

8. Carbon and its Compounds

8.1 Introduction

Over a million carbon compounds have been identified and many of these are useful to man. They are used as fuel and in the manufacture of drugs, fabrics, detergents, paints, plastics etc. Carbon and carbon compounds are very important industrial raw materials.

8.2 Allotropes of Carbon

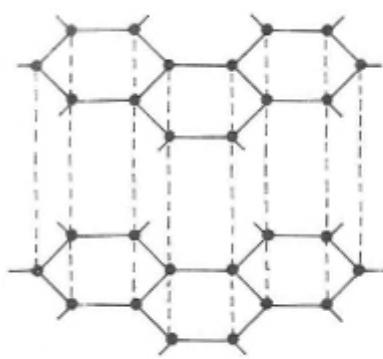
Carbon occurs naturally both in combination with other elements and as the free element. Diamond and graphite are the two elemental forms of carbon that occur naturally. These two forms differ greatly in physical characteristics.

The existence of an element in the same state but in more than one form is called allotropy.

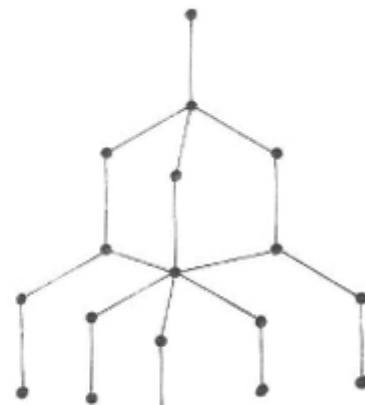
Carbon exhibits allotropy. The different forms of the element like graphite and diamond are called **allotropes**. Though these allotropes have different physical properties, they have the same chemical properties.

Diamond

Each carbon atom in diamond is covalently bonded to four other carbon atoms arranged tetrahedrally (Figure 8.1). This arrangement gives diamond a giant net-work structure. Diamond occurs as an octahedral crystal which is very dense and hard. It is the hardest naturally occurring substance. It is therefore used in glass-cutting and rock-drilling. When diamond is cut and polished, it has a high refractive index and lustre which makes it very important as a jewel. Diamond is mined in South Africa, Sierra Leone and India.



a) Graphite



(b) Diamond

Figure 8.1 Structures of graphite and diamond

Graphite

Graphite occurs as a black, slippery, hexagonal crystal. Internally, graphite consists of layers of carbon atoms. Each atom is joined to three others in the same plane, (Figure 8.1). Each layer of atoms is linked to another layer by weak van der Waal's forces. Because of these weak forces, the layers easily slide over one another. This makes graphite soft and greasy. It is therefore used as a lubricant in machines such as dynamos. Because of its soft and black nature it is used in the manufacture of lead pencils. Pencil is manufactured by mixing graphite with clay. If more clay is used, hard pencil is produced, but if more graphite is used soft pencil is produced. "Lead" pencil does not contain lead.



Pencil containing graphite



Diamond mounted on a ring

Figure 8.2 Uses of graphite and diamond

Graphite is the only non-metal that conducts electricity at room temperature and pressure. This is because it has free electrons. The free electrons exist because one of the four electrons in the outermost

shell of carbon is not used for bonding. Graphite is therefore used as electrodes. Graphite is also used in nuclear reactors to absorb neutrons and prevent explosion.

Amorphous Carbon

Other forms of carbon which do not exist naturally are loosely classified as amorphous. Some of the very fine varieties such as lampblack which appear amorphous, contain tiny crystals of graphite. The others such as animal and wood charcoal are impure forms of carbon.

Wood charcoal is prepared by heating wood in the absence of air to evaporate all the volatile constituents. This process is called **destructive distillation**. Wood charcoal is black, very light and porous.

Experiment 8.1 To investigate some properties of charcoal

Collect dry ammonia gas in a test tube. Invert the test tube over mercury in a small beaker as shown in Figure 8.3. Mark the level of the mercury. With the aid of a bent wire, push a bit of charcoal to the top of the mercury level inside the test tube. Leave the set-up to stand overnight.

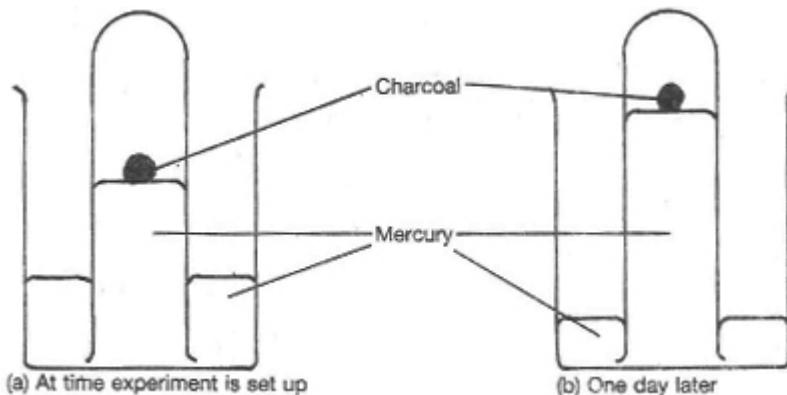


Figure 8.3: Charcoal absorbs gases

It will be seen that the level of the mercury has risen in the test-tube. An explanation for the rise of mercury in the tube in the above experiment is that charcoal absorbs part of the ammonia gas. Thus, wood charcoal absorbs gases.

Wood charcoal is therefore used in gas masks to absorb poisonous gases. Some crops grow well in soil treated with the ash from burnt charcoal. So charcoal must contain something else other than carbon; that is, it is impure. It contains oxides of phosphorus or other elements present in wood.

Animal or bone charcoal

Animal charcoal is formed when bone is heated in limited supply of air to distill off all the volatile constituents. Animal charcoal contains calcium and phosphorus which are present in bones.

Experiment 8.2 To investigate the absorption property of animal charcoal

Put three drops of bromine into a flask with ground glass stopper such as a volumetric flask. Stopper the flask immediately. Observe the reddish-brown vapours of bromine rising inside the flask, then put a spatula-full of animal charcoal into the flask and shake vigorously for three minutes. The vapour disappears. It must have been absorbed by the charcoal. To confirm that this was so, transfer the charcoal from the flask into a test tube and heat it. Bromine vapour will be evolved from the charcoal.

Experiment 8.3 Absorption property of charcoal

Put a drop of ink into sugar solution in a beaker. Add three spatula-loads of animal charcoal to it. Heat the mixture to boil, while stirring. Filter the hot solution. The solution is found to have turned colourless (Figure 8.5).

Heat another sample of ink in sugar solution but without adding charcoal, and again filter the hot solution. The filtrate will still be coloured with the ink colour.

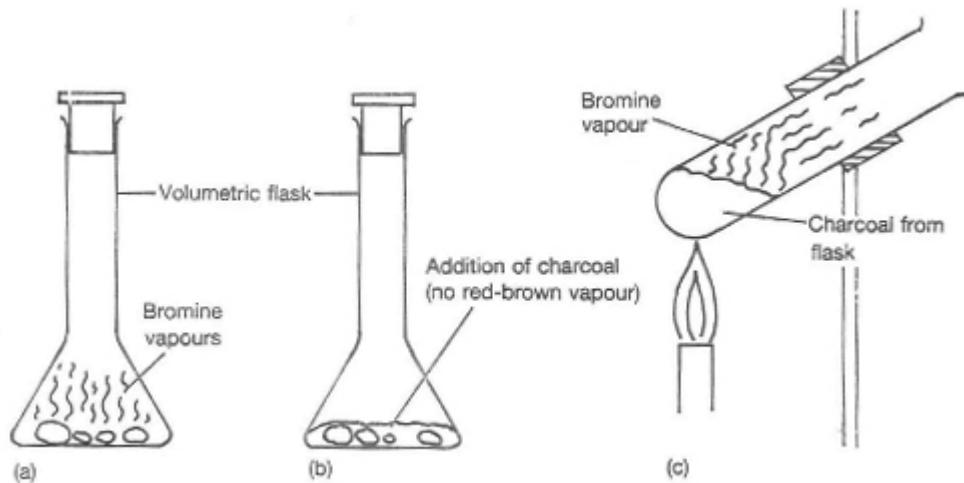


Figure 8.4 (a & b) Absorption of bromine by charcoal (c) Heat drives out the bromine

Evaporate both solutions to dryness. The colourless clear solution gives colourless crystals while the coloured solution forms coloured crystals.

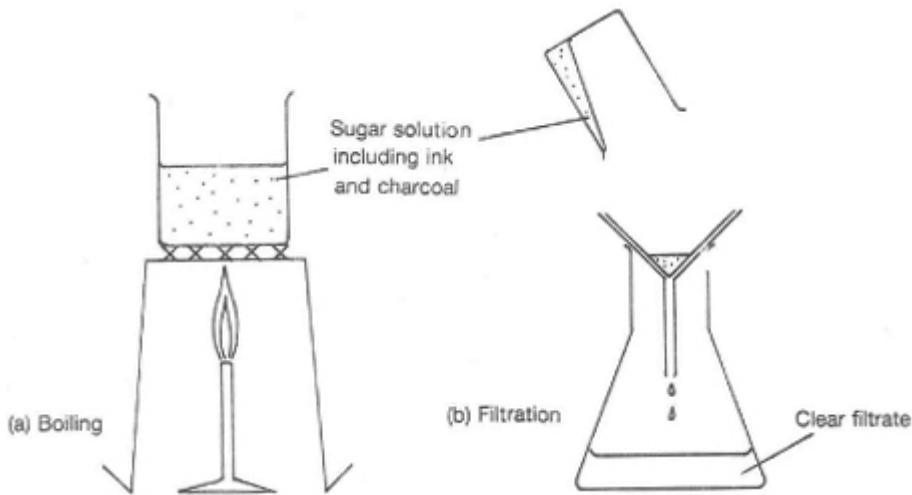


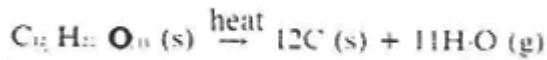
Figure 8.5 Absorption of colour by charcoal

Experiment 8.2 and 8.3 show that animal charcoal absorbs colours. It is used for removing colouring materials, e.g. in decolourising brown sugar obtained from the plant juice.

Lampblack is made by burning oils in a limited supply of air. It forms as soot on chimneys and glass globes of hurricane lanterns. The fine particles are tiny crystals of graphite. It is used for making printer's ink, shoe polish, and to give black colour to rubber tyres.

Sugar charcoal

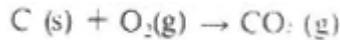
Sugar charcoal forms when sugar is heated in the absence of air.



It is the purest form of amorphous carbon. It also absorbs gases.

8.3 Properties of carbon

- (i) Carbon is insoluble in common solvents like water, hence the soot on hurricane lamp globe cannot be easily removed by washing with water.
- (ii) All the allotropes of carbon burn in air or oxygen, some at high temperatures, to form carbon(IV) oxide.



- (iii) Carbon is a reducing agent. When some metallic oxides are heated with carbon they are reduced to the metal while the carbon is oxidised to carbon(IV) oxide or carbon(II) oxide.

