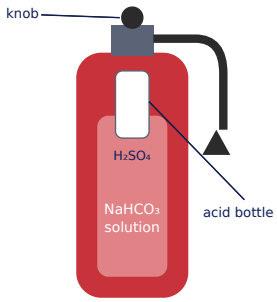


Fig. 13.7 Soda–acid fire extinguisher

Fire extinguisher (soda–acid type)

It contains sodium bicarbonate solution and a small bottle of sulphuric acid. When the knob is struck or the cylinder is turned over, the acid mixes with the bicarbonate and CO_2 forms, pushing a jet of liquid and gas out of the nozzle.

$$2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2\uparrow$$

How CO_2 puts out fire: it is heavier than air and does not support burning, so it covers the fire like a blanket and cuts off the supply of oxygen. CO_2 gas extinguishers are safe for electrical fires because they leave no water.

6. Burning of carbon and carbon compounds as fuels

$$C + O_2 \rightarrow CO_2 + \text{heat} \quad | \quad \text{Fuel } (C_xH_y) + O_2 \rightarrow CO_2 + H_2O + \text{heat}$$

- In a limited supply of air, carbon burns to form **carbon monoxide (CO)**, a poisonous gas: $2C + O_2 \rightarrow 2CO$. That is why stoves and heaters should be used only in ventilated rooms.
- **Carbon compounds are used as fuels** because they burn easily in air and give out a large amount of heat and light.
- **Petrol, diesel and coal are fossil fuels:** they were formed from the remains of plants and animals buried under the earth for millions of years. They cannot be made again quickly, so we must use them carefully.

7. Important questions for the exam

1. Fill in the blanks: Carbon forms **covalent** bonds by **sharing** electrons. Hydrocarbons with single bonds are **saturated**, and those with double/triple bonds are **unsaturated**. **Carbon** is the essential element in organic compounds.
2. Write the differences: (a) diamond and graphite (b) crystalline and non-crystalline forms of carbon.
3. Give scientific reasons: (a) Graphite conducts electricity. (b) Graphite is not used in ornaments. (c) Lime water turns milky with CO_2. (d) Biogas is eco-friendly.
4. Why is methane called marsh gas? Why are petrol, diesel and coal called fossil fuels?
5. Complete: $CH_4 + Cl_2 \rightarrow ?$ $2NaOH + CO_2 \rightarrow ?$ Fuel $+ O_2 \rightarrow ?$
6. Write the types and uses of coal. Describe an experiment to show that graphite conducts electricity.
7. How will you verify the properties of carbon dioxide? Explain how a fire extinguisher works.