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UNIT → I
FUELS

(Dr. Ria Nanda)

* INTRODUCTION →

- Any Combustible substance which on burning in presence of oxygen produces a large amount of heat that can be used for domestic and industrial purposes. Example : Wood, Charcoal, Coal, Kerosene.
- During Combustion of fuels, a chemical reaction involving breakage of bond of reactants and formation of new bonds in the products and this results in large amount of heat release ; therefore they are called as **CHEMICAL FUELS.**

* CLASSIFICATION →

- Chemical Fuels
  - Primary fuels
    - Solid (Wood)
    - Liquid (Crude oil)
    - Gas (Natural Gas)
  - Secondary fuels.
    - Solid (Coke)
    - Liquid (Petrol) LPG
    - Gas (Water Gas)

* CALORIFIC VALUE →

- It is defined as the total quantity of heat liberated when a unit mass of a fuel is burnt completely.

Solid/Liquid : Cal/g or kcal/kg

Gaseous : Cal/cm^3 or kcal/m^3

- $\boxed{1 \text{ cal} = 4.185 \text{ J} = 4.185 \times 10^7 \text{ erg}}$

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(b) **Calorie** :- It is defined as the amount of heat required to raise the temperature of 1 gram of water through 1°C.

GROSS and NET CALORIFIC VALUE →

→ **Gross Calorific Value** :

It is the total amount of heat generated when a unit quantity of fuel is completely burnt in oxygen and the products of combustion are cooled down to the room temperature.

It is also called as "Higher Calorific Value" (HCV)

The HCV is determined by Bomb Calorimeter.

→ **Net Calorific Value** :

It is defined as the net heat produced when a unit quantity of fuel is completely burnt & the products of combustion are allowed to escape.

It is also called as "Lower Calorific Value" (LCV)

$$\boxed{LCV = HCV - \text{Latent heat of water vapours}}$$

$$LCV = HCV - \text{Weight of } H_2 \times 9 \times \text{Latent Heat}$$

$$LCV = HCV - \text{Weight of } H_2 \times 9 \times 587 \text{ cal/g}$$

* DETERMINATION OF CALORIFIC VALUE →

I BOMB CALORIMETER :-

The Calorific value of solids & non-volatile liquid fuels is determined by Bomb Calorimeter.

Principle :- A known amount of the fuel is burnt in excess of oxygen and the heat liberated is

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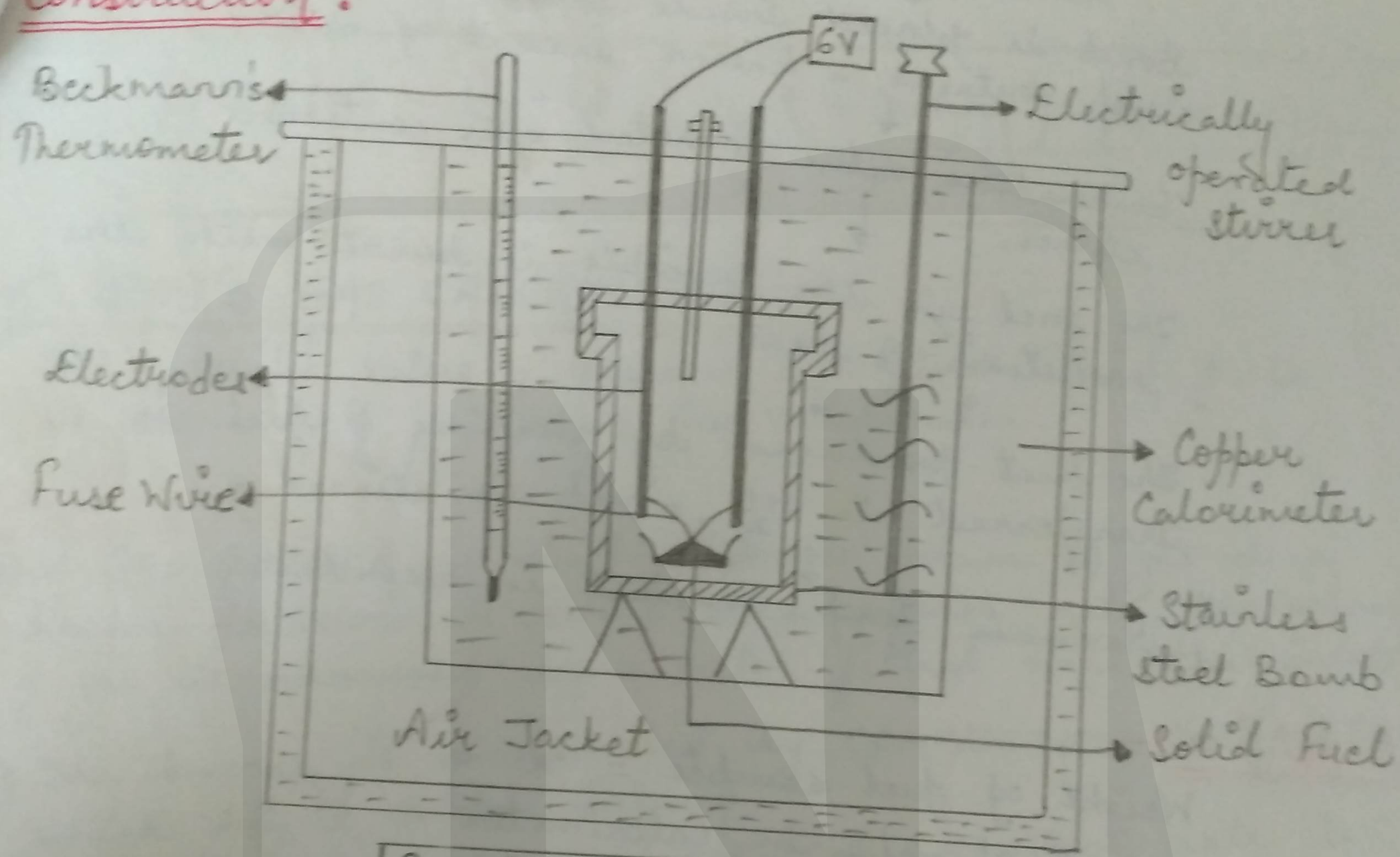
transferred to a known amount of water. Calorific value is calculated by applying law of calorimeter :-

Heat Gained = Heat Lost

Construction :-



BOMB CALORIMETER

(i) **Steel Bomb** : Steel bomb is a strong cylindrical container made up of stainless steel and can holds up the pressure upto 50 atm. The bomb is generally provided with two holes for electrodes & one oxygen inlet value.

(ii) **Copper Calorimeter** : The bomb is placed in copper calorimeter containing a known amount of water.

(iii) **Air Jacket & Water Jacket** : Copper calorimeter is surrounded by air jacket & water jacket to prevent any heat loss.

(iv) **Crucible** : A crucible is made up of Nickel which contain fuel.