Experiment 8.4 To investigate the reducing action of carbon

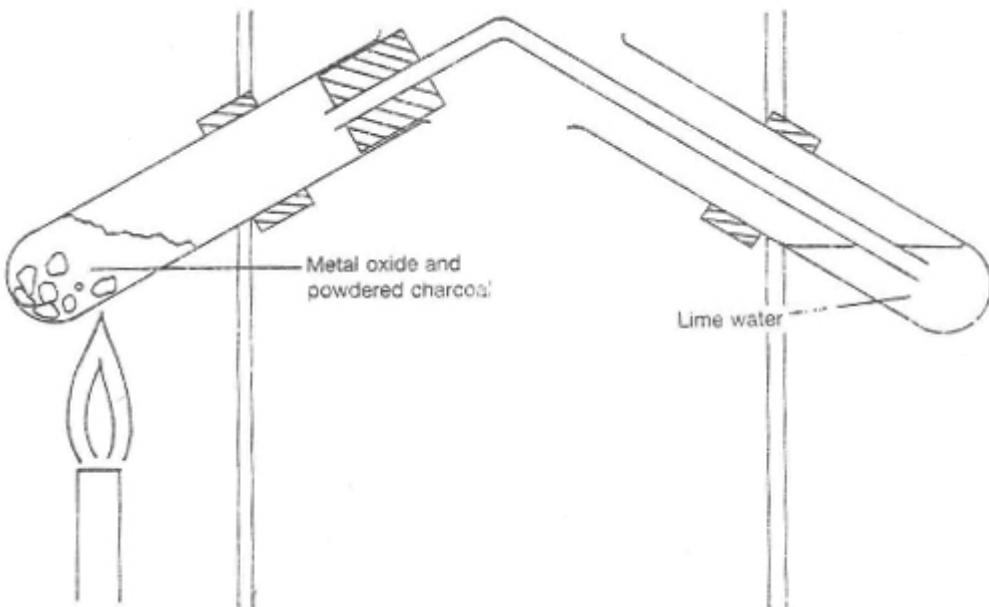
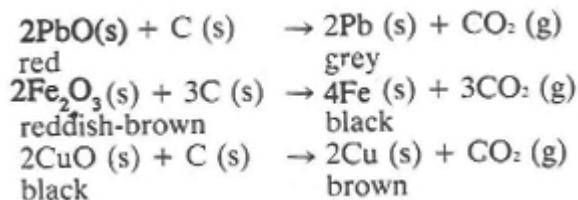


Figure 8.6 Heating a metal oxide and charcoal together

Observe the colours of lead(II) oxide, iron(III) oxide and copper(II) oxide. Heat each of these oxides with an equal amount of powdered charcoal in a hard test tube (Figure 8.6). Pass the gas evolved into lime water. You will notice that the lime water turns milky while each metal oxide changes colour as indicated below.

Metal oxide:	Colour before heating:	Colour after heating:
Lead(II) oxide	Red	Silvery grey
Iron(III) oxide	Reddish-brown	Black
Copper(II) oxide	Black	Brown



Each metal oxide has been reduced to the metal by carbon which becomes oxidised to carbon(IV) oxide that turns the lime water milky.

Use is made of this fact in metallurgy. Oxide ores of certain metals such as iron(III) oxide are heated with carbon (usually coke), to reduce the oxide ore to the metal.

In the charcoal block test a metallic oxide is reduced to the metal by carbon, by blowing a bunsen flame into the hole in a carbon block where the oxide is placed. The colour of the metallic oxide changes after the reduction.

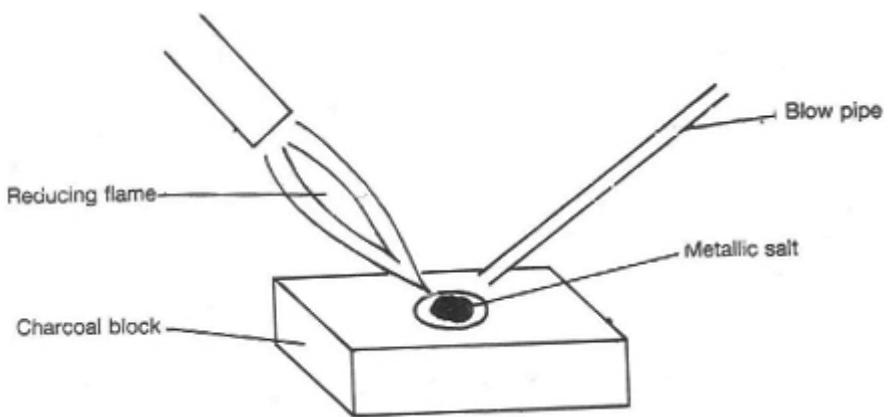


Figure 8.7 The charcoal block test

8.4 Coal

Coal is an impure form of carbon. It is formed from the remains of plants that lived several million years ago. The action of bacteria, heat and high pressures on the dead woods converted them into coal. The decomposition of wood into coal is a continuous process. The different grades of coal represent various stages of the decomposition. Table 8.1 shows the approximate composition of coal at different stages of formation.

TABLE 8.1 Types of coal

Grade	% Carbon	% Oxygen	% Hydrogen	% Other Elements
Wood	50	42	6	2
Peat	55	37	6	2
Lignite	75	14	5	1
Bituminous coal	85	9	5	1
Anthracite	91	3	5	1
Graphite	100	—	—	—

The lowest grade of coal is peat which is wood that has been subjected to little pressure after burial. Lignite is brown in colour. It has undergone little decomposition. It burns with very smoky flame. It is a low quality coal.

Bituminous coal is a high quality coal which is soft and found in many parts of the world, including Udi hills near Enugu. It has undergone a high degree of decomposition and lost all the wood-like structures. It burns with a hot flame and little smoke. It is the most important and widely used variety of coal. For a long time it was used by the Nigerian Railway Corporation for generating steam to run rail steam engines. It is also used in coal pot stoves for cooking, generation of electric power at Oji River, and also for producing coke

for the extraction of iron.

Anthracite or hard coal is a very high grade coal that burns without smoke.

Graphite, which is 100% carbon is the final stage of coal formation.

8.5 Distillation of coal

For a long time the only use of coal was as fuel for domestic and industrial purposes. Since coal was messy as fuel and produced acidic vapours, gaseous fuels were preferred to coal.

Experiment 8.5 Distillation of coal

Grind some coal to powder. Put some of the powder into a hard dry test tube. Set up the apparatus shown in Figure 8.8. Heat the test tube containing the coal strongly. Allow some bubbles of air to escape, then invert a gas jar filled with water over the bee-hive shelf. Collect any gas evolved by downward displacement of water.

Light the gas with a busen flame. It burns with a blue non-luminous flame. The gas is called **coal gas**.

In the water-cooled test tube it will be observed that two layers of liquid have separated. The lower layer is brownish-black and viscous while the top is watery.

The lower layer is **coal tar**. When the upper layer is tested with red litmus paper it turns blue showing that it is alkaline. This watery layer is **ammoniacal liquor**, that is, a solution of ammonia in water.

Examine the residue left in the hard test tube. It is a black solid, richer in carbon than the original coal. It is called **coke**.

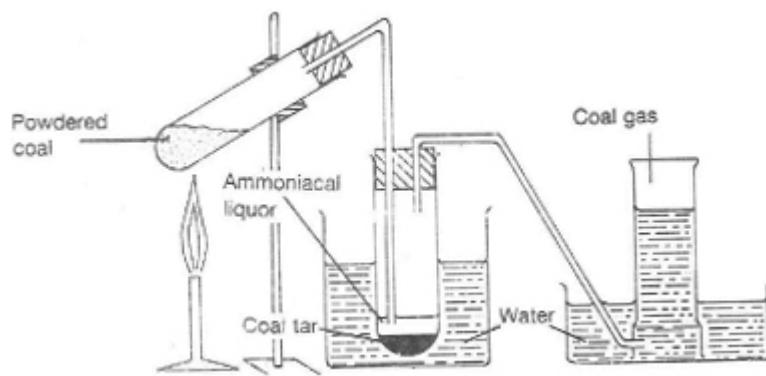


Figure 8.8 Distillation of coal

An application of Experiment 8.5 in industry is in the manufacture of coal gas. Coal is heated to about 1000°C , in the absence of air, in vertical retorts. Combustion does not occur, rather coal decomposes to yield a gaseous fraction, coal gas; two liquid fractions, ammoniacal liquor and coal tar; and a solid residue, coke, is left.

Coal is fed into the vertical column through hoppers. Producer gas

or coke is used as fuel. At about 1000°C , coal is decomposed in the retorts. Vapours leaving the retorts consist of coal tar, ammonia, coal gas and gaseous impurities such as hydrogen sulphide. Coal tar vapour condenses to a thick viscous liquid in the water-cooled condenser. The ammonia is dissolved out of the vapour by the water running down the scrubber. The presence of hydrogen sulphide impurity in coal gas is undesirable as it burns to produce poisonous sulphur(IV) oxide. It is removed by the action of iron(III) oxide in the purifier.



The remaining gas is then piped to houses for domestic purposes.

8.6 Products of destructive distillation of coal

- (i) Coal gas is a mixture of gases including hydrogen, methane and carbon(II) oxide.
It has a high calorific value and is widely used as industrial and domestic fuel. But its domestic use is rather dangerous since gas leakage is often disastrous due to its carbon(II) oxide content. This gas is a deadly poison. It kills by preventing oxygen from reaching the tissues because it combines irreversibly with haemoglobin.
- (ii) Ammoniacal liquor consists essentially of ammonia and benzene. The latter is obtained from the mixture by distillation. The ammonia solution that remains is used to manufacture nitrogenous fertilizer such as ammonium tetraoxosulphate(VI).
- (iii) Coal tar is a viscous brownish-black liquid. Its distillation yields five fractions at the boiling ranges indicated below.

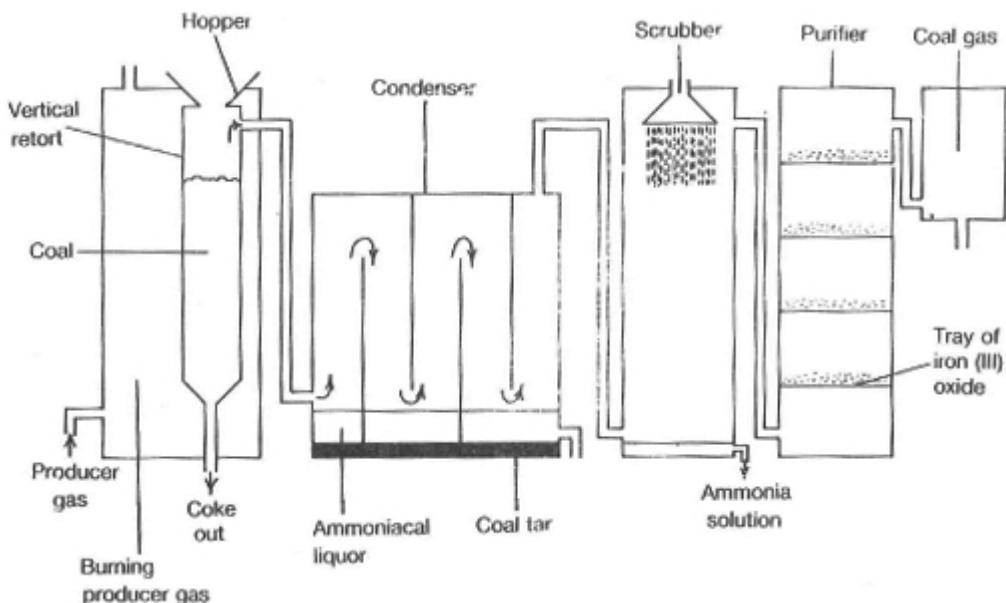
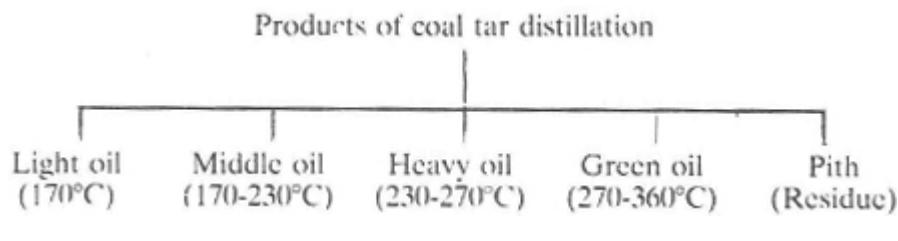
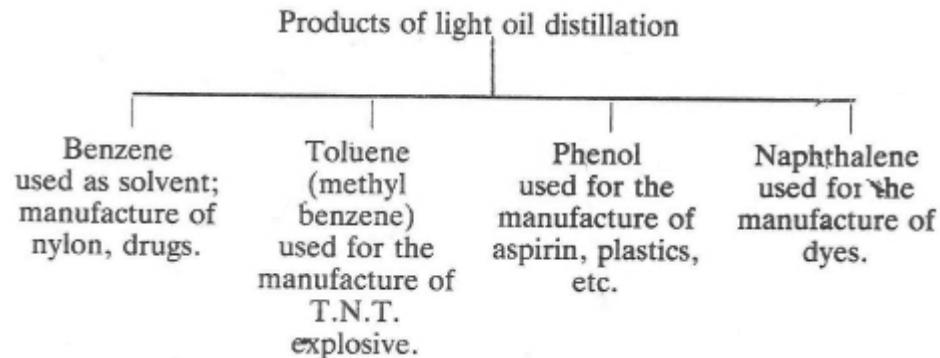


Figure 8.9 Manufacture of coal gas



After purifying the light oil fraction, by washing with acid and then base to remove basic and acidic impurities, it is subjected to further distillation. The products then obtained and their uses are summarized below.



