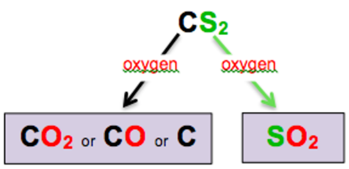
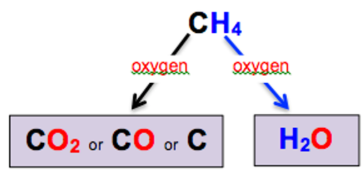
**h Chemistry - Atmosphere Science and Equilibria (G10 U2&U3)** Shakti Panda

## Reaction with Oxygen:

When compounds react with oxygen, each element in the compound joins up with oxygen.




carbon disulfide + oxygen ⟶ carbon dioxide + sulfur dioxide

carbon disulfide + oxygen ⟶ carbon monoxide + sulfur dioxide

carbon disulfide + oxygen ⟶ carbon + sulfur dioxide

methane + oxygen ⟶ carbon dioxide + water

methane + oxygen ⟶ carbon monoxide + water

methane + oxygen ⟶ carbon + water

## Definitions:

Combustion:

- It is a rapid reaction between substance and oxygen that releases heat and light energy.

Fuel:

- It is a substance that reacts with oxygen (combusts) to release useful energy.

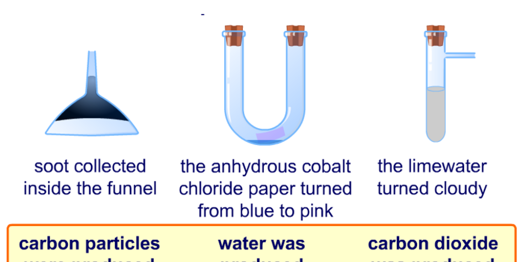
Complete Combustion:

- This occurs when there is a good supply of air for hydrocarbon fuels to burn completely.

Products of Complete Combustion:

**hydrocarbon + oxygen → carbon dioxide + water**

Example of products of complete combustion:



Incomplete Combustion:

- This occurs when there is a shortage of air (oxygen) during the burning of hydrocarbons.
- Instead of producing carbon dioxide and water, incomplete combustion also produces carbon monoxide and carbon (soot). It releases less energy than combustion.

Thermal Decomposition:

- Thermal decomposition is a type of reaction in which a compound breaks down into two or more substances when it is heated. Many metal carbonates take place in this type of reaction.

Example:

- When limestone is heated strongly, a chemical reaction takes place. Calcium carbonates break down and form calcium oxide and carbon dioxide. This type of reaction is called thermal decomposition.
- The limestone is heated to a temperature of 900°C.

Chemical Equation of Thermal Decomposition:

calcium carbonate → calcium oxide + carbon dioxide

magnesium carbonate → magnesium oxide + carbon dioxide

The general equation for the thermal decomposition of a metal carbonate is:

metal carbonate → metal oxide + carbon dioxide

# Atmospheric Science:

## Composition of Earth's Atmosphere:

The Earth's atmosphere is made up of

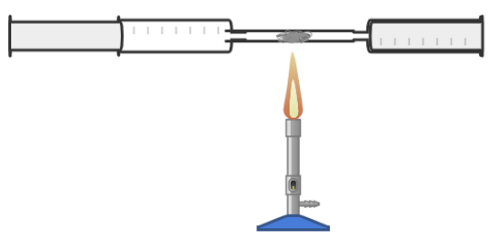
- 78% Nitrogen
- 21% Oxygen
- 0.93% Argon
- 0.035% Carbon dioxide
- Water vapour and other gases

## Importance of Earth's Atmosphere:

- The Earth's temperature is important as it can support life.
- The atmosphere is an envelope of different gases surrounding Earth.
- 80% of atmospheric gas is 15km closest to the Earth.

