Chapter – 5: Combustion of Fuels

- People light – candles and diyas – wax and oil – burn
- Wax and oil – cannot be recovered back – non-reversible chemical reaction
- Many other materials – burn – heat and light

Combustion

- Substance – burns in air – heat and light produced
- Conditions for combustion –
    - Combustible substance –
        - Substance – catch fire easily – **fuels**
        - Primary condition
        - All fuels – petrol, kerosene, LPG, CNG
        - Can be solid, liquid or gas
        - Substance – does not burn – **non-combustible**
    - Supporter of combustion –
        - Substance – helps in combustion
        - Combustion not possible without supporter
        - Most cases – oxygen
    - Ignition temperature –
        - Minimum temperature – substance starts burning
        - Nothing catches fire below ignition temperature
        - Piece of wood – low ignition than – log of wood
- Light a candle – cover it with glass – candle goes off after some time – oxygen used – air supply cut-off
- Light a cone of paper – burn easily – fill it with water and then light it – does not burn easily – water increases ignition temperature

Inflammable substances

- Some substance – catch fire easily and rapidly
- Low ignition temperature – littlest spark can ignite temperature – store carefully

Types of combustion

- Depending on rate of combustion
    - Slow combustion –
        - Moderate speed
        - Burning of coal, wood, candle
        - Fuel – does not burn completely – produce smoke
        - Digestion – slow combustion – 37^0 C
    - Rapid combustion –
        - Burns – short span of time – almost complete combustion – lots of heat and light
        - LPG in gas stove, oxyhydrogen flame in welding
    - Spontaneous combustion –
        - Catches fire – as soon as – ignition temperature reached

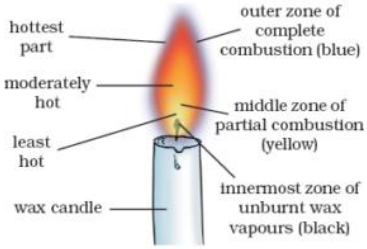
        - White phosphorus – burns at 35^0 C and above – without heat source
    - Explosion –
        - Takes place suddenly – evolution of heat, light, sound
        - Large amount of gas – evolved
        - Fire crackers

- Depending on supporters of combustion
    - Complete combustion –
        - Sufficient oxygen – substance burns completely
        - Produce – carbon dioxide, water (vapour), heat and light – blue flame
    - Incomplete combustion –
        - Insufficient oxygen – substance do not burn completely
        - Produce – yellow flame – carbon monoxide, soot (residue – left over) – pollute environment

Flame

- Different materials – burn with different colour flames
- Candle – yellow flame with smoke – LPG (liquefied petroleum gas) – blue flame
- Fuel – ignited – catches fire – region – it burns – **flame**
- Colour – depend on chemical substance burning or gases released
- All substance – do not burn with flame
- Substance – vapourise – produce flame
- Matchstick – wood gas released – yellow flame
- Light a candle – wax melts – vapour rises upwards through wick (thread) – yellow flame
- Charcoal – so not vapourise – no flame – only glow

Parts of a candle flame



- Non-luminous zone
    - Outermost part
    - Complete combustion of carbon
    - Carbon dioxide and water vapour produced
    - Carbon dioxide – no light added to flame
    - Hottest part – very little light
    - Flame colour – blue
- Luminous zone
    - Middle part
    - This zone – yellow colour of the flame
    - Partial or incomplete combustion – limited supply of oxygen

    - Unburnt carbon particles – produce smoke (soot)
    - Not very hot
- Dark zone
    - Close to the wick
    - Unburnt carbon particles – present here
    - Coldest part – presence of wax vapour
    - Innermost part
    - No oxygen – wax does not burn
- Blue zone
    - Base of the flame
    - Burning of carbon monoxide