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A known amount of fuel (1 g) is taken in silica crucible

↓

The lid of the bomb is tightly screwed & bomb is filled with oxygen (25 atm)

↓

Bomb is placed inside copper calorimeter which contains a known amount of water.

↓

Temperature value is noted after continous stirrer.

↓

The fuel in the crucible is burnt with the evolution of heat.

↓

The heat produced by burning of fuel is transferred to H_2O, which is stirred.

↓

Maximum temp. reached is recorded.

Calculations :-

Weight of fuel sample = x g

Weight of water in Calorimeter = W g

Water equivalent of Calorimeter = w g

Initial temp of water = t_1 °C

Final temp. of water = t_2 °C

Higher Calorific Value = C

$$\boxed{HCV;\ C = \frac{(W+w)(t_2-t_1)}{x}\ cal/g}$$

Corrections :-

- Fuse Wire Correction : Mg wire also take some amount of heat.
- Acid Correction : During combustion, sulphur and nitrogen present in the fuel are oxidised to acids.

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- Cooling Correction : Heating & Cooling are simultaneous process. As the temperature rises above the room temp, the loss of heat does occur due to radiation & hence the highest temp recorded will be slightly less than obtained.

$$HCV;\ C = \frac{(W+w)(t_2 - t_1 + \text{Cooling}) - [\text{Acid} + \text{Fuse}]}{x}$$

II BOY'S GAS CALORIMETER →

The calorific value of gaseous & volatile liquid fuels is determined by Boy's Gas calorimeter.

Construction :

a) A GAS BURNER in which a known volume of gas at a known pressure is burnt at a uniform rate. The volume of gas is measured by a meter fitted near the inlet.

b) The burner is surrounded by COMBUSTION CHAMBER, which has a Copper tubing. Through this Copper coil, H_2O at a constant rate is flown.

c) THERMOMETERS (t_1 & t_2) are fitted to note the temperature.

d) A CONTAINER is provided for collecting water which is formed due to condensation of steam.

The Whole Assembly is enclosed in an INSULATED CHAMBER.

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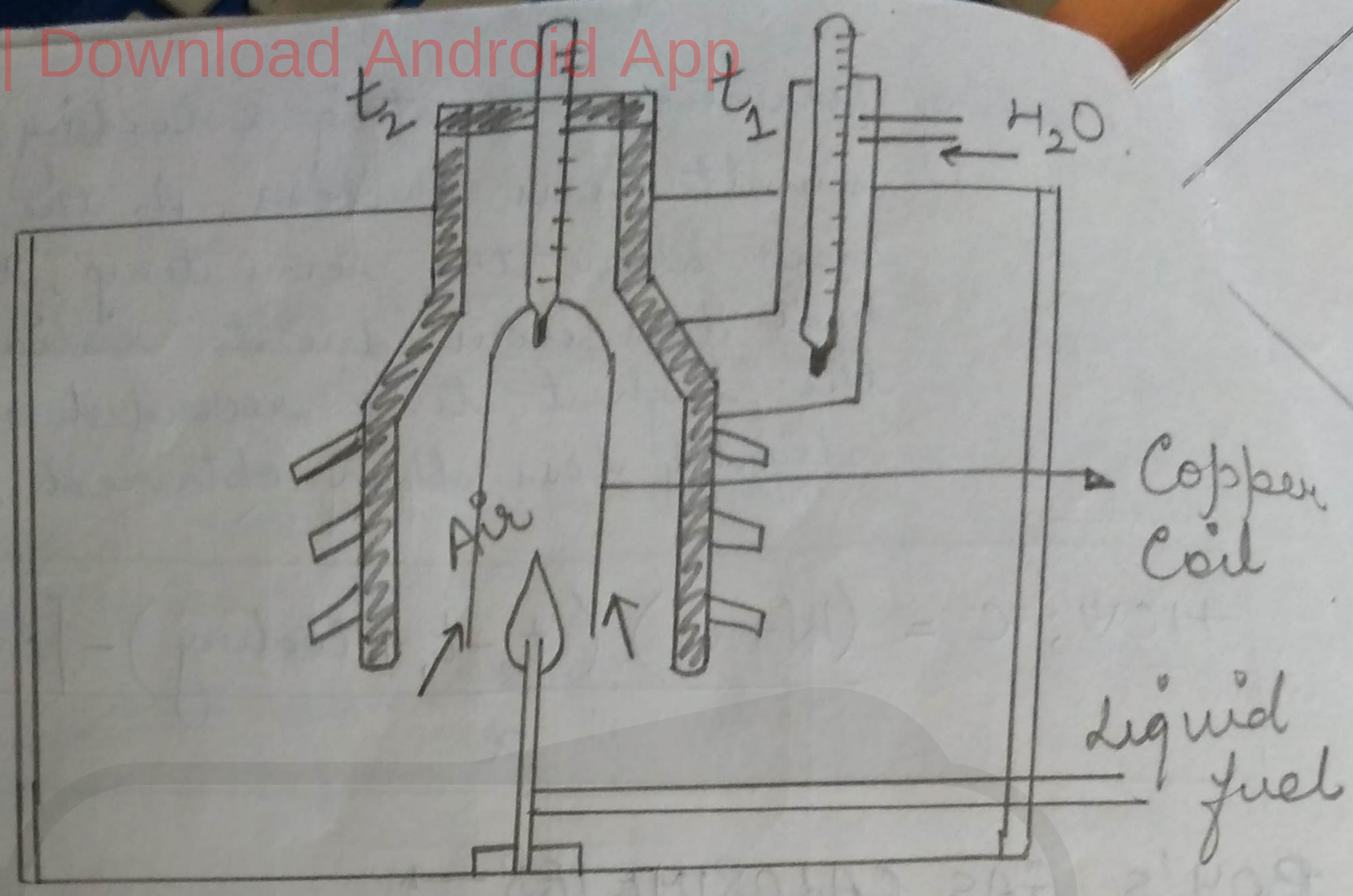

Working :- Burning of fuel & Circulation of water is done for 15 mins
↓
Heat produced by fuel is transferred to H_2O
↓
Rise in temperature is recorded.

Calculations :-

Volume of gas burnt = V (m^3)
Weight of water = W (kg)
Weight of water condensed = m (kg)
Temp. of incoming water = T_1
Temp. of outgoing water = T_2
Rise in temp = $(T_2 - T_1)$
Calorific Value = C

$$\boxed{\text{Heat Lost} = \text{Heat Gain}}$$

$$C = \frac{W(T_2 - T_1)}{V}$$

*** DULONG'S FORMULA :-**

$$HCV = \frac{1}{100}\left[8080 \times \%C + 34500\left(\%H - \frac{\%O}{8}\right) + 2240 \times \%S\right]$$

= cal/g.

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❖ CLASSIFICATION OF FUELS

NATURAL / PRIMARY FUEL: are naturally occuring fuel and utilized as such.