# Measuring Oxygen in the Air:

## Measuring Oxygen in Air Method 1:



copper + oxygen → copper oxide

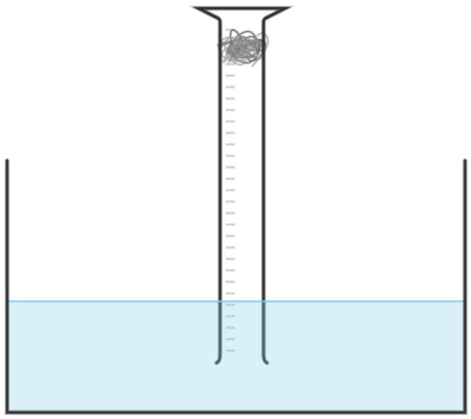
$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$

- The percentage of oxygen in the air can be measured using its reaction with copper.
- Pieces of copper are put into a glass tube and heated strongly with a Bunsen burner.
- Air repeatedly passes over the hot copper between two glass gas syringes. As the oxygen reacts with the hot copper to make copper oxide, the volume of the air goes down.

## Calculating Percentage of Oxygen in the Air:

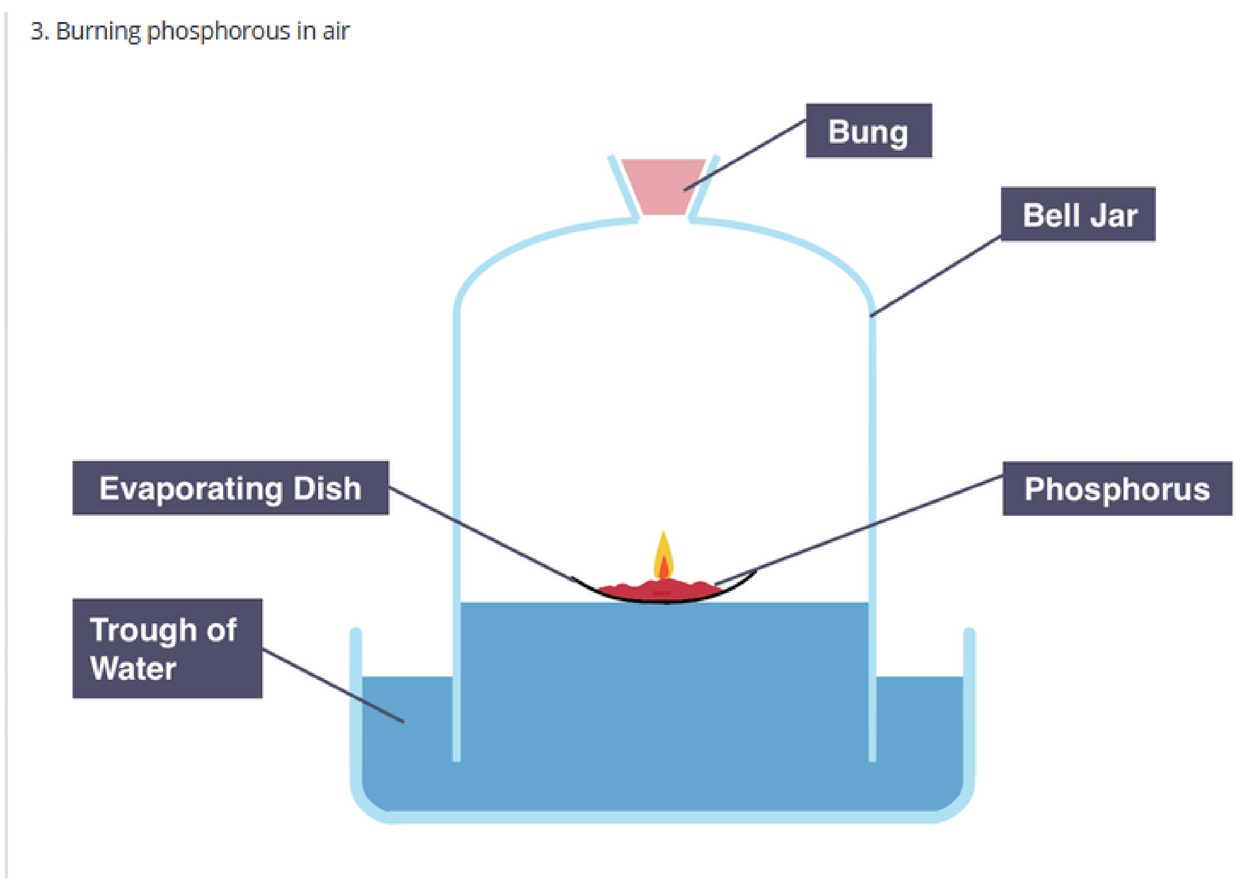
The percentage of oxygen = 100 × volume of oxygen ÷ volume of air at the start