- | | |
|-------------|--|
| Middle oil: | contains phenols. |
| Heavy oil: | is used for the preservation of wood. |
| Green oil: | contains anthracene, an important source of dyes. |
| Pith: | is a very black and sticky solid. It is used for covering road surfaces (asphalt). |

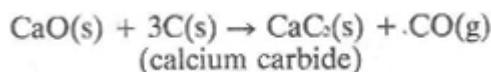
- (iv) Coke is essentially carbon which contains very little volatile impurities. Its composition depends on the composition of the

original coal. Depending on the source and efficiency of preparation, it may contain up to 90% of carbon.

It is used as fuel since it burns with little smoke. However, since gaseous fuels are preferred to solid fuel, coke is more often used to make water gas and producer gas.

Coke is used to reduce metallic oxides to the metals in their extraction processes. It is very important in the extraction of iron from its ores.

Coke is also used to manufacture calcium carbide.



The distillation of coal is termed the *destructive distillation of coal*.

This term is a misnomer because the distillation of coal yields useful products. If anything should be termed destructive, it is the combustion of coal which occurs when coal is used as solid fuel. Products of this combustion include impurities such as sulphur(IV) oxide, hydrogen sulphide, carbon(IV) oxide and particles of carbon, which pollute the atmosphere.

8.7 Producer gas and water gas

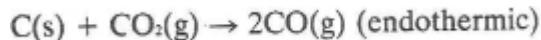
These are two gaseous fuels derived from coke.

Producer Gas

When air is blown through white-hot coke in a furnace, combustion takes place. Carbon(IV) oxide is formed.

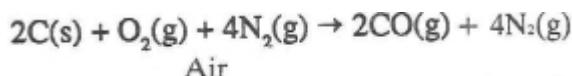


Much heat is liberated, and as the carbon(IV) oxide rises up the white hot coke, it is reduced to carbon(II) oxide because very little or no oxygen is available.



This reaction absorbs heat. Since the heat produced by the combustion is more than enough for the reduction, the temperature of the coke remains high.

Nitrogen of the air does not take part in the combustion or reduction reactions, so the overall reaction may be written as

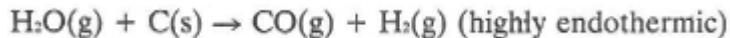


The gaseous mixture leaving the furnace which consists of carbon(II) oxide and nitrogen, is known as producer gas.

Of this product, only the carbon(II) oxide component is combustible, hence producer gas has a low calorific value.

Water Gas

By passing water vapour instead of air through white-hot coke in a furnace, a different composition of gaseous mixture called water gas is formed.



This reaction lowers temperature of the furnace drastically. After some time the passage of steam must be stopped, and air passed to raise the temperature so that the reaction with steam can take place.

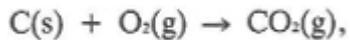
The mixture consists of 50% carbon(II) oxide and 50% hydrogen.

The two gases in water gas are combustible. Water gas also contains a greater percentage of carbon(II) oxide than producer gas. Water gas therefore has a higher calorific value than producer gas.

In practice a common furnace is used to produce both fuel gases alternately. Two inlets and outlets are provided. Air is first blown through heated coke for seven minutes. The coke becomes white-hot. Producer gas is collected at one outlet. The air inlet is then turned off and steam is blown through for about four minutes. Water gas is formed and collected at the second outlet. The temperature falls rapidly, and the steam is shut off. Air is then let in to raise the temperature (Figure 8.10)

The advantages derived from alternating the passage of air and steam through the same furnace instead of doing either separately are that:

1. The reaction



which is exothermic keeps the furnace at a very high temperature for a long time. The other reaction,



which is endothermic cools down the furnace.

Alternating both processes therefore, keeps the furnace working for a longer time.

2. Producer gas has a low calorific value whereas water gas has a high calorific value. When the two are mixed together a fuel gas

mixture that is good enough for most purposes is obtained.

8.8 Carbon(IV) oxide

Carbon(IV) oxide is the product of the final oxidation stage of carbon and carbon compounds with oxygen.

Experiment 8.6 Laboratory preparation of carbon(IV) oxide

Set up the apparatus shown in Figure 8.11. Place some calcium trioxocarbonate(IV) in the flat-bottomed flask. Pour dilute hydrogen chloride acid (hydrochloric acid) down the thistle funnel to cover half of the part of the funnel inside the flask. Pass the gas evolved through a solution of sodium hydrogen trioxocarbonate(IV), to absorb any hydrogen chloride acid (hydrochloric acid) which passes over, and also through concentrated tetraoxosulphate(VI) acid, (or a U-tube containing fused calcium chloride), to dry the gas. Collect the dry gas by downward delivery (upward displacement of air). Collect five gas jars and two test-tubes of the gas.

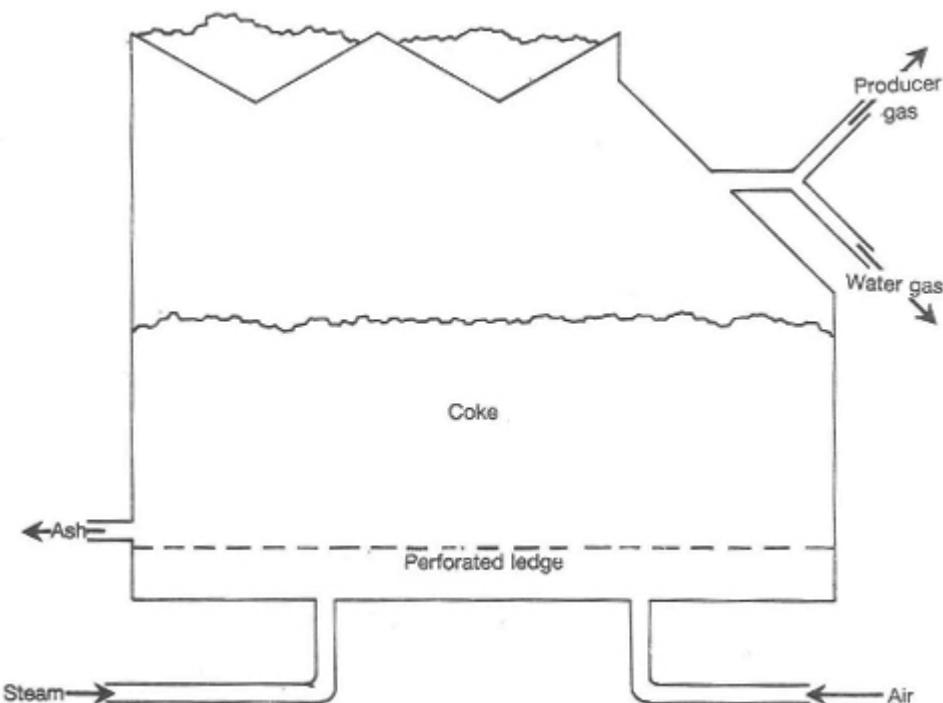


Figure 8.10 Manufacture of producer gas and water gas

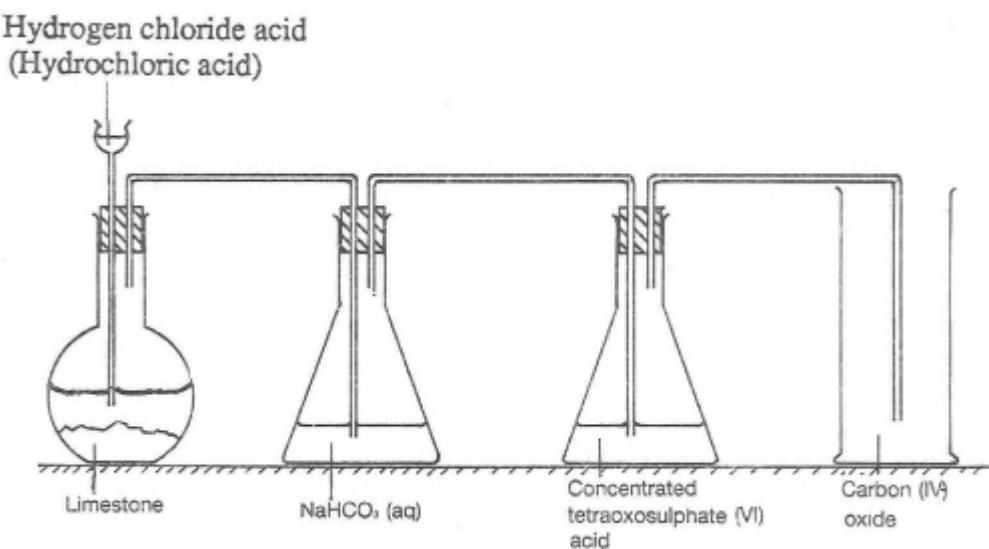


Figure 8.11 Laboratory preparation of carbon(IV) oxide

Experiment 8.7 To investigate the properties of carbon(IV) oxide

Carry out the following tests using the carbon(IV) oxide gas collected in the gas jars and test tubes in Experiment 8.6.

1. Stand a candle stick on a deflagrating spoon, then light it. Lower the burning candle into an open gas jar containing air. Pass carbon(IV) oxide from one of the gas jars over the flame as shown in Figure 8.12.

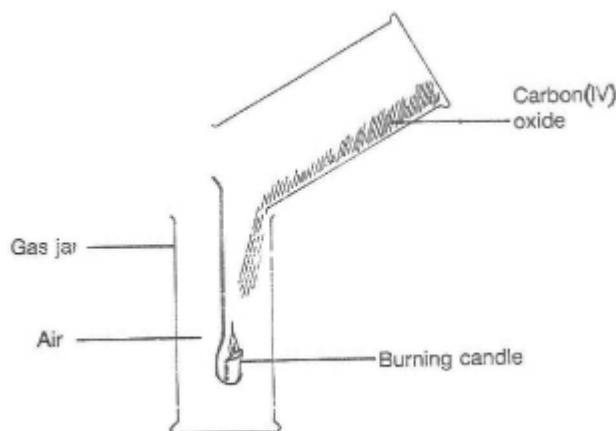


Figure 8.12 Carbon(IV) oxide is heavier than air

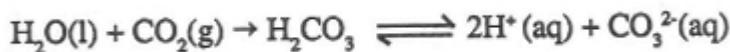
You will observe that the flame slowly goes out, showing that carbon(IV) oxide does not support combustion.

It is possible to pass carbon(IV) oxide into a gas jar containing air because carbon(IV) oxide is denser than air. It is for the same reason that carbon(IV) oxide is collected by downward delivery (upward displacement of air).

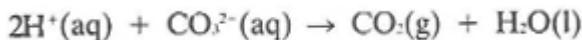
2. To about 20 cm³ of distilled water in a small conical flask add two drops of universal indicator. Bubble carbon(IV) oxide into the

water. The colour of the water turns faintly pink.