Fuel and its types

- Many substances – wood, coal, petrol, diesel, charcoal, kerosene – produce heat and light – **fuel**
- Contains carbon and hydrogen
- Sufficient supply of oxygen – lots of heat – complete combustion
- Efficiency – measured in **calorific value** – amount of heat energy produced on complete combustion of a unit mass of fuel
- Unit – kilojoules per kilogram (kJ/kg)
- Classification on the basis of source –
    - Natural fuels
        - Primary fuels
        - Occur in nature – used in same form
        - Coal, wood
    - Processed fuels
        - Secondary fuels
        - Some fuels – cannot be used in raw form – need to be processed – chemical methods
        - Petrol, diesel, kerosene
- Classification on the basis of physical state –
    - Solid fuels
        - Occur in solid state – room temperature
        - Coal, wood, coke, paraffin wax (solid wax)
        - Produce smoke – leave ash as residue
    - Liquid fuels
        - Occur in liquid state – room temperature
        - Kerosene, spirit, petrol, diesel
        - No residue
        - Lower ignition temperature
    - Gaseous fuels
        - Occur in gaseous state – room temperature
        - Compressed Natural Gas (CNG), coal gas, biogas
        - Very clean – no smoke or ash
- Advantages of liquid or gas over solid fuels
    - High **calorific value**

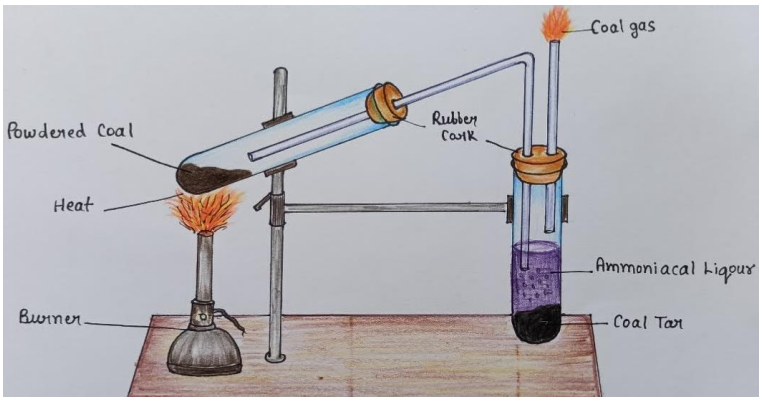
- Low **ignition temperature**
- **Burn completely** – no residue – little or no pollution
- **Convenient to store** – solid fuels require lots of space
- **Easy transportation** – pipelines – solid fuels are expensive to transport
- **Rate of combustion** – can be controlled

Fossil fuels

- Formed by decomposition of remains of organisms buried deep inside earth over millions of years
- 1000s of years – formation – exhaustible – limited quantity
- Imp. fossil fuels –
  - **Coal**
    - Made of carbon, hydrogen, oxygen
    - Found inside earth – form of deposits
    - High temperature and pressure
    - Plants, animals – die – gets buried inside earth – converted into coal over hundreds of thousands of years
    - **Formation of coal**
      - Started 300 million years ago
      - Plants, animals – forest – died and buried – due to cyclone, earthquake, other natural disasters
      - High temperature, high pressure, absence of air – organic matter decompose – oxygen, hydrogen removed – leaving carbon
      - High temperature, pressure – carbon – turned to stone-like residue – **coal**
      - This process – **carbonization**
    - Coal occurs in 3 forms
      - **Anthracite**
        - Highest calorific value
        - Cleanest form – 90 % carbon
        - Hard coal
        - Great depths – 6000 metres
      - **Bituminous coal**
        - 75 % carbon
        - Used for domestic purpose – soft coal
        - Depths – 3000-6000 metres
      - **Lignite**
        - 60-70 % carbon
        - Catches fire easily – brown colour
        - Causes pollution – contain Sulphur
    - Source – lots of other compounds and fuels
    - Obtained by **destructive distillation** – heated in absence of air at 1000^0 C
    - Products of destructive distillation –
      - **Coal tar**
        - Black thick drops during distillation

- Source – imp. compounds – benzene, phenol, naphthalene
- Used in synthetic dyes, paints, explosives, plastic