- SOLID FUEL: Wood, Coal
- LIQUID FUEL: Petroleum
- GASEOUS FUEL: Natural gas

SECONDARY FUEL: are manufactured fuel obtained from primary fuel

- SOLID FUEL: Coke, Charcoal
- LIQUID FUEL: Kerosene, LPG
- GASEOUS FUEL: Biogas, Water gas.

❖ FOSSIL FUEL (COAL & ITS ANALYSIS)

Solid fuels are mainly composed of CARBON and HYDROGEN as major components.

Coal:

1. It is a fossil fuel
2. It is produced from vegetable residue under condition of high temperature & pressure.

Analysis of Coal:

PROXIMATE ANALYSIS

ULTIMATE ANALYSIS

PROXIMATE ANALYSIS:

This analysis of parameters is done in around TWO HOURS with approximate results, accurate is not required.

❖ PERCENTAGE OF MOISTURE:

PROCESS:

Take weight of coal (x g) → Dry it at 100°C for 1 hr → Again take the weight of coal (y g) → Repeat the process until constant weight is recorded.

CALCULATION:

LOSS IN WEIGHT OF COAL = ($x-y$) g

% of Moisture = Loss in weight/ Total weight * 100

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% of Moisture = (x-y)/(x) * 100

❖ PERCENTAGE OF VOLATILE MATTER:

PROCESS:

Take the above dried sample of coal (y g) → Place in electric oven at 925°C covered with a crucible → Take out crucible after 7 mins → Weigh the matter found in crucible (z g).

CALCULATIONS:

LOSS IN WEIGH = (y-z) g

% volatile matter = (y-z)/ (y) * 100

❖ PERCENTAGE OF ASH CONTENT:

PROCESS:

Burn the above sample of coal in the presence of oxygen (z) g → weigh the residue after burning (z') g

CALCULATIONS:

% of ash content = z'/x * 100

❖ PERCENTAGE OF CARBON:

% of Carbon = 100- % [moisture + volatile matter + ash]

% of Moisture	•Temp = 100° C
% of Volatile matter	•Temp = 925°C
% of Ash content	•Complete burning process

ULTIMATE ANALYSIS

This analysis gives us the information about the percentage of carbon, hydrogen, Sulphur, nitrogen and oxygen.

❖ PERCENTAGE OF CARBON & HYDROGEN:

A known amount of coal is burnt in excess of oxygen.

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ULTIMATE ANALYSIS →

Determination of Carbon & Hydrogen :-

- Greater the % of Carbon, better is the quality and greater is calorific value.
- A known amount of Coal is burnt and oxidised. The gaseous products are passed through $CaCl_2$ and KOH.
- The tube contains weighed amount of anhydrous $CaCl_2$ and absorbs H_2O.

$$CaCl_2 + H_2O \longrightarrow CaCl_2 \cdot xH_2O$$

- The potash bulb absorbs CO_2.

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

- The increase in weight is then determined.

Calculations :-

In fuel : $C + O_2 \longrightarrow CO_2$
(12g) (44g)

In fuel : $H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$
(2g) (18g)

$$\boxed{\frac{\text{Wt of C}}{\text{Wt. of } CO_2} = \frac{\text{At wt C}}{\text{M. wt } CO_2}}$$

$$\text{Wt. of C} = \frac{12}{44} \times \frac{\text{Wt. of KOH}}{\text{Wt. of Coal}}$$

$$\% \text{ of C} = \text{Wt. of C} \times 100$$

$$\% \text{ of Carbon} = \frac{\text{Weight of Carbon}}{\text{Weight of Coal}} \times 100$$

$$\boxed{\% \text{ of Carbon} = \frac{\text{Inc. in wt of KOH} \times \frac{12}{44}}{\text{Wt of Coal}} \times 100}$$

$$\boxed{\% \text{ of Hydrogen} = \frac{\text{Inc. in wt. of } CaCl_2}{\text{Wt. of Coal}} \times \frac{2}{18} \times 100}$$

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Estimation of Nitrogen :-

Nitrogen is inert and incombustible gas.

It is carried out by " KJELDAHAL's METHOD "

- 1 g of powdered Coal is heated with H_2SO_4 along $K_2SO_4 + CuSO_4$ in long neck flask.

↓

Clear solution $((NH_4)_2SO_4)$ is mixed with NaOH to liberate $NH_3(g)$

↓

$NH_3(g)$ is distilled & absorbed in known volume of 0.1 N H_2SO_4.

Reaction :-

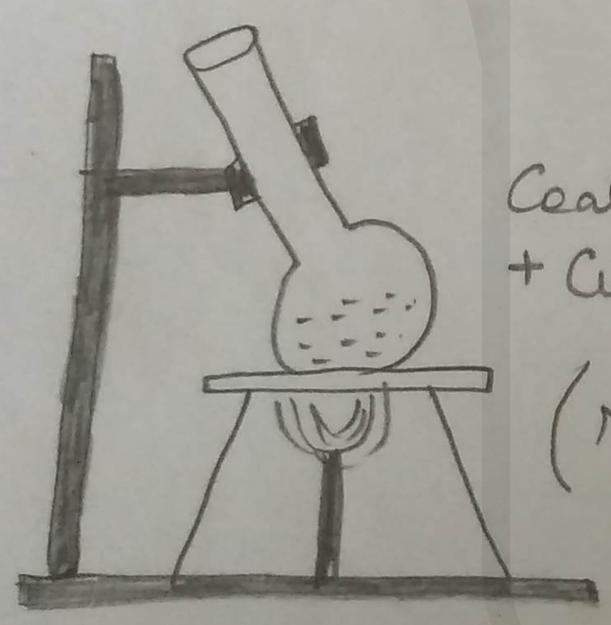
$$\underset{\text{(Coal)}}{\overset{10}{N_2}} + H_2SO_4 \longrightarrow \overset{10}{(NH_4)_2SO_4} \xrightarrow{NaOH} \overset{10}{NH_3(g)}$$