Warm the resulting solution gently at first, then heat to boil. The faint colour disappears. The faint colour suggests that a weak acid is formed when carbon(IV) oxide dissolves in water. The acid is trioxocarbonate(IV) acid.



The discharge of the faint colour on heating shows that the hydrogen ion is able to react with trioxocarbonate(IV) ion, liberating carbon(IV) oxide.



That is, the dissolution of carbon(IV) oxide in water is a reversible reaction.

The acid formed is a weak and volatile acid which is easily decomposed by heating.

3. Put about 125 cm³ of water and dilute sodium hydroxide solution into two separate beakers. Invert one covered test tube of carbon(IV) oxide into each of the beakers as shown in Figure 8.13. Remove the corks from the test tubes of carbon(IV) oxide.

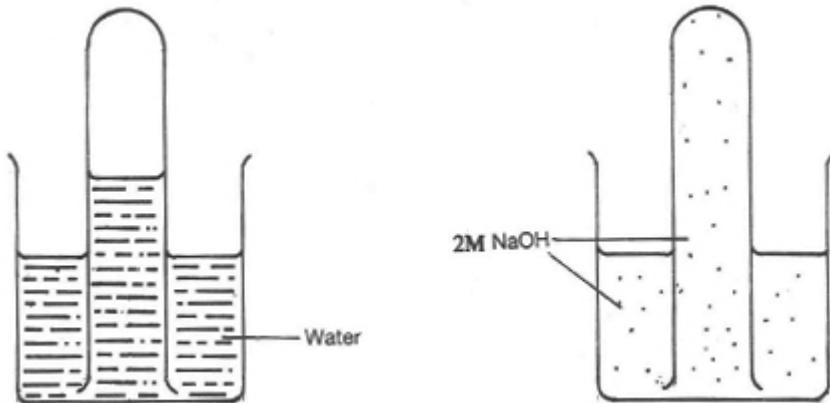


Figure 8.13 Reaction of carbon(IV) oxide with alkali

It is observed that the test tube inverted into sodium hydroxide solution becomes filled up with the aqueous solution whereas the other test tube inverted in water is not filled.

Carbon(IV) oxide is only slightly soluble in water. The aqueous solution of sodium hydroxide reacts with carbon(IV) oxide forming sodium trioxocarbonate(IV).



Since all the carbon(IV) oxide in the test-tube reacts, the vacuum in

the test-tube becomes filled with the aqueous solution of sodium hydroxide.

4. Pass the carbon(IV) oxide into lime water contained in a test-tube.

Note that the lime water turns milky. Continue passing carbon(IV) oxide into the milky solution. The solution becomes clear again.

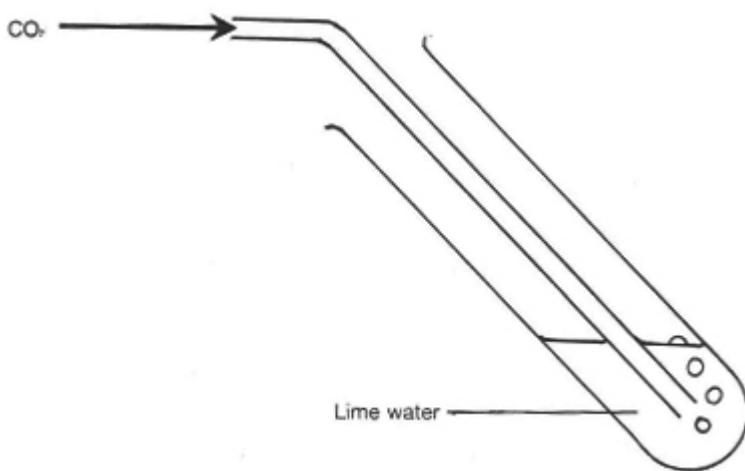
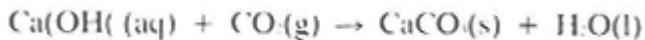


Figure 8.14 Test for carbon(IV) oxide

Lime water is a saturated solution of calcium hydroxide. When carbon(IV) oxide is passed into it, calcium trioxocarbonate(IV) is formed.



Being an insoluble salt, a white suspension results. The solution appears milky. As more carbon(IV) oxide is passed, further reaction occurs resulting in the formation of calcium hydrogen trioxocarbonate(IV). This acid salt is soluble in water, hence the milkiness disappears, forming a clear solution.



5. Attach magnesium ribbon to a deflagrating spoon. Light the ribbon on a bunsen flame, then lower it into a gas jar of carbon(IV) oxide. The magnesium continues to burn. Why is this surprising? Does it contradict the statement that carbon(IV) oxide does not support combustion?

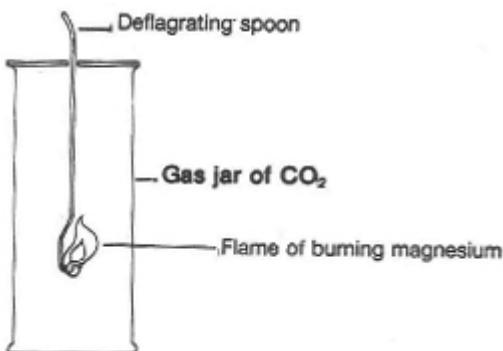
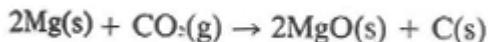


Figure 8.15 Burning magnesium in carbon(IV) oxide

Black specks will be seen on the wall of the gas jar along with some white specks. The white specks are particles of magnesium oxide. What has happened is that the very hot flame of the burning magnesium ribbon decomposes the carbon(IV) oxide to carbon particles and oxygen. The oxygen combines with the magnesium to form magnesium oxide. The particles of carbon are deposited as the black specks.



Magnesium has reduced carbon(IV) oxide to carbon, another surprising statement? Did we not say that carbon reduces metallic oxides to the metals, becoming itself oxidised to carbon(IV) oxide?

That is true. Magnesium behaves differently in this case because it is an active metal.

Is magnesium alone in this difference in behaviour?

6. CAUTION: PERFORM ONLY IN A FUME CUPBOARD. Pass carbon(IV) oxide over heated zinc in a combustion tube as shown in Figure 8.16. Pass any gas liberated through concentrated sodium hydroxide solution, then collect it in a test tube. Observe the colour of the residue in the combustion tube while hot, and on cooling. The residue will be seen to be yellow while hot, but white on cooling. No black specks of carbon are observed.

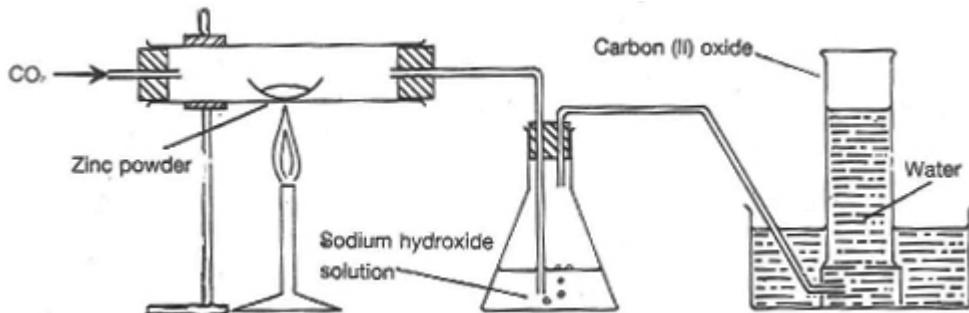


Figure 8.16 Action of zinc on carbon(IV) oxide

Light the gas collected. It burns with a blue flame. The solid residue is zinc oxide while the gaseous product is carbon(II) oxide.



Zn is oxidised by carbon(IV) oxide to zinc oxide, while carbon(IV) oxide is reduced to carbon(II) oxide.

The situation is not quite similar to that observed in magnesium, but it does show a direct opposite of the reducing property of carbon as used in metallurgy.

Summary of the properties of carbon(IV) oxide

1. Carbon(IV) oxide is a colourless, odourless gas.
2. It is about one and half times as dense as air.
3. It does not support combustion and does not burn.
4. It is slightly soluble in water. At room temperature a given volume of water dissolves its volume of carbon(IV) oxide, forming a slightly acidic solution.
5. The gas turns both lime water and baryta water (barium hydroxide solution) milky. This is a test for carbon(IV) oxide.
6. It reacts with sodium hydroxide solution forming sodium trioxocarbonate(IV).
7. Burning magnesium continues to burn in it, forming magnesium oxide and carbon.
8. When carbon(IV) oxide is passed over heated zinc, it forms zinc oxide and carbon(II) oxide.

Uses of carbon(IV) oxide

- (i) Fizzy drinks such as Coca-cola, Sprite and Fanta, are made by dissolving carbon(IV) oxide under pressure in water. Colouring and sweetening agents are also added. The resulting weakly acidic solution gives the drink its sharp taste. The drink fizzes when the bottle is opened because of the escaping gas. If the opened bottle is left for a long time, the drink loses its taste.

Experiment 8.8 Determining the volume of dissolved carbon(IV) oxide in a bottle of fizzy drink

Select a suitable cork for a bottle of fizzy drink. Fit a delivery tube to the cork. Set up the rest of the apparatus shown in Figure 8.17, then open a bottle of the fizzy drink and immediately close it with the cork carrying a delivery tube. Heat the bottle in a water bath until no more gas is evolved. Record the volume of water displaced from the measuring cylinder. This is the volume of carbon(IV) oxide liberated from the fizzy drink. It is found to be much more than the volume of

the drink itself at room temperature and pressure. Put some lime water into the aspirator bottle and shake. A white precipitate is observed, showing the presence of carbon(IV) oxide.

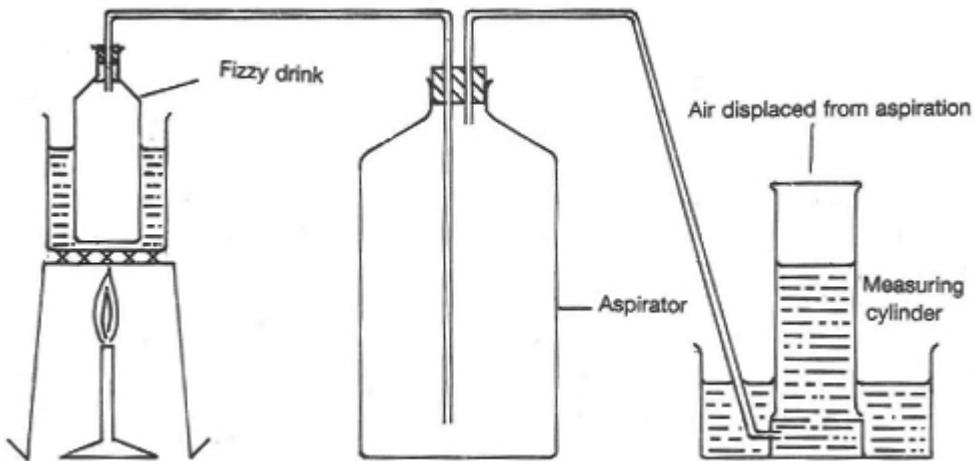


Figure 8.17 Carbon (IV) oxide from a fizzy drink

- (ii) Carbon(IV) oxide is used to put out fires. Since the gas is denser than air, it blankets the fires, cutting off oxygen supply to it. Since it does not support combustion, the fire is extinguished.

In one type of fire extinguisher, H_2SO_4 and sodium hydrogen trioxocarbonate(IV) are kept separate and made to react when the need arises. In using the type shown in Figure 8.18, when the striker is struck the glass containing the concentrated acid is broken and it mixes with the sodium hydrogen trioxocarbonate(IV). The reaction produces carbon(IV) oxide which is directed towards the fire. Carbon(IV) oxide and the solution are forced out of the nozzle under pressure.