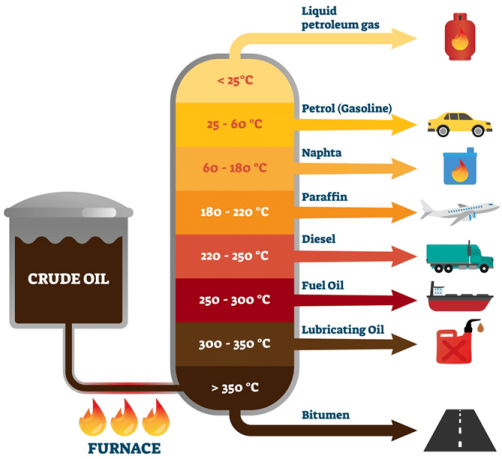
- **Coal gas**
  - Contain hydrogen, methane, carbon monoxide, other gases
  - Used as a fuel – many industries near coal processing plants
- **Coke**
  - Residue from distillation
  - Non-polluting fuel
  - Used for production of gaseous fuels
    - $C + H_2O \rightarrow CO + H_2$ (water gas)
    - $2C + O_2 + 4N_2 \rightarrow 2CO + 4N_2$ (producer gas)
  - Almost purest form of carbon
  - Tough and porous
  - Used in manufacturing of steel and extraction of many metals
- **Ammonium compounds**
  - Mixture of compounds
  - Form ammoniacal liquor – dissolved in water – used in manufacture of fertilisers



- **Petroleum**
  - Petra – rock – oleum – oil
  - Found in rocks – mixture of solid, liquid, gaseous hydrocarbons
  - **Formation of petroleum**
    - Formed from remains of dead sea animals
    - Bodies – got covered in layers of sand
    - Over 1000s of years – bodies converted to liquid – **petroleum** – absence of air, high temperature, pressure
    - Dark, viscous, foul-smelling liquid – **crude oil**
  - Many useful compounds – obtained by **fractional distillation** – separation of substances – different boiling points
  - This process – **refining of petroleum**
  - Products –
    - **Petroleum gas**
      - Liquefied Petroleum Gas (LPG) – most common domestic fuel
      - Very less air pollution – compared to other fuels

- LPG – used to run vehicles

- **Gasoline**
  - Petrol obtained from it
  - Used as fuel in motors
  - Also used for dry cleaning clothes
- **Kerosene**
  - Commonly used as domestic fuel
  - Also used in jet engines
  - Lighting petromax (lantern) in villages – absence of electricity
- **Light oil**
  - Diesel obtained from it
  - Used as fuel in motors
  - Also used in generators – produce electricity
- **Heavy oil**
  - Used in production of various chemicals
  - Also used to heat boilers and furnaces
- **Residue**
  - Paraffin wax, lubricating oil, asphalt – derived from residue



- **Natural gas**
  - Fossil fuel – stored under high pressure as Compressed Natural Gas (CNG)
  - Contains mainly methane (95 %)
  - Occurs – deep under earth – alone or with oil
  - Sometimes – obtained as by-product – mining of petroleum
  - Advantages –
    - Higher calorific value than other fuels
    - No toxic gas, smoke on burning – better fuel for transport vehicles
      - $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
    - Burns readily to produce heat
    - Easy to transport – direct pipelines

Characteristics of an ideal fuel

- Choice of efficient fuel – depend on purpose – household, vehicles, industries
- Imp. properties – ideal fuel –

- High calorific value
- Moderate ignition temperature
- No pollution – neither harmful gases nor any residue
- Easily available and economical
- Easy to transport and store
- Burning rate – moderate
- Easy to handle

Pollution due to combustion of fuels

- All fuels – including fossil fuels – produce carbon dioxide and water vapour on combustion
- No fuel – 100 % pure – produce other gases – Sulphur dioxide, Nitrogen dioxide
- Insufficient supply of oxygen – incomplete combustion – produce Carbon monoxide – highly toxic (poisonous)
- Carbon monoxide – combines with haemoglobin – stopping supply of oxygen – poisoning – can cause death
- Carbon dioxide – released in atmosphere – absorb infrared radiation – raises temperature – global warming
- Harmful gases – combine with rain – form acid rain – soil and water pollution

Judicious use of fossil fuels

- Fossil fuels – limited – non-renewable – cannot be used again
- Millions of years – formation
- Advancement in technology – increasing consumption
- Everyone's duty and responsibility – use them wisely
- Non-conventional sources – also available
- Solar, wind, ocean energy
- Wise use can be done through –
    - Preventing wastage in kitchen
        - Stove – higher efficiency
        - Lighting only after all items ready – use pressure cooker – cover vessel while cooking
        - Clean stove regularly – improve functioning
    - Use public transport
    - Switch off electrical appliances when not in use