↓ Distill, H_2SO_4. know 30

$$(NH_4)_2SO_4 \quad 10$$

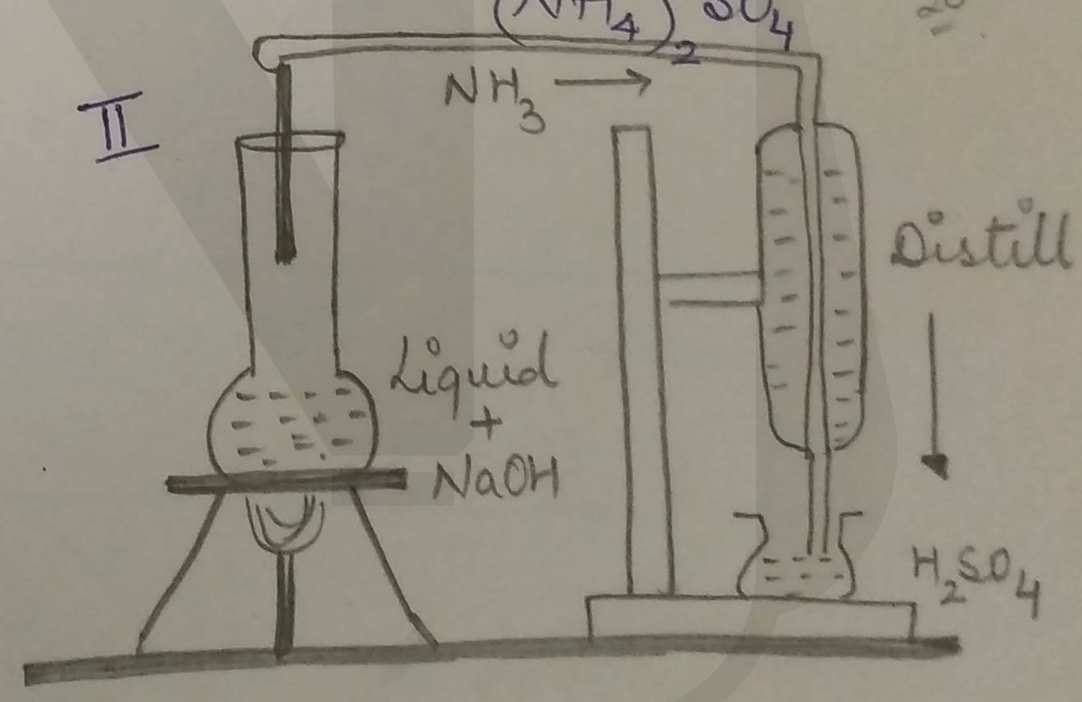
20

I



Coal + H_2SO_4 + $CuSO_4$ + K_2SO_4 ↓ $(NH_4)_2SO_4$

II



- Volume of Unused H_2SO_4 is titrated using 0.1 N NaOH solution. Let V_2 mL is NaOH required to neutralised unused H_2SO_4.

Amount of H_2SO_4 used for evolved NH_3 = (Volume X Normality)

$= (V_1 - V_2) \times 0.1$ milleq.

$= \dfrac{(V_1 - V_2) \times 0.1}{1000}$ equ.

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Weight of Nitrogen $= \frac{(V_1 - V_2) \times 0.1}{1000} \times 14$

$$\% \text{ of Nitrogen in Coal} = \frac{(V_1 - V_2) \times 0.1}{1000} \times 14 \times 100 \times \frac{1}{\text{wt. of Coal}}$$

c) Determination of Sulphur :-

- On oxidation, sulphur produces toxic gases SO_2 & SO_3.
- The Ash obtained is extracted with dil. HCl. The acid is reacted to $BaCl_2$ to form $BaSO_4$. The precipitate is filtered, dried & weigh.

$$\underset{(32g)}{S} \xrightarrow{O_2} SO_4^{2-} \xrightarrow{BaCl_2} \underset{(233g)}{BaSO_4}$$

$$\frac{\text{Weight of S}}{\text{Weight of } BaSO_4} = \frac{\text{Atomic wt. of S } (32g)}{\text{Mole. wt of } BaSO_4 \ (233g)}$$

$$\text{Weight of Sulphur} = \frac{32}{233} \times W_2$$

$$\% \text{ of Sulphur} = \frac{32}{233} \times \frac{W_2}{\text{Wt of Coal}} \times 100$$

DULONG'S FORMULA :

$$GCV = \frac{1}{100}\left[8080\,\%C + 34500\left(\%H - \frac{\%O}{8}\right) + 2240\,\%S\right]$$

BOMB CALORIMETER :

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1. 0.80 g of solid fuel is combused & rise in temp is 2.5°C. Cal HCV, if water taken in Calorimeter is 2000g & water Equivalent is 2200g. (13125 cal/g)

2. 0.72 g of fuel contain 80% carbon. Temp increased from 27.3°C to 29.1°C. If calorimeter contain 250 g of water & water equivalent is 150 g. Cal. HCV (1000 cal/g)

3. The following data :-

Weight of crucible = 3.649 g
Wt of Fuel + crucible = 4.678 g
Wt of equi water = 570 g
Wt of water = 2200 g
Rise in temp = 2.3°C
Cooling correction = 0.047°C
Acid " = 62.6 cal
Fuse wire " = 3.8 cal
Cotton Thread = 1.6 cal. (6251.88 cal/g)

D.F

4. A sample of Coal contain 60% C, 33% O, 6% H & 0.5% S 0.2% N & 0.3% Ash. Cal GCV.

D.F

5. A sample of Coal contain 84% C, 1.5% S, N = 0.6%, H = 5.5%, O = 8%. Cal. GCV

B.Calo'

6. Wt fuel = 0.85 g
Wt H_2O = 650 g
Wt H_2O = 2500 g
Rise = 2.5°C
C. Corr = 0.03°C
Fuse wire = 10 cal
Acid corr = 50 cal (9205.2 cal/g.

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Numericals

FUEL

1. 3.25 g of coal was Kjeldahlized and NH_3 gas thus was absorbed in 45 mL of 0.1 N H_2SO_4. After absorption the excess acid required 11.5 mL of 0.1 N NaOH for neutralization. Determination of % of Nitrogen.

Ans:-

$$\% \text{ of Nitrogen} = \frac{(V_1 - V_2) \times 0.1}{1000} \times 14 \times 100 \times \frac{1}{3.25}$$

4. 0.1 gm of Sample of coal was analysed and precipitate of $BaSO_4$ is 0.01 gm. Cal % of sulphure.

5. Cal the % of Carbon and % of Hydrogen when 10 g coal analysed :-

Actual KOH = 2 g Final KOH = 2.5 g
Actual $CaCl_2$ = 4 g Final $CaCl_2$ = 5.2 g.

Also Cal. % of Moisture when same 10 g coal was heated & residue is 4.25 g. Cal % of Ash if final residue is 2 g.

6. Cal. the % of Hydrogen in 2 g Coal when ~~KOH~~ $CaCl_2$ increased its weight to 0.5 g from its actual weight. Also Cal % of Ash when 2 g coal gave 0.155 g of residue.

7. Analyse the Sample for :- 10 g coal

% of Moisture → 40 %
% of V. matter → 2.4 g
% of Ash → 1 g

% of Carbon when 10 g coal increased KOH weight from 10 g to 11.5 g and % of Hydrogen when 10 g coal increased $CaCl_2$ weight from 2 g to 4 g.

