# MODULE 1

# FUELS AND COMBUSTION

# DETAILED CONTENT

- Definition,
- Classification,
- Characteristics of a good fuel,
- Units of heat (no conversions).
- Calorific value- Gross or Higher calorific value & Net or lower calorific value,
- Dulong's formula & numerical for calculations of Gross and Net calorific values.
- Solid fuels- Analysis of coal- Proximate and Ultimate Analysis- numerical problems and significance.

# INTRODUCTION

- A fuel can be defined as a combustible substance, containing carbon as a main constituent, which on proper burning gives a large amount of heat, which can be used economically for domestic & industrial purposes.

- Eg: wood, charcoal, coal, kerosene, petrol, diesel etc.

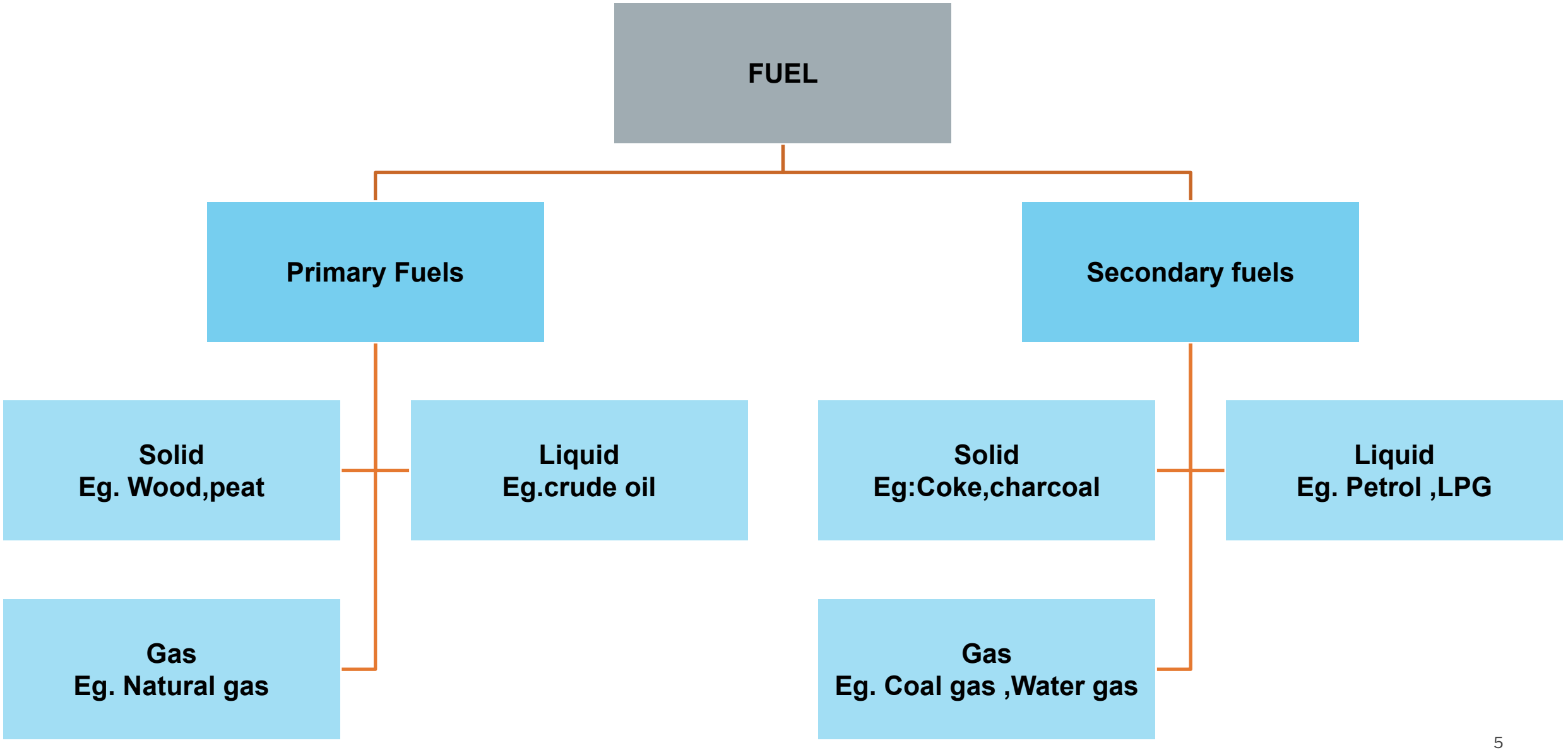
Fuel + $O_2$ → ($CO_2$) Products + Heat

# CLASSIFICATION OF FUEL

Fuels are classified as

- Primary fuels – Naturally occurring fuels such as coal, crude petroleum, and natural gas. Coal and crude petroleum, formed from organic matter millions of years ago, are called fossil fuels.