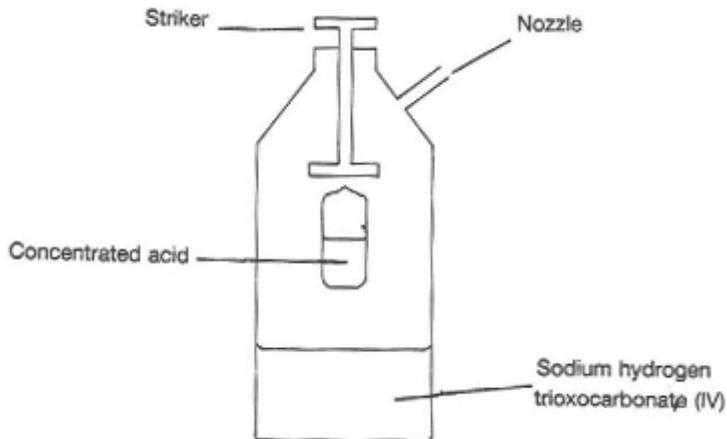


Figure 8.18 A fire extinguisher



A fire extinguisher uses aluminium tetraoxosulphate(VI) and saponin in place of acid. When the two chemicals mix with sodium hydrogen trioxocarbonate(IV), foaming carbon(IV) oxide is produced. Its effect lasts longer than the gaseous oxide.

- (iii) Carbon(IV) oxide is used as a refrigerant. "Dry ice" is solid carbon(IV) oxide at -78°C . It sublimes on absorption of heat, cooling the surrounding atmosphere. The compressor of the refrigerator resolidifies the gaseous oxide for the process to continue.



Plate 8.1 A refrigerator

- (iv) Fruits are preserved in an atmosphere enriched with carbon(IV)oxide.
- (v) The action of yeast and baking powder on flour and sugar to which water has been added (dough), produces carbon(IV) oxide which causes bread and cake to rise and become light.
- (vi) Effervescent salts like Andrews liver salt contain tartaric acid (an organic acid) and sodium hydrogen trioxocarbonate(IV). In water, they liberate carbon(IV) oxide which causes the effervescence.

8.9 Carbon(II) oxide

Carbon(II) oxide is the product of incomplete combustion of carbon.

Experiment 8.9 Preparation of Carbon(II) Oxide from Sodium Methanoate

CAUTION: PERFORM ONLY IN A FUME CUPBOARD

Set up the apparatus shown in Figure 8.19. Place about 10g of sodium methanoate, HCOONa , in the flat-bottomed flask. Add about 25cm^3 of concentrated tetraoxosulphate(VI) acid to it, through the thistle funnel. Collect a few jars of the carbon(II) oxide from the delivery tube by displacement of water, for use in studying its properties.

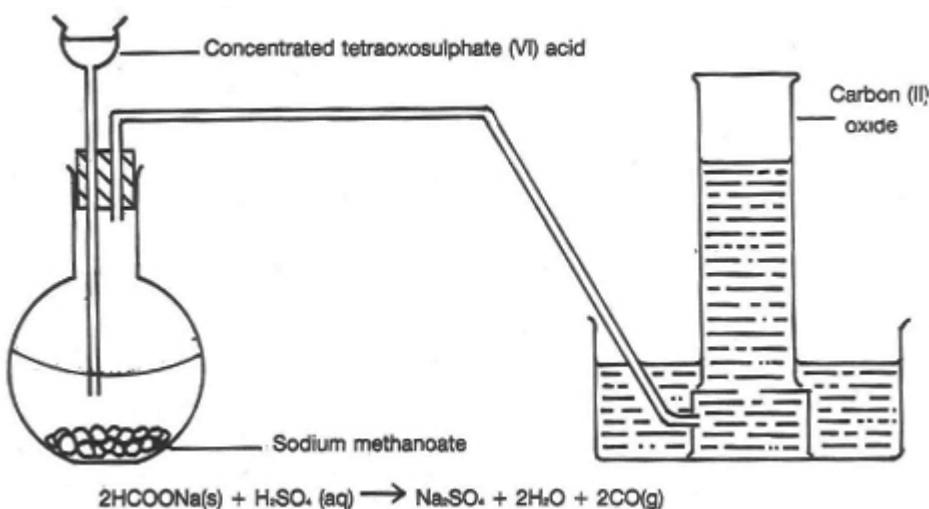


Figure 8.19 Preparation of carbon(II) oxide from sodium methanoate

Experiment 8.10 Preparation of carbon(II) oxide from ethanedioic acid

Carbon(II) oxide can be prepared from ethanedioic acid, $\text{H}_2\text{C}_2\text{O}_4$, and concentrated tetraoxosulphate(VI) acid using the apparatus shown in Figure 8.20. Put about 10g of ethanedioic acid crystals into a round-bottomed flask, then add about 25 cm^3 of concentrated tetraoxosulphate(VI) acid. Heat the round-bottomed flask. Pass the gas evolved through sodium hydroxide solution to absorb the carbon(IV) oxide component of the products. Collect carbon(II) oxide over water in few gas jars for use in studying the properties of the gas.

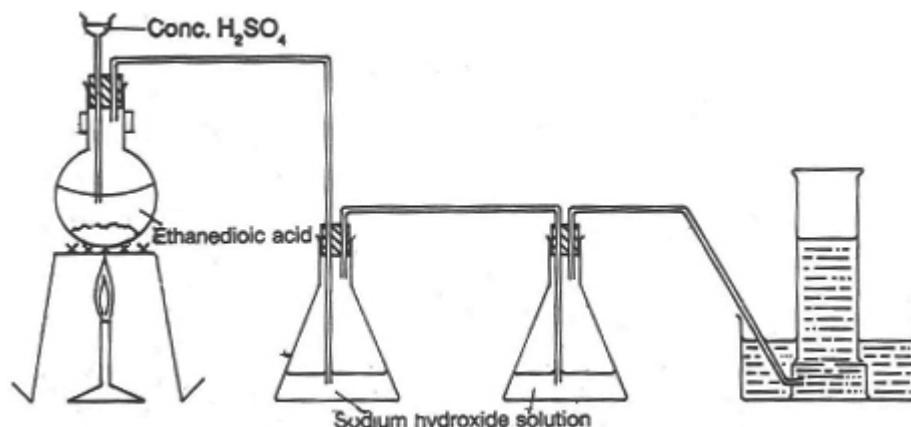
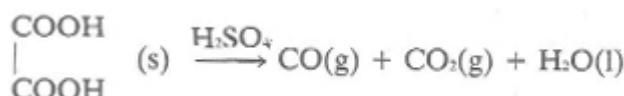


Figure 8.20 Preparation of carbon(II) oxide from ethanedioic acid



Experiment 8.11 Preparation of carbon(II) oxide from carbon(IV) oxide and investigation of its properties

Carbon(II) oxide can be prepared by reducing carbon(IV) oxide with carbon. Pass carbon(IV) oxide through heated charcoal in a combustion tube. Bubble the resulting gaseous mixture into sodium hydroxide solution to absorb excess carbon(IV) oxide, then collect the carbon(II) oxide over water. The set up is as shown in Figure 8.21.

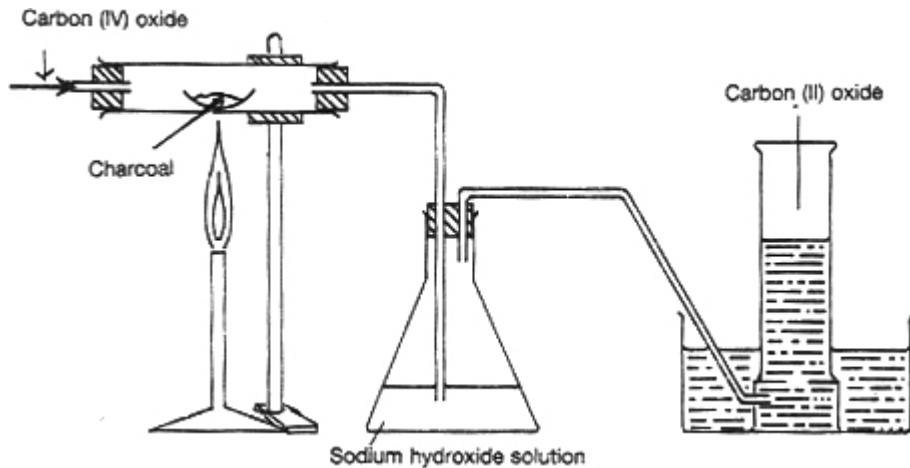


Figure 8.21 Reduction of carbon(IV) oxide

Carry out the following tests with the gas collected by either method.

- Pass the gas into lime water and shake. Note that the lime water remains unchanged.
- Light the gas in a gas jar. It burns with a blue flame. This test is used to identify carbon(II) oxide.
- Pass the gas over heated copper(II) oxide and iron(III) oxide contained in separate porcelain boats in a combustion tube. Burn off the excess carbon(II) oxide at the opposite end of the combustion tube (Figure 8.22).

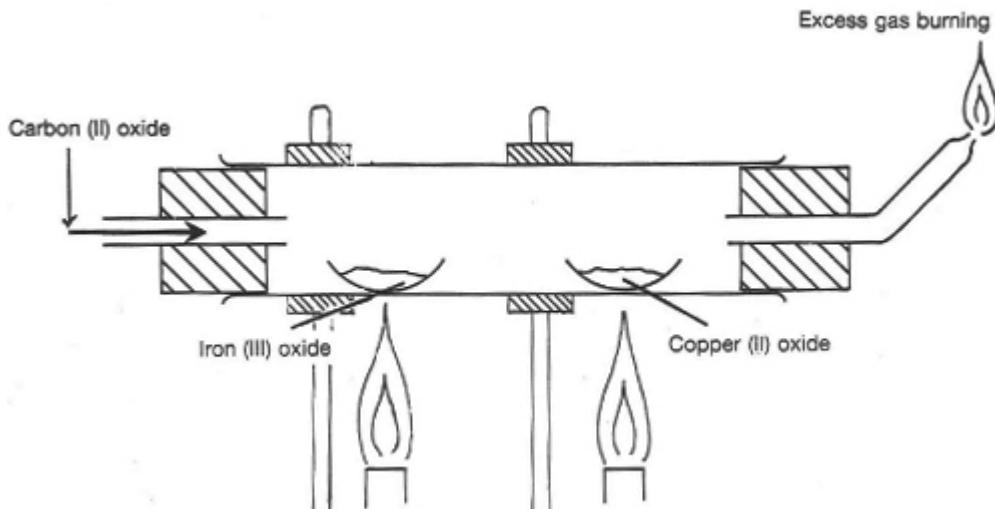
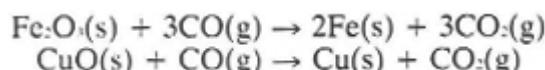


Figure 8.22 Reducing action of carbon(II) oxide

The reddish-brown iron(III) oxide turns black while the black copper(II) oxide turns brown. This shows that the two metallic oxides are reduced by carbon(II) oxide to the metals.



The metallurgy of some metals, notably iron, depends on this reaction. Even when carbon (coke) is used, the carbon is first burnt to carbon(IV) oxide which is converted to carbon(II) oxide. The carbon(II) oxide then effects the reduction of the iron oxide.

- (d) Shake the gas with copper(I) chloride solution in aqueous ammonia, then light the gas to determine whether carbon(II) oxide dissolved. The absence of a blue flame shows that the gas is soluble in ammoniacal copper(I) chloride solution.

Summary of the properties of carbon(II) oxide

1. Carbon(II) oxide is a colourless, odourless gas.
2. It is slightly less dense than air.
3. It burns with a blue flame.
4. It is very slightly soluble in water.
5. It dissolves readily in ammoniacal copper(I) chloride solution. This solution is used to absorb the gas whenever it is necessary to do so.
6. The gas is a deadly poison. It kills by combining with the haemoglobin of blood thereby preventing haemoglobin from carrying oxygen. The body tissues are therefore starved of oxygen and die of suffocation. The exhaust gas of motor cars contains carbon(II) oxide, hence it is dangerous to start the engine of a car in a closed garage.
7. It reduces the oxides of copper, lead, iron, and zinc to the metals, becoming itself oxidised to carbon(IV) oxide.