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NUMERICALS

UNIT: FUEL

1. A sample of Coal contain : C = 83% H = 6% Ash = 1%
   Weight of Coal = 0.92 g
   Weight of Water = 550 g
   Water Equivalent = 2200 g
   Rise in temp = 2.42°C
   Fuse wire correction = 10 cal , Acid Correction = 50 cal.
   (Ans = 7168.5 cal/g)

2. On burning 0.83 g of Coal , the temp of 3500 g of water rises from 26.5°C to 29.2°C. Water Equivalent is 385 g. Cal calorific value.
   (Ans = 12,638 cal/g)

3. 0.5 g of Coal Sample was analysed for Sulphur using $BaCl_2$. The precipitate was filtered & was found to be 0.05 g. Cal % of Sulphur.
   (Ans = 1.3734 %)

4. Calculate HCV of a coal sample {H = 7% , O = 3% , C = 80% , S = 3.5% , N = 2.1% , Ash = 4%}
   (HINT → DULONG'S FORMULA)

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Numericals

CALORIFIC VALUE.

Bomb

$$HCV = \frac{(W+w)(t_2-t_1)}{x}$$

$$HCV = \frac{(W+w)(t_2-t_1+\text{cooling})-(FAC)}{x}.$$

Boy's

$$HCV = \frac{W(t_2-t_1)}{V}$$

Dulong

$$HCV = \frac{1}{100}\left[8080\,\%C + 34500\left(\%H - \frac{\%O}{8}\right) + 2240\,\%S\right]$$

$$LCV = HCV - 0.09H \times 587$$
$$= ____ \text{ cal/g}$$

Q1: A sample of coal contains 92% C, when tested for C.V, Bomb Calorimeter gave

Wt. of coal = 0.95 g
Wt. of H_2O = 700 g
Wt. of H_2O equi = 2000 g
Inc. in temp = 2.48 °C

Acid C = 60.0 cal
Cooling = 0.02°C
Fuse wire = 10.0 cal.

(7031.6 cal/g)

Q2 Cal. CV using Boy's Calorimeter:-

Vol. of gas = 0.098 m^3
Wt. of water = 50 kg.
Temp = 26.1 °C
Temp = 46.5 °C

(10408.2 kcal/m^3)

Q3 Cal. GCV & LCV for C = 82%, H = 8% O = 5%, S = 2.5%, N = 1.4% Ash = 2.1%

(9225.9 kcal/g)

Q4 Cal. GCV for C = 80% H = 7% O = 3%, S = 3.5% N = 2.1%

(8828 kcal/g)

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JIMS ENGINEERING MANAGEMENT TECHNICAL CAMPUS

B.TECH (1st SEM) SECTION-A

APPLIED CHEMISTRY (ETCH-113)

TEST/QUIZ

Date: 31st August 2017

NOTE: Attempt all questions. All carry equal marks.

1. When 2 g of coal is heated to 100®C and weight get reduced to 1.67g. On further heating to 900®C, weight reduced to 1.43g. Final residue was only 0.23g. Calculate the % of fixed carbon.
2. 15 g coal was analysed 20% moisture and reduced its weight to 9.5 g when analysed for volatile matter. Calculate all parameters if ash is 5%.
3. 1.26 g of coal was analysed for ammonia where 15ml of 0.1N H_2SO_4 was used. After absorbtion, residual acid required 6.75 ml of same normality NaOH. Determine % of Nitrogen.
4. A coal sample (2g) contains 80% C, 10%H, 8%O, 2% S, 1%N & 2% Ash. Calculate HCV .
5. 1.5 g of coal is analysed for its calorific value using Bomb calorimeter where water equivalent is 300g and weight of water is 2000g. Temperature changes from 100 to 110®C with cooling error of 0.01®C. Correction error is 60cals. Cal. HCV of fuel.
6. When 5 g coal is analysed, it raises the weight of KOH to 1.45g, $CaCl_2$ to 2.45g, precipitate of $BaSO_4$ was 0.05g. Moreover, %of O was found to be half of %H. Determine all the parameters and HCV of fuel.
7. Bomb Calorimeter analysed coal sample with initial temperature 26®C and final temperature 27.6®C. Water weight was 2000g with cooling error temperature nil. But fuse wire correction was found to be 50cal and acid correction 50cal. Cal HCV.
8. Sample of coal has HCV 9430cal/g with composition as C=92% , O= 2%, S= 0.5%, N=1.5%. Calculate the % of H.
9. What is the cooling error of thermometer if HCV is 5400cal/g, with equivalent water weight 400g & weight of water 2500g. Rise in temp recorded is 2.5®C & correction errors is 50 cals.
10. Explain the following:
    Calorific value
    Characteristic of good fuel
    Principle of bomb calorimeter
    Flowchart of Proximate analysis

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* CRACKING *

INTRODUCTION :-

- By fractional distillation of crude petroleum, gasoline is considered to be most important fraction. But the yield is only 20%.
- "Cracking" is the process by which heavier fractions are converted into lighter fractions by the application of heat, with or without catalyst.
- It involves rupture of C-C and C-H bond in the chains of high molecular weight hydrocarbons.

$$\underset{\substack{\text{(Decane)} \\ \text{B.pt} = 174^\circ C}}{C_{10}H_{22}} \xrightarrow{\text{Cracking}} \underset{\substack{\text{(n-pentane)} \\ \text{B.pt} = 36^\circ C}}{C_5H_{12}} + \underset{\text{(Pentene)}}{C_5H_{10}}$$

- The process of cracking involves following changes :-
  - → Higher hydrocarbons converted to lower hydrocarbons.
  - → Products has lower Boiling point than the initial reactants.
  - → Unsaturated hydrocarbons are formed from saturated hydrocarbons.
  - → Cyclization may take place.

* TYPES :-

Cracking

- **Thermal**
  - Liquid phase
  - Vapour phase
- **Catalytic**
  - Fixed Bed
  - Unfixed / Moving Bed.

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I THERMAL CRACKING :-

- Cracking takes place by application of heat & pressure.
- Heavy oils are subjected to high temperature & pressure & they break up into paraffins & olefin

a) Liquid Phase Thermal Cracking :

- By this method, any type of oil can be cracked.
- The charge is kept in the LIQUID FORM by applying high pressure of 30 kg/cm^2 - 100 kg/cm^2 and a temperature of 476-530 °C.
- The products are separated by fractionating columb.
- Products are :- Cracked Gasoline (30-35%)
  Cracked Gases
  Cracked Fuel oil

b) Vapour Phase Thermal Cracking :

- By this method, only those oils which can vapourise at low temperature can be cracked.
- Like Kerosene oil, are heated at a temperature of 670-720°C under low pressure of 10-20 kg/cm^2.
- Time required for cracking is too low than liquid phase.
- Mechanism :- "FREE RADICAL MECHANISM"
  - Initiation by HEAT
  - Propagation
  - Termination

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Initiation → By using heat.

$$CH_3-(CH_2)_7-CH_3 \xrightarrow{\Delta} CH_3-(CH_2)_3-\dot{C}H_2 + \dot{C}H_2-(CH_2)_2-CH_3$$

Propagation → The free radicals are thermally unstable & undergoes fission at β-position to yeild OLEFINS & new radical.

$$CH_3-CH_2-CH_2-CH_2-\dot{C}H_2 \longrightarrow CH_3-CH_2-\dot{C}H_2 + CH_2=CH_2$$

$$CH_3-CH_2-\dot{C}H_2 \longrightarrow \dot{C}H_3 + CH_2=CH_2$$

Termination :

$$\dot{C}H_3 + \dot{C}H_3 \longrightarrow CH_3-CH_3$$

II CATALYTIC CRACKING :-

- Cracking takes place at lower temp & pressure in the presence of CATALYST.
- CATALYST is MIXTURE of SILICA & ALUMINA. (hydrated aluminium silicate)

- **Advantages** :-
  a) High temp and pressure is not required.
  b) Use of catalyst increases the rate of reaction.
  c) The yield of gasoline is higher 70%.
  d) Gasoline obtained from catalytic cracking has octane number 80.
  e) The process can be better controlled than thermal.
  f) Catalyst are selective in action and hence cracking of only high boiling fractions takes place.