- Secondary fuels – Fuels derived from naturally occurring ones by a treatment process such as coke, gasoline, coal gas etc.


FUEL
Primary Fuels
Secondary fuels
Solid
Eg. Wood,peat
Liquid
Eg.crude oil
Gas
Eg. Natural gas
Solid
Eg:Coke,charcoal
Liquid
Eg. Petrol ,LPG
Gas
Eg. Coal gas ,Water gas

# CHARACTERISTICS OF A GOOD FUEL

1. High calorific value.
2. Moderate ignition temperature.
3. Low moisture content.
4. Low non-combustible matter content.
5. Moderate velocity of combustion.
6. Less Products of combustion.
7. Low cost.
8. Easy Transportation.
9. Combustion should be easily controllable.
10. Efficiency.

# CALORIFIC VALUE

- The calorific value of a fuel is defined as the quantity of heat (expressed in calories or kilo calories) liberated by the complete combustion of unit weight (1gm or 1kg) of the fuel in air or oxygen, with subsequent cooling of the products of combustion to the initial temperature of the fuel.

- Calorific value can be considered in two ways:

1. Higher calorific value or Gross calorific value.
2. Lower calorific value or Net calorific value.

# HIGHER CALORIFIC VALUE (HCV) / GROSS CALORIFIC VALUE (GCV)

- The gross calorific value refers to the heat evolved when the water produced by combustion is condensed as a liquid.

- Thus the gross calorific value is the quantity of heat liberated by the complete combustion of the unit weight of the fuel with subsequent cooling of the products of combustion to the initial temperature of the fuel.

# LOWER CALORIFIC VALUE (LCV) / NET CALORIFIC VALUE (NCV)

- The net calorific value gives the heat liberated when water is in the form of steam or water vapour.

- Under normal working conditions, water vapours produced during combustion are not condensed and escape as such along with the hot gases. Hence lesser amount of heat is available, which is called Lower or net calorific value.

# THEORETICAL CALCULATION OF CALORIFIC VALUE OF FUEL (DULONG'S FORMULA)

HCV = 1/100[8080 C + 34500 {H − O/8}+2240 S] kcal/kg

LCV= [GCV-9H/100 x 587]

= [GCV-0.09 H x 587] kcal/kg

where C, H, O, and S refer to % of carbon, hydrogen, oxygen and sulphur respectively.

Latent heat of steam = 587kcal/kg

# ANALYSIS OF COAL AND ITS SIGNIFICANCE

The composition of coal varies widely according to source & age. hence its analysis is necessary to interpret the results from the point of view of classification, price fixation and industrial utilization of coal.

In order to determine the quality of coal, it is subjected to the following two types of analysis:

1. Proximate analysis
2. Ultimate analysis

## Proximate Analysis Of Coal

- Determines only fixed carbon, volatile matter, moisture and ash
- Useful to find out heating value (GCV)
- Simple analysis equipment

## Ultimate Analysis Of Coal

- Determines all coal component elements: carbon, hydrogen, oxygen, sulphur, nitrogen other
- Useful for furnace design
- Laboratory analysis

# PROXIMATE ANALYSIS

## Moisture content

- % of moisture in fuel (0.5 – 10%)
- Reduces heating value of fuel
- Weight loss from heated and then cooled powdered raw coal

## Volatile matter

- Methane, hydrocarbons, hydrogen, CO, other
- Typically 25-35%
- Easy ignition with high volatile matter
- Weight loss from heated then cooled crushed coal