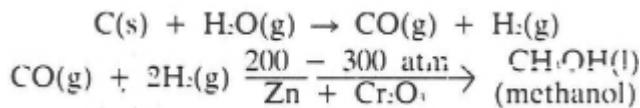
Uses of carbon(II) oxide

- (i) Carbon(II) oxide is an important constituent of fuel gases.

TABLE 8.2 Composition of Fuel Gases

Fuel gas	% composition				
	CO	H ₂	CH ₄	N ₂	Others
Water gas	50	50	—	—	—
Producer gas	33	—	—	67	—
Coal gas	10	50	35	—	5

- (ii) It is used in the manufacture of methanol. Water gas is subjected to a pressure of between 200 and 300 atmospheres in the presence of zinc and chromium(III) oxide as catalyst. The reaction that results yields methanol.



- (iii) It is widely used for reducing the oxides of metals in their extraction processes.

8.10 Trioxocarbonate(IV) salts

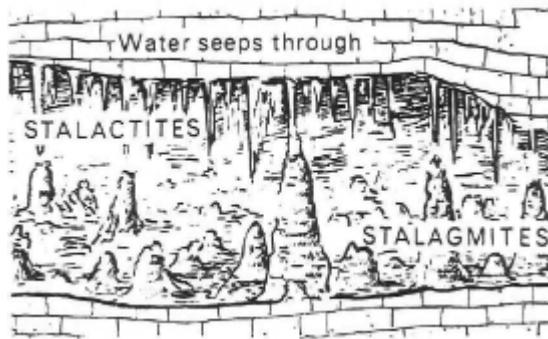


Plate 8.2 Limestone Region

Calcium trioxocarbonate(IV), CaCO_3 is the most abundant metal trioxocarbonate(IV) in the earth's crust. It occurs in nature as chalk, limestone and marble. Of the three forms, chalk is the softest and marble the hardest.

Stalactites and stalagmites which are found in caves and limestone regions are made of calcium trioxocarbonate(IV)

Experiment 8.12 Investigating the nature of shells

Collect some shells of sea animals such as periwinkles, snails and egg shells. Grind samples of each to powder. Put each in a separate test tube. Add dilute hydrogen chloride acid (hydrochloric acid) to each and stopper with a cork carrying a delivery tube immediately. Rapid effervescence occurs. Pass the colourless gas evolved into lime water. The lime water is turned milky.

Carbon(IV) oxide is liberated from shells by the action of dilute acids. This shows that shells of animals contain the trioxocarbonate(IV) ion. Bones and teeth of animals with internal skeleton also contain the trioxocarbonate(IV) ion. The ion is present in both exo- and endo- skeletons as calcium trioxocarbonate(IV).

Other metallic trioxocarbonates(IV) found in nature include

magnesium trioxocarbonate(IV) as dolomite $MgCO_3 \cdot CaCO_3$; iron(II) trioxocarbonate(IV) as spathic iron ore, $FeCO_3$; copper(II) trioxocarbonate(IV) as malachite, $CuCO_3 \cdot Cu(OH)_2$; and zinc trioxocarbonate(IV) as calamine, $ZnCO_3$.

Preparation of Trioxocarbonates(IV)

- Precipitation of insoluble trioxocarbonates(IV) by double decomposition.

Experiment 8.13 Preparation of trioxocarbonate(IV) by precipitation

Make saturated aqueous solutions of the following salts:

potassium chloride, ammonium chloride, calcium trioxonitrate(V), magnesium chloride, zinc trioxonitrate(V), lead trioxonitrate(V) and copper tetraoxosulphate(VI). Put 5 cm³ of each in different test-tubes labelled 1, 2, ..., 7 respectively as in Figure 8.23.

To each solution add aqueous sodium trioxocarbonate(IV) solution. Note what happens. Filter off any precipitate that forms. Wash with cold water, then leave in the desiccator to dry.

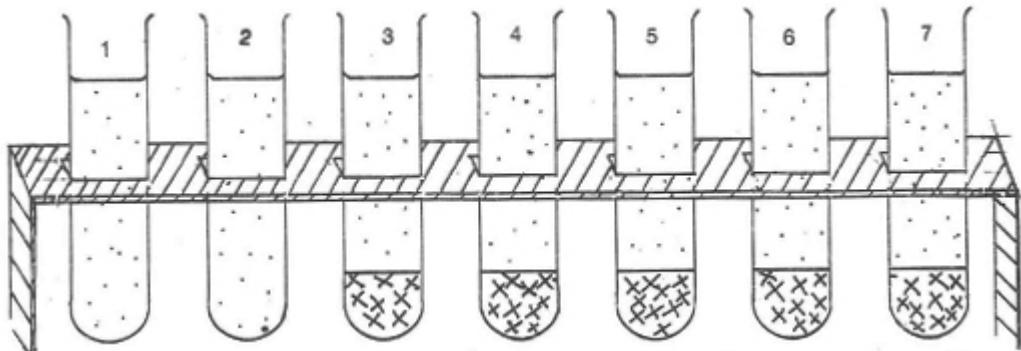
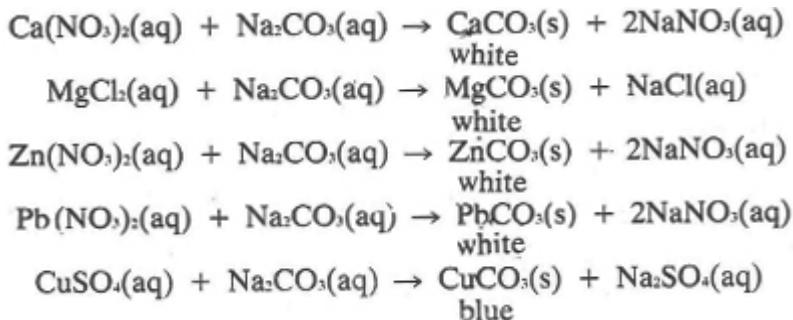
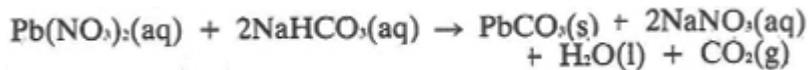


Figure 8.23 Preparation of trioxocarbonates(IV) by double decomposition

Precipitates of calcium, magnesium, zinc, lead and copper trioxocarbonates(IV) are formed in test-tubes 3, 4, 5, 6, and 7 respectively. Test-tubes 1 and 2 contain no precipitate because potassium and ammonium trioxocarbonates(IV) are soluble. They cannot be prepared by double decomposition reactions.



When sodium hydrogen trioxocarbonate(IV) solution is used as the precipitating agent, water and carbon(IV) oxide are formed as part of the products. For example:



2. By the action of carbon(IV) oxide on soluble hydroxides.

Experiment 8.14 Preparation of trioxocarbonate(IV) by neutralization
 Generate carbon(IV) oxide from a Kippâ€™s apparatus. (Figure 8.24). Pass the gas through cold water to remove acid spray, then bubble the gas into an icecold solution of saturated sodium hydroxide until enough white precipitate is formed. Filter off the precipitate and dry between filter papers.

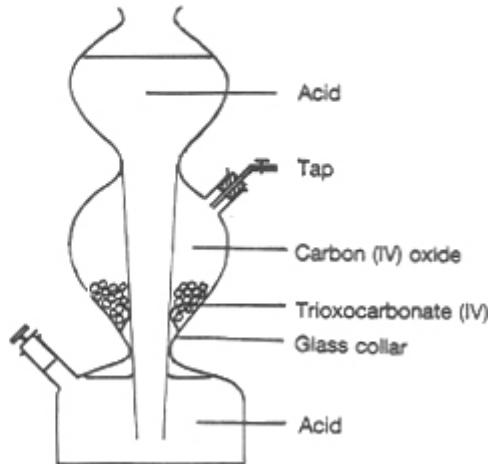
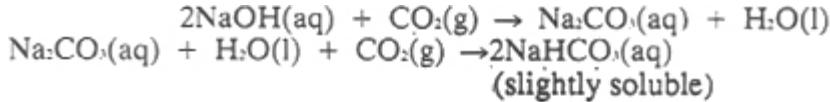
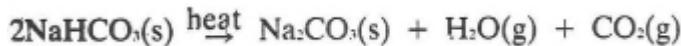


Figure 8.24 Kippâ€™s apparatus

Heat the dry precipitate. It loses water and carbon(IV) oxide and crumbles to a powder which is sodium trioxocarbonate(IV).



Other soluble trioxocarbonates(IV) are prepared by reaction between the corresponding alkali and carbon(IV) oxide.

Properties of Trioxocarbonates(IV)

With the exception of the trioxocarbonates(IV) of the group I metals and ammonium ion, the trioxocarbonates(IV) of all other metallic ions are insoluble in water. Also with the exception of the trioxocarbonates(IV) of the group 1 metals, all trioxocarbonates(IV) are decomposed by heating. Trioxocarbonates (IV) react with dilute acids to liberate carbon(IV) oxide. These properties will be investigated in Experiments 8.13 and 8.14.

Action of heat on trioxocarbonates(IV)

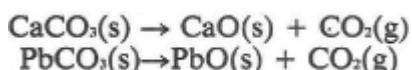
Experiment 8.15 Investigating the Action of Heat on Trioxocarbonates(IV)

Heat the trioxocarbonates of Na, Ca, Mg, Zn, Fe, Pb, Cu and NH_4^+ separately in hard test-tubes. Heat gently first and then strongly. Pass any gas evolved through lime water. If water condenses near the mouth of the test-tube, it shows that water vapour is given off. Observe the colours of the residues left in the test-tubes and note their colours while hot, and on cooling. The results are as tabulated in Table 8.3

TABLE 8.3 Action of heat on trioxocarbonates(IV)

Trioxo-carbonate(IV) of:	Action of Gas Evolved on lime water	Colour of Residue When		Remark
		Hot	Cold	
Na	None	White	White	Not decomposed by heating
K	None	White	White	"
Ca	Turns milky	White	White	Decomposed by heating
Mg	Turns milky	White	White	"
Zn	Turns milky	Yellow	White	"
Fe(III)	Turns milky	Black	Rust-red	"
Pb	Turns milky	Orange	Yellow	"
Cu(II)	Turns milky	Black	Black	"
NH_4^+	Turns milky	--	--	Sublimes

Heat decomposes trioxocarbonates (IV) of most metals to the oxides of the metals, liberating carbon(IV) oxide. Only sodium and potassium trioxocarbonates(IV) are not decomposed.



Zinc oxide is yellow when hot but white when cold. Iron(III) oxide is almost black while hot but rust-brown when cold. Lead(III) oxide is orange when hot, but yellow when cold. These characteristic colours can be used to identify the metals. Most of the other oxides are white both when hot and cold.

Hydrated trioxocarbonate(IV) salts give off water vapour in addition to carbon(IV) oxide. The water vapour condenses near the mouth of the test tube where it can be seen or tested with white anhydrous copper(II) etraoxosulphate(VI), which it turns blue.

Action of dilute mineral acids on trioxocarbonates(IV)

Experiment 8.16 Action of mineral Acids on trioxocarbonates(IV)

Add dilute hydrogen chloride acid (hydrochloric acid), dilute trioxonitrate(V) acid, and dilute tetraoxosulphate(VI) acid to small quantities of each of the trioxocarbonates(IV) used in Experiment 8.15. Pass the gas evolved in each case through lime water. Note whether the mixture left in the test tube is a clear solution or contains an insoluble salt. Table 8.4 summarises the results.