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(2)

a) Fixed - Bed Catalytic Cracking :-

In this type of cracking the catalyst is in a form of granules or pellets. These are used in the form of fixed bed in catalyst towers.

Heavy oil is passed through a heater having temp 450°C

↓

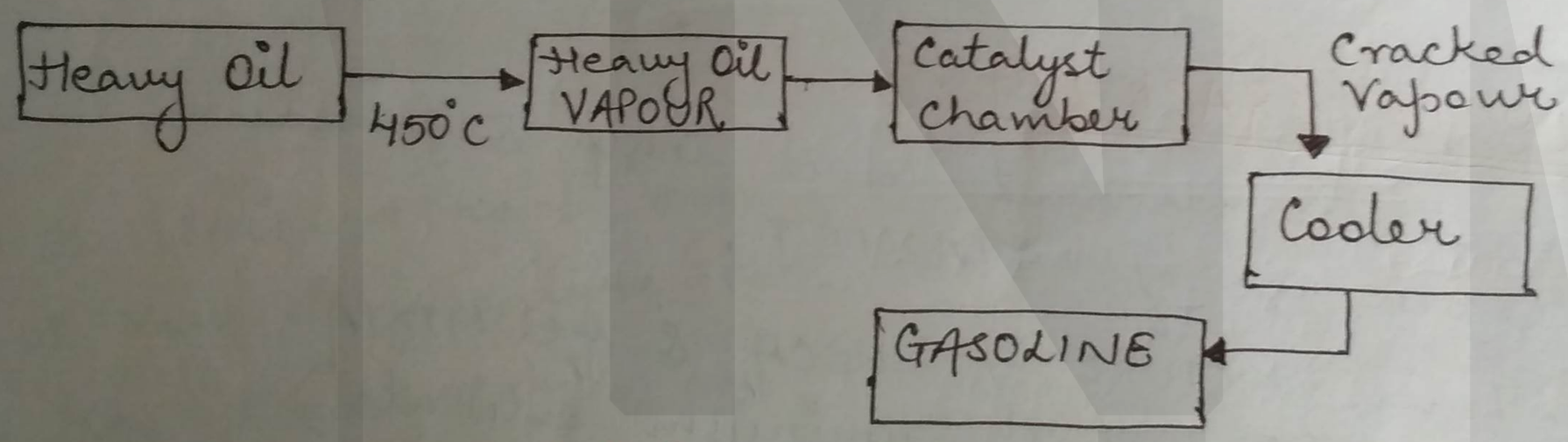
And Passed through Catalyst chamber ($SiO_2 . Al_2O_3$)

↓

30-40% of heavy oil is converted to low molecular weight hydrocarbon.

↓

The cracked vapours are passed through the fractionating columb, where gasoline is recovered.



b) Moving Bed Catalytic Chamber :-

In this type of cracking, the catalyst is in the form of fine powder which flows down to the Cracking chamber.

Heavy Oil is heated & Vapours are allowed to mix with hot catalyst (powder)

↓

Mixture is forced into a large reactor (500°C)

↓

Cracking of heavy Oil takes place

↓

Passed to fractionating Columb.

* KNOCKING *

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* OCTANE & CETANE NUMBER *

KNOCKING :-

It is a sharp metallic sound which is produced in internal combustion engines due to immature ignition of air-gasoline mixture.

Knocking decreases the efficiency of engines and causes huge loss of energy.

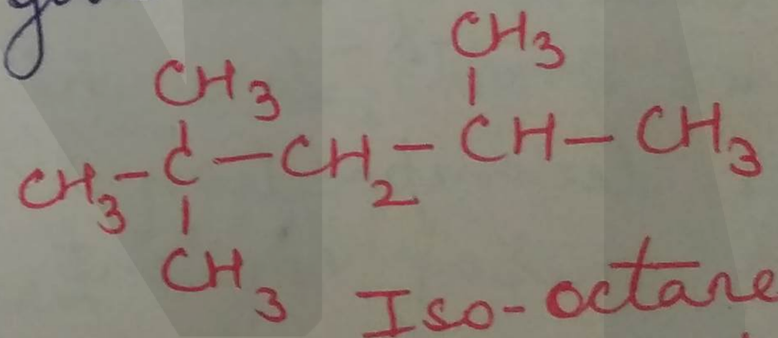
This undesirable phenomenon is believed to be closely related with chemical composition of fuel.

Straight chain paraffin > Branched chain > Olefin > Cycloparafin > Aromatic

* OCTANE NUMBER :-

- The anti-knocking characteristic can be explained by arbitarily scale known as "OCTANE RATING".
- n-heptane knocks very badly so given ZERO anti-knock.
- 2,2,4-trimethylpentane has given 100 anti-knock value.

$CH_3-(CH_2)_5-CH_3$
n-heptane
Anti-knock = Zero



Iso-octane
Anti-knock = 100

- **Definition** → Octane number of fuel is defined as the percentage of iso-octane present in a mixture of iso-octane & n-heptane, which has the same knocking characteristic as that of fuel under examination, under same set of condition.
- **Anti-knock Agents** → Certain additives are added to gasoline to improve its anti-knocking characteristics.

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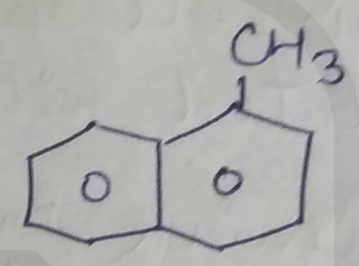
(3)
a) Benzol
b) Alcohol
c) $(C_2H_5)_4Pb$ Tetra-ethyl lead (TEL)

* CETANE NUMBER :-

- Definition : The cetane number of a diesel oil may be defined as the percentage of cetane in a mixture of cetane & α-methylnapthalene will have the same ignition characteristics as the fuel under test.

$CH_3(CH_2)_{14}CH_3$
Cetane / n-hexadecane
(100)



(zero)

a) Acetone
b) Ethyl nitrate
] increases cetane number.