## Ash

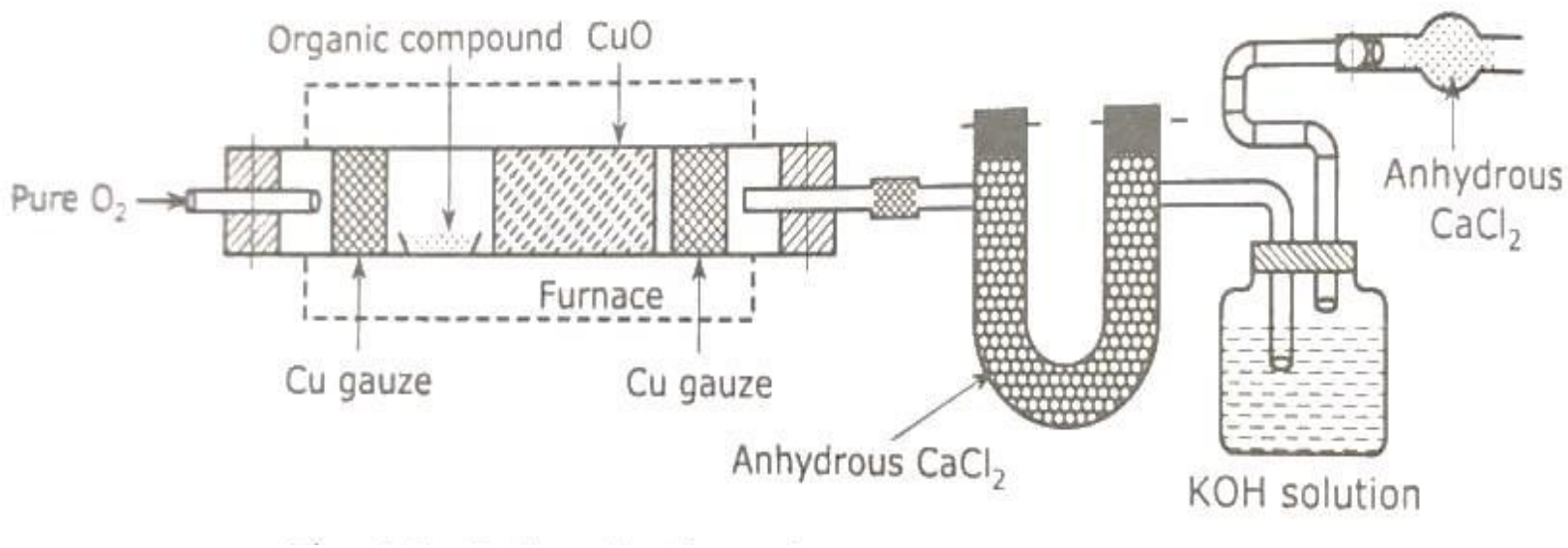
- Impurity that will not burn
- Important for design of furnace
- Ash = residue after combustion


## Fixed carbon

Fixed carbon%= 100 – (moisture%+ volatile matter% + ash%)

# ULTIMATE ANALYSIS

## Determination Of Carbon & Hydrogen




Animation: https://www.youtube.com/watch?v=3ShLtHkv-Y8
Full Explanation: https://www.youtube.com/watch?v=iflZI9_87JI

## Significance:

Higher the % of carbon , greater is the calorific value & better is the quality of coal.

$$C + O_2 \longrightarrow CO_2$$

$$CO_2 + 2KOH \longrightarrow K_2CO_3 + H_2O$$

$$\% \text{ of } C = \frac{\text{increase in weight of KOH tube x 12 x100}}{\text{weight of coal taken x 44}}$$

## Significance:

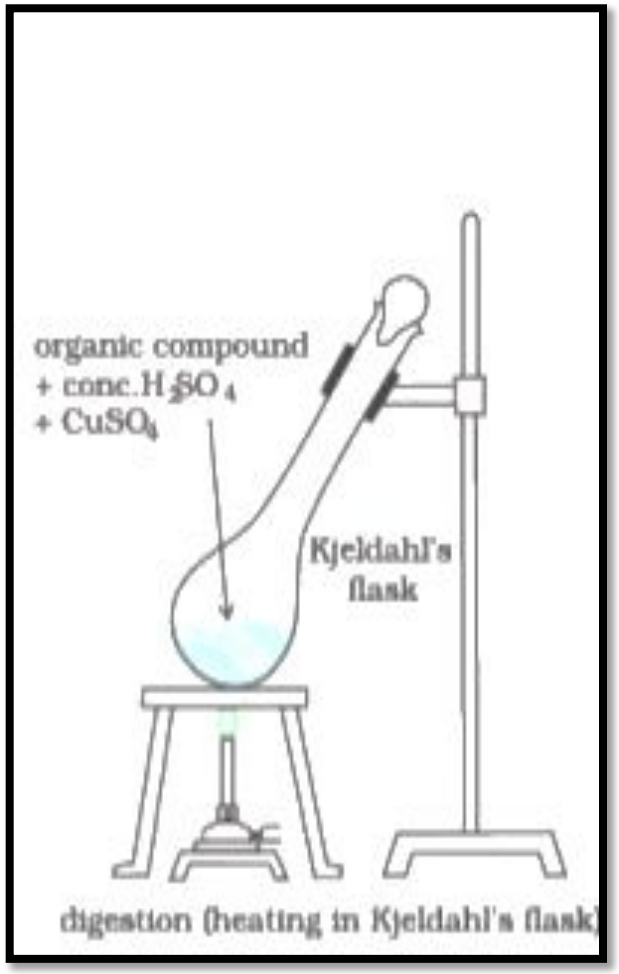
Lesser the % of hydrogen better is the quality of coal.