TABLE 8.4 Action of mineral acids on trioxocarbonates(IV)

CO_3^{2-}	Acid	Is CO_2 Evolved?	Clear Solution or White Residue Formed?	Equation of Reaction
K	HCl	YES	Clear solution	$\text{K}_2\text{CO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow 2\text{KCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	HNO_3	YES	Clear solution	$\text{K}_2\text{CO}_3(\text{s}) + 2\text{HNO}_3(\text{aq}) \rightarrow 2\text{KNO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	H_2SO_4	YES	Clear solution	$\text{K}_2\text{CO}_3(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{K}_2\text{SO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
Na	HCl	YES	Clear solution	$\text{Na}_2\text{CO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	HNO_3	YES	Clear solution	$\text{Na}_2\text{CO}_3(\text{s}) + 2\text{HNO}_3(\text{aq}) \rightarrow 2\text{NaNO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	H_2SO_4	YES	Clear solution	$\text{Na}_2\text{CO}_3(\text{s}) + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
Ca	HCl	YES	Clear solution	$\text{CaCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	HNO_3	YES	Clear solution	$\text{CaCO}_3(\text{s}) + 2\text{HNO}_3(\text{aq}) \rightarrow \text{Ca}(\text{NO}_3)_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	H_2SO_4	Slightly	White residue	$\text{CaCO}_3(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{CaSO}_4(\text{s}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
Mg	HCl	YES	Clear solution	$\text{MgCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	HNO_3	YES	Clear solution	$\text{MgCO}_3(\text{s}) + 2\text{HNO}_3(\text{aq}) \rightarrow \text{Mg}(\text{NO}_3)_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	H_2SO_4	YES	Clear solution	$\text{MgCO}_3(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{MgSO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
Al	HCl	YES	Clear solution	$\text{Al}_2(\text{CO}_3)_3(\text{s}) + 6\text{HCl}(\text{aq}) \rightarrow 2\text{AlCl}_3(\text{aq}) + 3\text{H}_2\text{O}(\text{l}) + 3\text{CO}_2(\text{g})$
	HNO_3	YES	Clear solution	$\text{Al}_2(\text{CO}_3)_3(\text{s}) + 6\text{HNO}_3(\text{aq}) \rightarrow 2\text{Al}(\text{NO}_3)_3 + 3\text{H}_2\text{O}(\text{l}) + 3\text{CO}_2(\text{g})$
	H_2SO_4	YES	Clear solution	$\text{Al}_2(\text{CO}_3)_3(\text{s}) + 3\text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{Al}_2(\text{SO}_4)_3(\text{aq}) + 3\text{H}_2\text{O}(\text{l}) + 3\text{CO}_2(\text{g})$
Zn	HCl	YES	Clear solution	$\text{ZnCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{ZnCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	HNO_3	YES	Clear solution	$\text{ZnCO}_3(\text{s}) + \text{HNO}_3(\text{aq}) \rightarrow \text{Zn}(\text{NO}_3)_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	H_2SO_4	YES	Clear solution	$\text{ZnCO}_3(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{ZnSO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
Pb	HCl	Slightly	White residue	$\text{PbCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{PbCl}_2(\text{s}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	HNO_3	YES	Clear solution	$\text{PbCO}_3(\text{s}) + 2\text{HNO}_3(\text{aq}) \rightarrow \text{Pb}(\text{NO}_3)_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	H_2SO_4	Slightly	White residue	$\text{PbCO}_3(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{PbSO}_4(\text{s}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
Cu	HCl	YES	Clear solution	$\text{CuCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CuCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	HNO_3	YES	Clear solution	$\text{CuCO}_3(\text{s}) + 2\text{HNO}_3(\text{aq}) \rightarrow \text{Cu}(\text{NO}_3)_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
	H_2SO_4	YES	Clear solution	$\text{CuCO}_3(\text{s}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{CuSO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$

All trioxocarbonates(IV) react with dilute mineral acids liberating carbon(IV) oxide. The evolution of the gas is accompanied by rapid effervescence. This effervescence with dilute acids and the turning of lime water milky by the gas evolved, are the confirmatory tests for the trioxocarbonate(IV) ion.

Dilute tetraoxosulphate(VI) acid reacts only slightly with some trioxocarbonates(IV) such as those of calcium and lead. This is because one of the products of the reaction is insoluble in water and therefore prevents further reaction by covering the trioxocarbonate(IV) salt. The same effect is noticed when dilute hydrogen chloride acid (hydrochloric acid) reacts with lead trioxocarbonate(IV) because the insoluble lead(II) chloride is one of the products.

Uses of trioxocarbonates(IV)

Sodium trioxocarbonate(IV) decahydrate, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, which is called **washing soda**, is a component of many dry soap powders. It is also used for making glass and for softening water.

Lead(II) trioxocarbonate(IV) is used in the form of basic trioxocarbonate(IV), $\text{PbCO}_3 \cdot 2\text{Pb}(\text{OH})_2$ (white lead) as white paint when mixed with oils.

Calcium trioxocarbonate(IV) which occurs as limestone is used in making cement. Another form of calcium trioxocarbonate(IV) called marble is polished and used in building houses.

Limestone is decomposed by heating in lime kilns to produce quicklime, CaO , which is used in the manufacture of paints, mortar, bleaching powder and for the reduction of soil acidity.

8.11 Hydrogen trioxocarbonates(IV)

Because trioxocarbonate(IV) acid is dibasic, it forms acid salts when only one of the two replaceable hydrogen atoms is replaced by a metal. However, only three solid hydrogen trioxocarbonates(IV) exist. They are those of sodium, potassium and ammonium ion. Calcium and magnesium hydrogen trioxocarbonates(IV) exist only in solution.

Manufacture of sodium hydrogen trioxocarbonates(IV) by the Solvay or ammonia soda process.

Concentrated sodium chloride solution (brine) is saturated with ammonia and made to flow down a Solvay tower (Figure 8.25) Gaseous carbon(IV) oxide is forced up that tower from the bottom. Perforated metal plates fitted in the tower ensures thorough mixing of the solution and counter current carbon(IV) oxide gas. The following

reaction occurs.



Sodium hydrogen trioxocarbonate(IV) is only slightly soluble in water and therefore precipitates out of solution. This precipitation is facilitated by cooling the lower part of the tower. It is removed from the tower, washed and dried for use as baking powder. Some of it, however, is heated to yield sodium trioxocarbonate(IV).

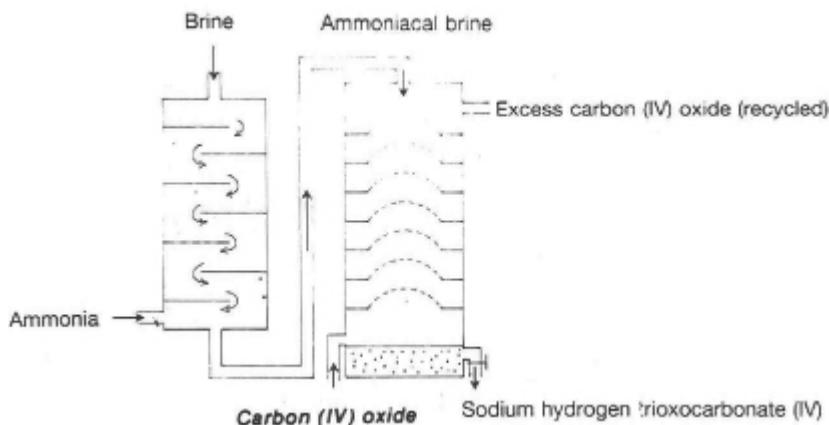
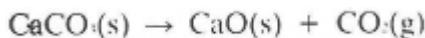


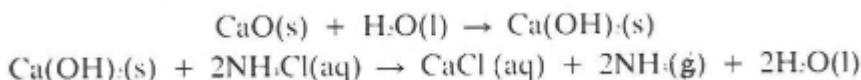
Figure 8.25 Solvay tower

This method of manufacturing sodium hydrogen trioxocarbonate IV) is a very efficient process as the raw materials like sodium chloride and calcium trioxocarbonate(IV) (limestone) are very cheap and abundant.

The carbon(IV) oxide for the process is obtained by the decomposition of the limestone by heating.



The calcium oxide produced in the decomposition of limestone is used to recover the ammonia used in the process which has been converted to ammonium chloride. This is done by heating the solution from the tower and the solution from the washing of the precipitate with calcium hydroxide.



The ammonia liberated is pumped back to the tower. As a result of this, once the initial quantity of ammonia required by the system has been provided no other external supply of ammonia will be required. However, a little quantity of ammonia is usually supplied to the system

externally to make up for minor losses during the process.

The carbon(IV) oxide produced during the conversion of the sodium hydrogen trioxocarbonate(IV) to sodium trioxocarbonate(IV) is recirculated into the tower.

With the exception of calcium chloride which has no further use in the process, none of the by-products of the process is wasted. Calcium chloride is the only waste product.

Properties of Hydrogen Trioxocarbonates(IV)

Experiment 8.17 Distinguishing Reactions of Sodium Trioxocarbonate(IV) and Sodium Hydrogen Trioxocarbonate(IV)

Both salts are white and crystalline (anhydrous sodium trioxocarbonate(IV) is powdery). To distinguish between them carry out the following tests.

1. Heat a little of each salt in a dry test-tube.
2. Treat a little of each salt in a test-tube with dilute hydrochloric acid.
3. Add magnesium tetraoxosulphate(VI) to a solution of each salt in a test-tube.

The results of the tests are summarised in Table 8.5.

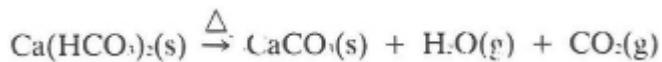
TABLE 8.5 Distinguishing reactions of sodium trioxocarbonate(IV) and sodium hydrogen trioxocarbonate(IV)

Test	Sodium Trioxocarbonate(IV)	Sodium Hydrogen Trioxocarbonate(IV)
1. Action on litmus	Solution is alkaline to litmus	Solution is neutral to litmus
2. Action of heat	No effect if anhydrous. Water vapour liberated if hydrated $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}(s) \rightarrow \text{Na}_2\text{CO}_3 + 10\text{H}_2\text{O}$	Carbon(IV) oxide and water vapour liberated. $2\text{NaHCO}_3(s) \rightarrow \text{Na}_2\text{CO}_3(s) + \text{H}_2\text{O}(g) + \text{CO}(g)$
3. Action of dilute acids	Effervescence; Carbon(IV) oxide liberated $\text{Na}_2\text{CO}_3(s) + 2\text{HCl(aq)} \rightarrow 2\text{NaCl(aq)} + \text{H}_2\text{O(l)} + \text{CO(g)}$	Effervescence Carbon(IV) oxide liberated $\text{NaHCO}_3(s) + \text{HCl(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)} + \text{CO(g)}$
4. Action of magnesium tetraoxosulphate(VI) solution	White precipitate of magnesium trioxocarbonate(IV) $\text{Na}_2\text{CO}_3(\text{aq}) + \text{MgSO}_4(\text{aq}) \rightarrow \text{MgCO}_3(\text{s}) + \text{Na}_2\text{SO}_4(\text{aq})$	No precipitate formed, as no insoluble salt results

Exercise 8A

Which of these four tests can be used to distinguish between the two sodium salts?

All hydrogen trioxocarbonate(IV) salts decompose on heating to give the corresponding trioxocarbonate(IV), water vapour and carbon(IV) oxide.



Uses of hydrogen trioxocarbonates(IV)

1. As **baking soda**, sodium hydrogen trioxocarbonate(IV) is used to make baking powder. Mixed with tartaric acid, the action of heat liberates carbon(IV) oxide which causes bread or cake to rise and become light.
2. Sodium hydrogen trioxocarbonate(IV) is also used to make fire extinguishers.

8.12 The carbon cycle

Carbon is essential to living things which derive it from carbon(IV) oxide in the atmosphere, directly or indirectly. The respiration of animals and plants as well as the decay of dead plants and animals return carbon(IV) oxide to the atmosphere to maintain a balance.