* CARBONIZATION OF COAL *

- Carbonization of Coal is the process of heating coal in absence of air, to a high temperature, so that coal undergoes decomposition & yields a residue which is richer in carbon content.
- "The process of converting coal into coke is Carbonization".
- Process of Carbonization →

TEMP	REMARK
260-270°C	→ (H_2O, H_2S, alkene, alkane) removed.
350°C	→ Decomposition of Coal.
400°C	→ Soft mass
700°C	→ Hydrogen is evolved
800°C	→ All gases are evolved
	→ Foam like mass
	→ Solidies to COKE.

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Types of Carbonization

Low Temperature (LTC)
(500-700°C)

- Yield of coke = 75-80%
- Volatile matter = 5-15%

High Temperature (HTC)
(900-1200°C)

- Yield = 65-75%
- Volatile = 1-3%

* METALLURGICAL COKE →

The properties of coke depend on porosity, reactivity and the amount of volatile matter retained by coke during carbonization.

Coke is used as Reducing Agent in Metallurgy.

- **Manufacture :-** "OTTO-HOFFMANN OVEN"

a) The Oven is made up of Silica bricks & is tighly closed so that no air can enter.

b) From the top, Coal is added into each chamber.

c) Each Chamber is provided with gas take off & door at each end for discharging coke.

Working :-

Coal is charged into the chamber
↓
Chambers are closed tightly
↓
Oven is heated to 1200°C
↓
Process starts layer by layer.
↓
Decrease in volume is observed during conversion of coal to coke.
↓
Plastic mass solidies into hard & porous mass called coke.

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Regeneration Process :

Waste gases are passed through Regenerators.

a) Recovery of Tar : Liquor NH_3 is sprayed and Tar can be recovered.

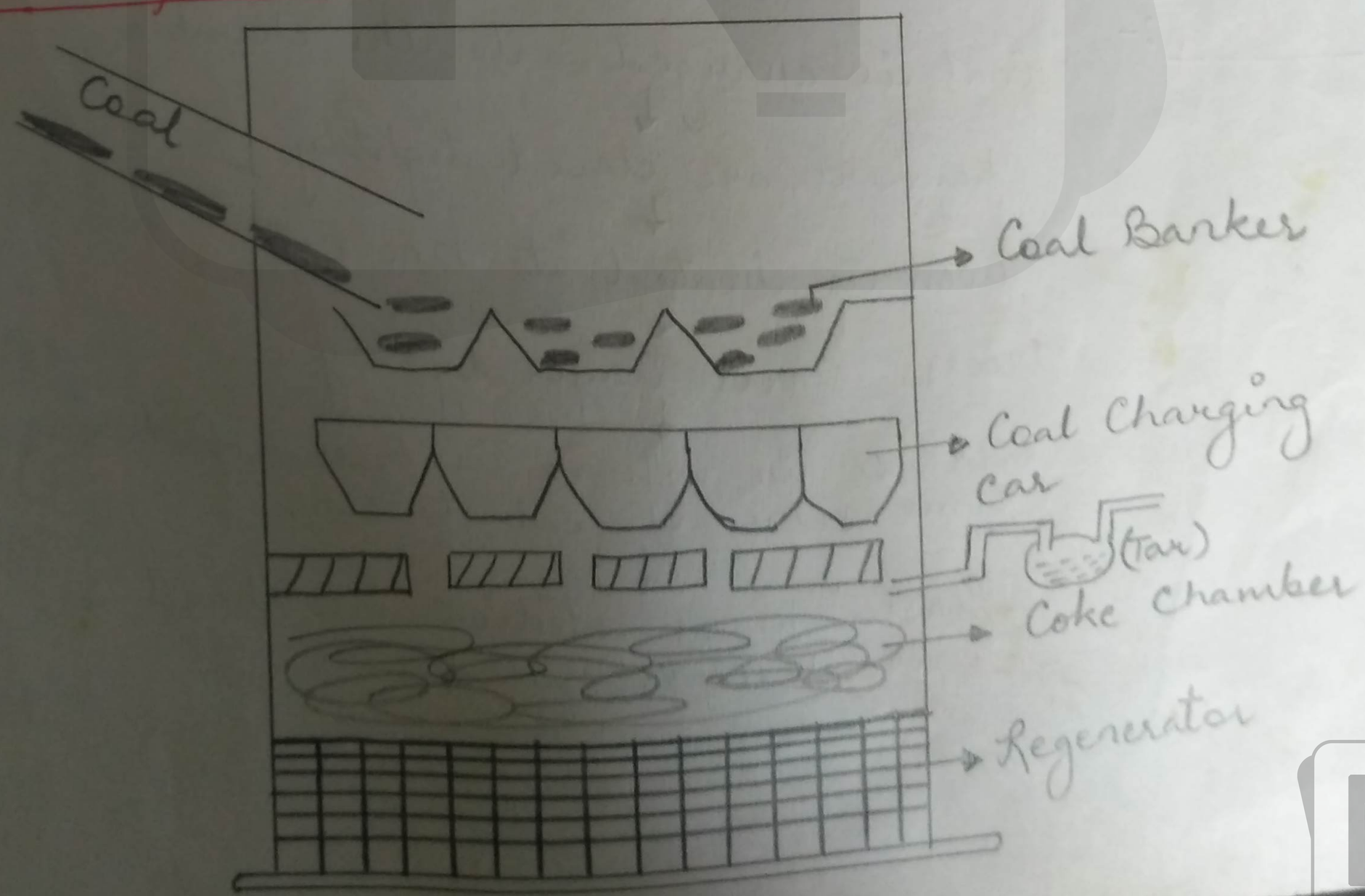
b) Recovery of NH_3 : Gases are passed to Second chamber where H_2O is sprayed & NH_4OH is formed. H_2SO_4 can also be used.

c) Recovery of Naphthalene : Gases are passed through another tower, where H_2O at lower temp is sprayed.

d) Recovery of Benzol : Benzol scrubber is sprayed where aromatic by-products are obtained.

e) Recovery of H_2S : Fe_2O_3 is used to remove H_2S as Fe_2S_3.