## Measuring Oxygen in Air Method 2:



- The percentage of oxygen in the air can be measured using its reaction with iron wool.
- Iron wool is placed at the top of test tube and the record the initial level of water
- After one week record the final level of water in the test tube
- Iron wool rusts as it reacts with the oxygen in the air
- The water level inside tube rises up to replace the oxygen used up

Measuring Oxygen in Air Method 3:



- Phosphorus reacts with air when it dries out
- It also highly toxic
- The initial height of the water inside the beaker is recorded
- The final height of the water inside the beaker is recorded
- As the phosphorus reacts with the air inside the beaker the water level rises to replace the oxygen used up

Calculating Percentage of Oxygen in the Air:
(Change in height of water/Original height of the air) x 100

## Air Pollution:

| Substance formed | How it is formed | Potential problems | Ways to reduce the problem |
|---|---|---|---|
| **Carbon dioxide**<br>**$CO_2$** | Complete combustion (reaction with oxygen) of C in fuel | Greenhouse gas causing global warming | Burn less fossil fuels |
| **Carbon monoxide**<br>**CO** | Incomplete combustion (reaction with oxygen) of C in fuel | Toxic | Ensure there is a good supply of air/oxygen when burned |
| **Carbon**<br>**C** | Incomplete combustion (reaction with oxygen) of C in fuel | Blackens buildings<br>Global dimming | Ensure there is a good supply of air/oxygen when burned |
| **Sulfur dioxide**<br>**$SO_2$** | Combustion of S (reaction with oxygen) in fuel | Acid rain | Remove S from fuel before burning;<br>or remove $SO_2$ from fumes after burning (flue gas desulfurization) |
| **Nitrogen oxides**<br>**NO & $NO_2$** | Reaction of $N_2$ in air with $O_2$ in air at very high temperatures (often in engines or furnaces) | Acid rain | For engines use a catalytic converter |
| **Unburned fuel** | Not all fuel burns | Harmful and a greenhouse gas | Ensure correct fuel:air mixture when fuel is burned |

# Reversible and Irreversible Reactions:

**Definitions:**

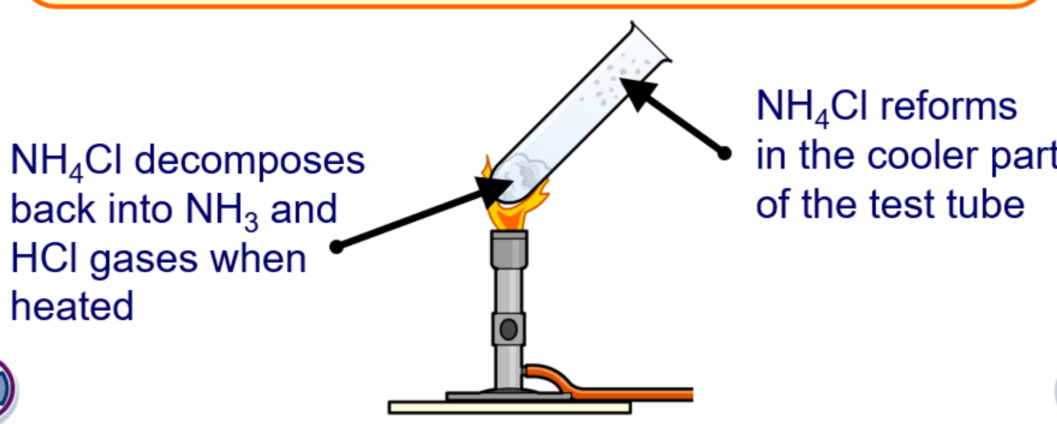
- Irreversible reactions occur when the product cannot readily be changed back into their reactants.
- Example:
  Magnesium reacting with hydrochloric acid to form magnesium chloride and hydrogen
- Reversible reactions occur when the products can be easily changed back into the reactant under the same conditions as the original reaction.