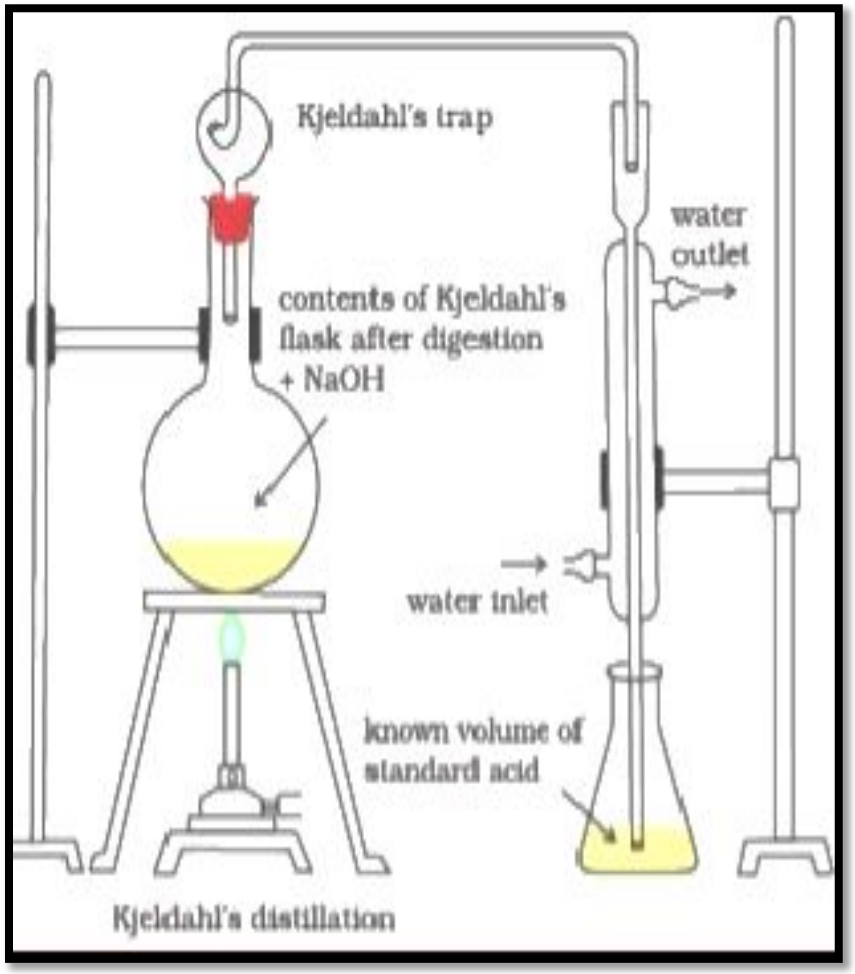
$$2H_2 + O_2 \longrightarrow 2H_2O$$

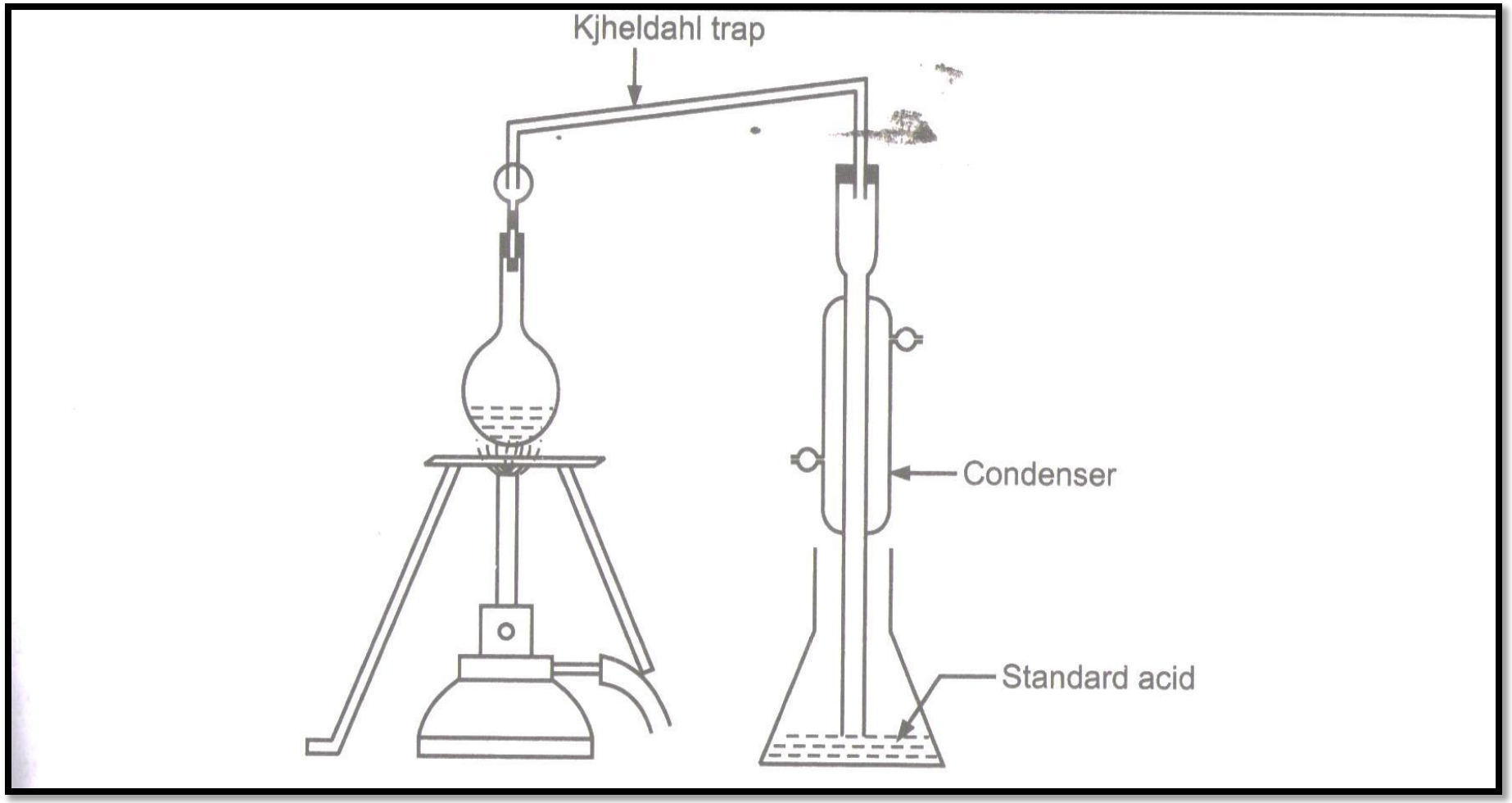
$$CaCl_2 + H_2O \longrightarrow CaCl_2.xH_2O$$

$$\% \text{ of } H = \frac{\text{increase in weight of } CaCl_2 \text{ tube} \times 2 \times 100}{\text{weight of coal taken} \times 18}$$

# Determination Of Nitrogen






Animation: https://www.youtube.com/watch?v=hOAt9UOkOq4
Full explanation: https://www.youtube.com/watch?v=-SVjSVg0Dkk

## Significance:

Nitrogen is an inert and incombustible gas &does not contribute any useful properties.

$$\text{Fuel} + \text{conc. } H_2SO_4 + K_2SO_4 + CuSO_4 \longrightarrow (NH_4)_2SO_4$$

$$(NH_4)_2SO_4 + 2\,NaOH \xrightarrow{\Delta} Na_2SO_4 + NH_3 + 2H_2O$$

$$\%\text{ of N} = \frac{\text{volume of acid used x Normality x 1.4}}{\text{Weight of coal taken}}$$

# Determination Of Sulphur

Coal is burnt in a bomb calorimeter in a current of oxygen. During burning sulphur present in coal is oxidized & converted in to sulphate. The ash formed is now extracted with dilute hydrochloric acid and the acid extract is heated with barium chloride solution to give a white precipitate of barium sulphate which is filtered , washed, dried and weighed.

$$S \rightarrow SO_2 \rightarrow BaSO_4$$


Bomb Calorimeter working: https://www.youtube.com/watch?v=wwJG2JVg6qM
https://www.youtube.com/watch?v=NG41IbDtd44

## Significance:

Sulphur present in coal is harmful for use. oxidation products of sulphur have corrosive effect. hence the presence of sulphur in coal is undesirable.

$$\% \text{ of } S = \frac{32 \times \text{weight of } BaSO_4 \times 100}{233 \times \text{weight of coal}}$$

# REFERENCE BOOKS

1. Engineering Chemistry, Jain and Jain, Dhanpat Rai Publication

2. A textbook of Engineering Chemistry, S. S. Dara, S.Chand and Company

“Sustainable energy is not a dream of the future, but a necessity of the present.”

# Thank You