Schematic representation :-



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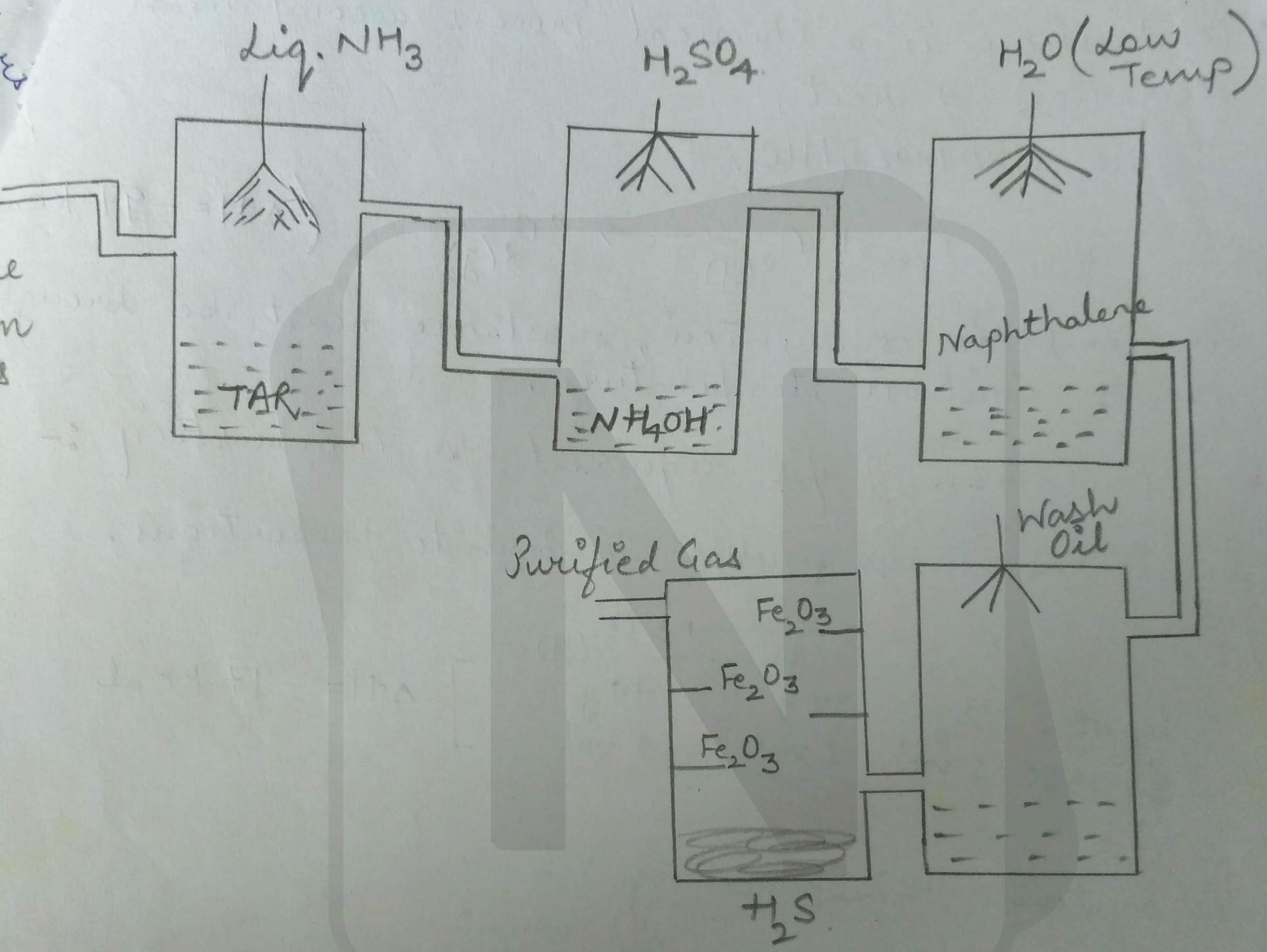

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* COMBUSTION *

- Combustion is a Chemical Process accompanied by liberation of heat.
- It is EXOTHERMIC.

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad (\Delta H = -97 \text{ kcal})$$

- For complete combustion, substance must be brought to its ignition temperature.

→ Calculation of Air required for combustion :-

1. Substances always combine in definite proportions.

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad \Delta H = -97 \text{ kcal}$$

By wt :	12 g	32 g	44 g
By vol :	1 vol	1 vol	1 vol

2. Air contains 21% oxygen by volume
   23% oxygen by weight
   28.94 g weight of air & 22.4 L STP

3. Steps →
   - Write balanced chemical Equation
   - Cal weight or volume of O_2 required by each.
   - Find total oxygen required by adding up oxygen required & substracting O_2 already present.
   - Convert volume / weight of O_2 into air :-

$$\text{Wt. of air} = \text{Total } O_2 \times \frac{100}{23} \text{ gm}$$

$$\text{Vol. of air} = \text{Total } O_2 \times \frac{100}{21} \text{ m}^3$$

- To convert volume into weight :-

$$= \frac{28.94}{22.4} \times y$$

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Q: **Q1:** Cal. the weight and volume of air required for combustion of 1 kg carbon.

Solution →

$$C + O_2 \longrightarrow CO_2$$
$$(12g) \quad (32g)$$

Weight of O_2 required to burn 12g C = 32 g

" " " " " " 1000 g C = $\frac{32}{12} \times 1000$

= 2.67 kg.

Weight of air required = $\frac{100}{23} \times 2.67$

= **11.60 kg.**

Volume of air required = $11600 \times \frac{22.4}{28.94}$ L/g

= **8978.6 L.**

Q2 Cal. amount of air required for complete combustion of 100 kg of fuel if C = 80%, H_2 = 6%, O_2 = 5%, S = 2%.

Solution :-

Constituent	Amount	Rxn	Wt. of O_2
C	80	$C + O_2 \rightarrow CO_2$	$\frac{32}{12} \times 80 = 213$
H	6	$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$	$\frac{16}{2} \times 6 = 48$
S	2	$S + O_2 \rightarrow SO_2$	$\frac{32}{32} \times 2 = 2$
O	5		

Net amt of O_2 = [213+48+2] − 5 = **258.3 kg.**

Air required = $\frac{100}{23} \times 258.3$

= **1123 kg**

Practice

1. Cal. volume of air required for complete combustion of $1 m^3$ of gaseous fuel having composition :

CO = 48%
CH_4 = 8%
H_2 = 40%
C_2H_2 = 2%
N_2 = 1%.

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(2)

2. A gas has composition by volume:

$H_2 = 22\%$ $CO = 20\%$ $O_2 = 3\%$

$CH_4 = 4\%$ $CO_2 = 6\%$ $N_2 = 45\%$

If 25% excess air is used, find the weight of air.

Solution:

Constituent	Amt	Reaction	Volume
H_2	0.22	$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$	$0.22 \times 0.5 = 0.11$
CH_4	0.04	$CH_4 + 2O_2 \rightarrow CO_2$	$0.04 \times 2 = 0.08$
CO	0.20	$CO + \frac{1}{2}O_2 \rightarrow CO_2$	$0.2 \times 0.5 = 0.1$
CO_2	0.06		
O_2	0.03		
N_2	0.45		

$$\text{Volume } O_2 \text{ required} = [0.11 + 0.08 + 0.1 - 0.03]$$
$$= 0.26 \ m^3$$

$$\text{Volume of air} = \frac{100}{21} \times 0.26 = \underline{\underline{1.238}} \ m^3$$

$$\text{Vol. of air actually supplied} = 1.238 \times \frac{125}{100}$$
$$= \underline{\underline{1.5475}} \ m^3$$

$$\text{Weight of air supplied} = 1547.5 \times \frac{28.94}{22.4}$$
$$= \underline{\underline{1.999 \ kg}}$$