This process of taking carbon(IV) oxide from the atmosphere and later returning it to the atmosphere is termed "the carbon cycle". The cycle has been extended by man's activities. Whether the balance is still maintained or not, is a question scientists are still working on. Already, there are speculations that there is a net increase in the composition of carbon(IV) oxide of the atmosphere.

The essentials of the carbon cycle are summarised in Figure 8.26.

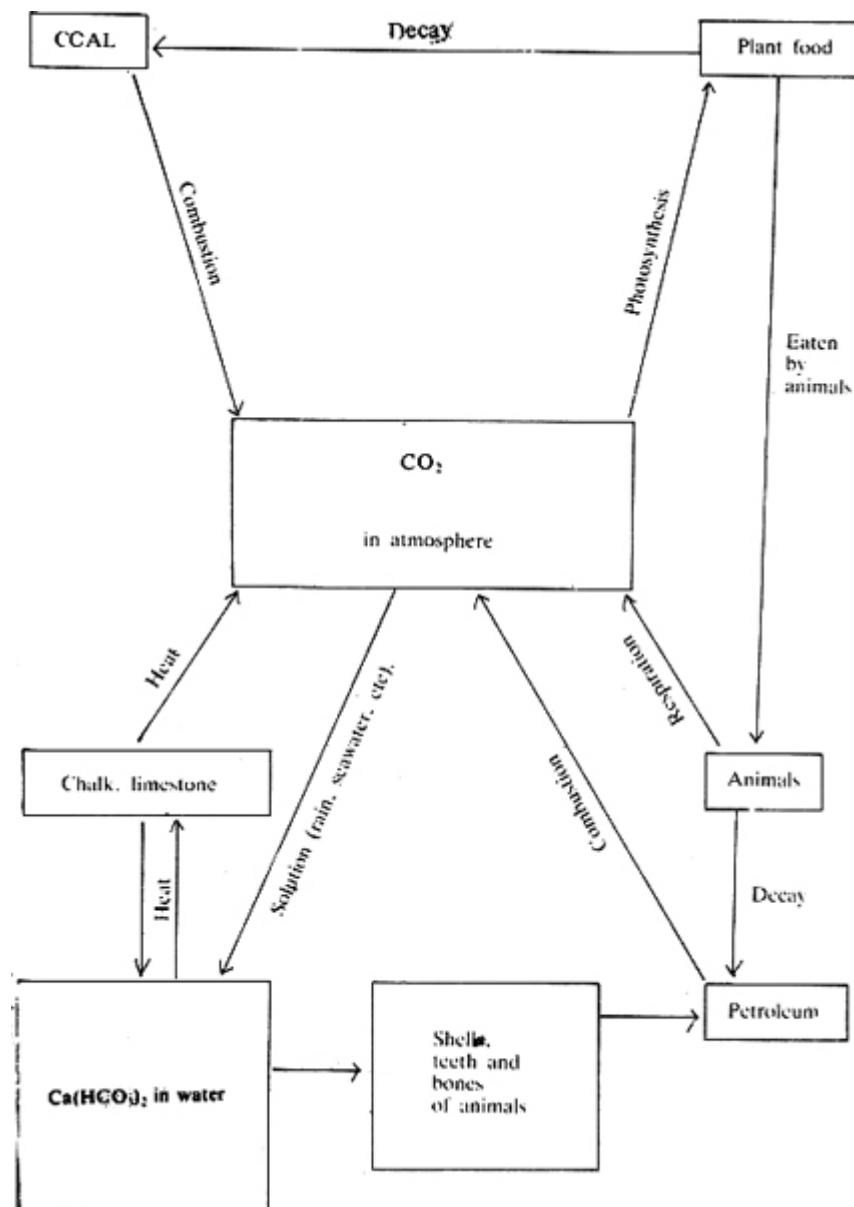
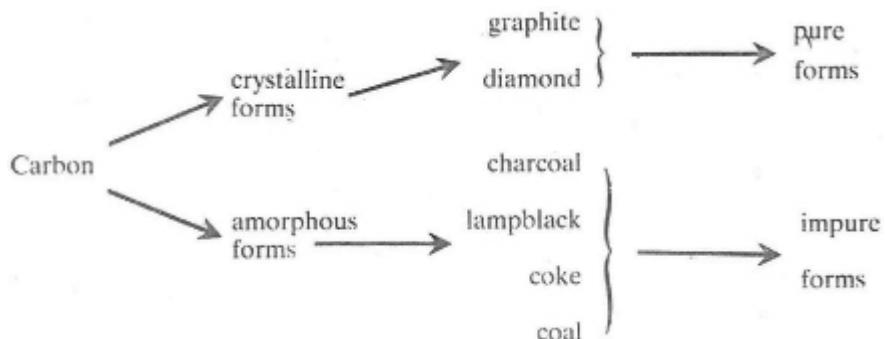


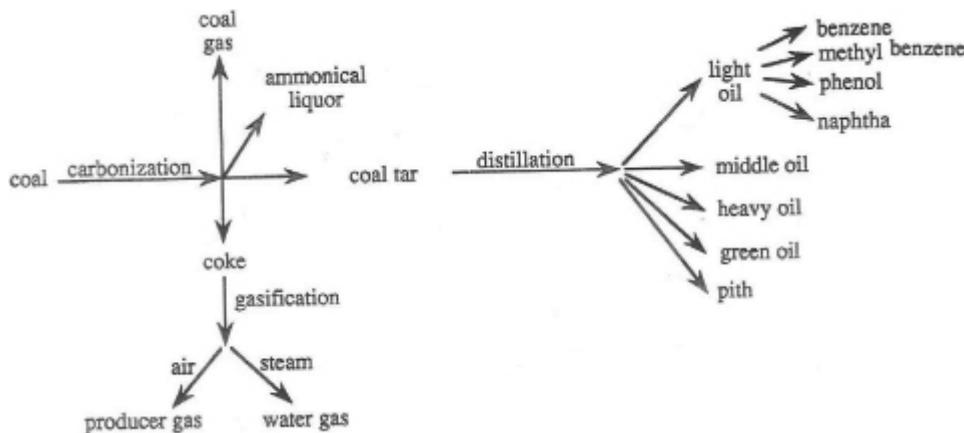
Figure 8.26 The carbon cycle

Chapter Summary

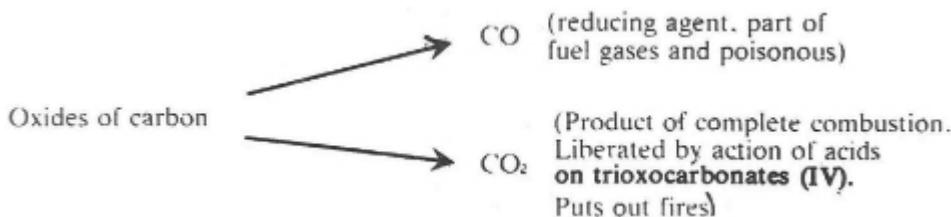
(a) Forms of carbon;



(b) Products from coal



(c) Oxides of carbon



(d) Trioxocarbonate(IV) salts of metals

Metal	Solubility in water	Action of Heat	Action of dilute acids
K	Soluble	Not decomposed	Liberates CO ₂
Na	"	"	" "
Ca	Insoluble	Decomposed to CO ₂ and metallic oxide	" "
Mg	"	"	" "
Zn	"	"	" "
Fe	"	"	" "
Pb	"	"	" "
Cu	"	"	" "

Assessment

- Why would you consider carbon an important element? How are the following fuel gases made: producer gas, water gas, coal gas?
- Why is graphite often mistaken to be a metal? Explain the use of graphite as a lubricant and the use of diamond for cutting stones.
- Define the term allotropy. With the aid of illustrative diagrams show the structural difference between diamond and graphite. How would you show that both are forms of the same element?
- With the aid of a labelled diagram describe the laboratory preparation of carbon(IV) oxide. How does carbon(IV) oxide react with

- (i) carbon
- (ii) magnesium?

When carbon(IV) oxide is passed into lime water the solution first turns milky, then becomes clear again. Explain what happens. Would the same thing happen if the gas is passed into potassium hydroxide solution? Explain your answer.

5. How would you prepare sodium trioxocarbonate(IV) in the laboratory? What is the action of (a) heat, (b) dilute hydrochloric acid on the salt? Write equations for the reactions.
Give two uses of sodium trioxocarbonate(IV) and three uses of carbon(IV) oxide.
6. (a) Describe what is observed and explain what happens when the following are heated:
(i) sodium trioxocarbonate(IV) decahydrate;
(ii) sodium hydrogen trioxocarbonate(IV);
(iii) ammonium trioxocarbonate(IV)
(iv) zinc trioxocarbonate(IV)
(b) How would you test for the trioxocarbonate(IV) ion?
7. (a) Write two chemical equations each representing a laboratory method for preparing carbon(II) oxide.
(b) (i) How is the carbon(II) oxide used in the extraction of iron from its ore obtained? (ii) What part does the carbon(II) oxide play in the extraction of iron?
(c) How and under what conditions will carbon(II) oxide react with
(i) copper(II) oxide
(ii) hydrogen?
8. Which of the following compounds does not leave a solid residue when heated?
A. Ammonium trioxocarbonate(IV)
B. Calcium trioxocarbonate(IV)
C. Zinc trioxocarbonate(IV)
D. Copper(II) trioxocarbonate(IV)
E. Sodium trioxocarbonate(IV)
9. (a) A fizzy soft drink is gently warmed as shown in Figure 8.27.
(i) Name X
(ii) Describe a chemical test for X
(iii) What would happen if you put a lighted splint into a test tube full of X?

Figure 8.27

10. Suggest the identity of the substance A, revealed by the following information, explaining how you reach your conclusion.

On gentle heating, solid A gave off steam and a gas which turned lime water milky. The cold residue, on treatment with dilute acid, gave a gas which turned lime water milky.

11. When ethanedioic acid, $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$, is heated with concentrated tetraoxosulphate(VI) acid, a mixture of two gases is given off. Name these gases and explain, giving a diagram and an equation for the reaction, how you would prepare and collect some of this mixture. How would you determine the percentage by volume of each gas in the mixture you have collected?

Project “Experimental Project

Preparation of Carbon(IV) oxide from locally available materials.

The early chemists did not have as many chemicals in their laboratories as we do today. A lot of their work was done with materials available in their localities. For example, Black, one of the first chemists who worked on carbon(IV) oxide and trioxocarbonates(IV) used **magnesia alba**, which we know today as basic magnesium trioxocarbonate(IV). This compound was used in Blackâ€™s time as a drug. He also worked with marble, chalk and limestone, all of which gave off carbon(IV) oxide on heating.

In this project you are going to prepare carbon(IV) oxide from substances found in your own locality. Collect shells of animals such as snails, periwinkles, or egg shells. Grind these to powder. Use 1g of each, in place of calcium trioxocarbonate(IV), to prepare carbon(IV) oxide by the action of dilute hydrogen chloride acid (hydrochloric acid). Heat the mixture of ground shell and hydrogen chloride acid (hydrochloric acid) if the reaction is not vigorous at room temperature. Collect the gas in a measuring cylinder, and note the volume of gas 1g of each animal shell yields.

Also grind potash (*akaun/kaun/kanwa*) sold locally in our markets, and prepare carbon(IV) oxide from it by the action of dilute hydrogen chloride acid (hydrochloric acid). Potash is potassium trioxocarbonate(IV).

You may also prepare potash from wood ash, especially the ash from burnt plantain peelings or palm fruit bunch. Burn the dry plantain peelings, or palm fruit bunch (whose fruits have been removed), in the open air. Collect the ash, add water to it and stir thoroughly. Filter off any undissolved solid. Concentrate the filtrate by evaporation, then

cool and allow crystals to form. Filter off and dry the crystals. What is the colour of the crystals?

Use these crystals in place of calcium trioxocarbonate(IV) in the preparation of carbon(IV) oxide by the action of dilute hydrogen chloride acid (hydrochloric acid).