$$A + B \rightleftharpoons C + D$$

*(reactants)* *(products)*

An ammonium salt can be made by reacting ammonia with an acid. Some of the salt will decompose back into the reactants when heated.

| | | | | |
|---|---|---|---|---|
| **ammonia** | **+** | **hydrogen chloride** | $\rightleftharpoons$ | **ammonium chloride** |
| $NH_3$ (g) | **+** | $HCl$ (g) | $\rightleftharpoons$ | $NH_4Cl$ (s) |



## Dynamic Equilibrium:

- Reactions in which there is no overall change of products and reactants, even though the reactions are going are known to be in a state called dynamic equilibrium.
- This only occurs in a closed system
- The position of dynamic equilibrium is not always at the halfway point
- The position of equilibrium is affected by two main factors:
    - Temperature
    - Concentration (pressure if involving gases)
- Adding a catalyst speeds up the time it takes to reach equilibrium, but does not change the position of equilibrium

## Factors affecting Equilibrium Position:

- Concentration:
  Adding a chemical that is present on either side of the equation will cause a shift in the position of the equilibrium, as the system adjusts to counteract the change.

$$Br_2(l) + H_2O(l) \rightleftharpoons 2H^+(aq) + Br^-(aq) + BrO^-(aq)$$

If hydrochloric acid was added to the equilibrium mixture, both hydrogen ions ($H^+$) and chloride ions ($Cl^-$) are being added.

Hydrogen ions are on the right hand side of the equilibrium, therefore the equilibrium will shift to the left hand side to compensate, resulting in a higher concentration of reactants.

- Temperature:
  Altering the temperature of an equilibrium mixture results in a shift depending on the enthalpy change of the reaction.

$$\begin{array}{llll} N_2O_4(g) & \rightleftharpoons & 2NO_2(g) & \Delta H = +ve \\ Colourless & & Brown & \end{array}$$

- An increase in temperature favours the endothermic reaction. In the above equilibrium, the enthalpy change shows that the forward reaction is endothermic. Increasing the temperature will shift the equilibrium to the right hand side. This results in more nitrogen dioxide being formed and the reaction mixture becoming darker in colour.
- A decrease in temperature favours the exothermic reaction. In the equilibrium above, decreasing the temperature will favour the backwards reaction. This will shift

the equilibrium to the left, resulting in the formation of more dinitrogen tetroxide and the reaction mixture becoming lighter in colour.

- Pressure:
- Changing the pressure of the equilibrium mixture can affect the position when the equilibrium involves chemicals in the gaseous state. An increase in pressure favours the side with the lower gas volume.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

- In the above reaction, sulfur dioxide and oxygen react together to form sulfur trioxide. There are three moles of gaseous reactants on the left hand side of the equation and two moles on the right hand side.
- This means that an increase in pressure would move the equilibrium to the right and result in more sulfur trioxide being formed.
- Pressure can only affect the position of equilibrium if there is a change in the total gas volume.
- Catalysts:
    - Adding a catalyst to a reaction at equilibrium has no effect on the position of equilibrium. As the catalyst increases the rate of reaction for both sides it does not affect the position of equilibrium.
    - It does however allow equilibrium to be reached more quickly, or established at a lower temperature, which makes reactions more profitable.

## Haber Process:

- Ammonia is an important compound in the manufacture of fertilizer and other chemicals such as cleaning fluids and floor waxes.
- It is made industrially by reacting nitrogen with hydrogen in the Haber Process
- It is a reversible reaction

$$\text{nitrogen} + \text{hydrogen} \rightleftharpoons \text{ammonia}$$

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$$

- The amount of product produced in the process in a reaction is called yield. The yield of ammonia depends on the pressure and the temperature of the reaction.
- Highest yield of ammonia is theoretically produced by using a low temperature and a high pressure.
- Reasons for not implementing these conditions:
  Lowering the temperature could slow down the rate of reaction which increase the required for ammonia to be a produced
  Increasing the pressure means stronger and more expensive equipment. This increases the cost of producing the ammonia
- The process is carried out at 450°C and 200 atmospheres.
- Most important factor of the process is the total cost for the manufacturer