ENGINEERING CHEMISTRY-CY8151

Unit-IV

Fuels and Combustion

Question Bank (Part-A & Part-B)

Part-A (2 Marks)

1. Write the characteristics of a good fuel **(2010)**
2. What is the drawback of presence of sulphur in the coal? **(2009) 3.** What is metallurgical coke? **(Or)** What is Carbonisation of coal?
4. What are the desirable characteristics of metallurgical coke?

5. Why coke is preferred to coal for metallurgical purpose? **(Or)** Why is coke used in metallurgical process than coal?
6. What is calorie? Give the different units of calorific value. **(2018)**
7. How coals are classified? **(2018) (Or)** What are the different varieties of coal? How do you rank them in the order of increasing calorific value?
8. Distinguish between proximate and ultimate analysis **(2009, 2017)**
9. Define Octane number. **(Or)** Octane rating of a petrol? How can it be improved?
10. Define Cetane number **(Or)** Cetane rating of a diesel oil? How can it be improved?
11. What is CNG? Give its composition.
12. What are the advantages of CNG over LPG.
13. What is meant by hydrogenation of coal?
14. What do you mean by Synthetic petrol?
15. Explain the term "knocking" of a petrol engine. **(2009, 2013)**
16. Give the composition and uses of LPG. **(Or)** What is LPG? Mention its composition and uses.
17. What is power alcohol? Give its properties and uses.
18. What is difference between caking coals and coking coals?
19. Define Calorific value. Give its units.
20. Define GCV and NCV of a fuel.
21. What is ignition temperature?
22. What is Spontaneous ignition temperature?

Part-B (8 Marks)

1. Explain the proximate analysis of coal. Write its significance. **(2009)**
2. Explain the ultimate analysis of coal. Write its significance **(2009)**
3. Describe the Otto – Hoffman method of coke manufacture and the recovery of various by product. **(2008, 2010, 2012)**
4. What is Synthetic petrol? How is it manufactured by Bergius process? **(2010)**
5. With a neat diagram explain the analysis of flue gas by ORSAT METHOD. **(2015, 2012, 2013)**

Part-A

1. **Write the characteristics of a good fuel. (2010)**

i. It should be cheap and readily available ii. It should be safe and economical for storage transport iii. It should be higher calorific value

iv. The combustion should be easily controllable

2. What is the drawback of presence of Sulphur in the coal?

1. The combustion products of **Sulphur like SO_2 & SO_3 are harmful** and have corrosion effects on equipments.
2. The coal containing Sulphur is not suitable for the preparation of metallurgical coke as it affects the properties of the metal.

3. What is metallurgical coke? (Or) What is Carbonisation of coal?

When bituminous coal is heated strongly in the absence of air, the volatile matter escapes out and the mass becomes **hard, strong, porous and coherent** which is called as metallurgical coke. This process is called carbonization.

4. What are the desirable characteristics of metallurgical coke?

i. **Purity:** The moisture, ash, sulphur contents in metallurgical coke should be low.

ii. **Porosity:** Coke should be highly porous. **iii. Strength:** It should have high mechanical strength.

iv. Calorific value: The calorific value of coke should be high.

5. Why coke is preferred to coal for metallurgical purpose? (or) Why is coke used in metallurgical process than coal?

- Percentage of fixed carbon in coke is more
- The moisture, ash, sulphur contents are very low
- The mechanical strength, calorific value is high

6. What is calorie? Give the different units of calorific value. (2018)

It is defined as the amount of heat required to raise the temperature of **1 gram** of water through **1°C (15 to 16°C).**

Units of Calorific value: Calorie, Kilocalorie, British Thermal Unit (B.T.U), Centigrade Heat Unit (C.H.U)

7. How coals are classified? (2018) (or) What are the different varieties of coal? How do you rank them in the order of increasing calorific value?

Coal is classified on the basis of its rank. The rank of coal indicates its degree of maturity. Various types of coal are:

Wood → Peat → Lignite → Bituminous → Anthracite Coal

Calorific values increases from left to right.

8. Distinguish between proximate and ultimate analysis (2009, 2017)

S.No	Proximate analysis	Ultimate analysis
1.	It involves the determinations of physical constituents like moisture, volatile, ash and fixed carbon contents in coal.	It involves the determination of chemical constituents like carbon, hydrogen, nitrogen and sulphur and oxygen contents in coal.
2.	It gives the approximate composition of the main constituents of coal.	It gives the exact composition of the elementary constituents of coal.

9. Define Octane number. (or) Octane rating of a petrol? How can it be improved?

It is defined as the percentage of iso-octane present in a mixture of iso-octane and n-heptane.

Octane number can be improved by adding anti-knock agents like Tetra Ethyl Lead (TEL)

10. Define Cetane number (or) Cetane rating of a diesel oil? How can it be improved?

It is defined as the percentage of cetane present in a mixture of cetane and α-methyl naphthalene. The cetane number of a diesel oil can be improved by adding dopes like Ethyl nitrate

11. What is CNG? Give its composition.

When the natural gas is compressed, it is called as compressed natural gas. The primary

Component present in CNG is methane. It is manily derived from natural gas. Calorific value=10,000 k.cal/cum

Constituents	%
Methane	88.5
Ethane	5.5
Propane	3.7
Butane	1.8
Pentane	0.5

12. What are the advantages of CNG over LPG.

1. It produces **less pollutants** than LPG.
2. CNG is **cheaper** and **cleaner** than LPG.
3. **Noise Level** is much less than **diesel.**

4. The Octane rating of CNG is high.

13. What is meant by hydrogenation of coal?

Coal is heated with hydrogen to high temperature under high pressure, it is converted to gasoline. The preparation of liquid fuels from solid coal is called hydrogenation of coal.

14. What do you mean by Synthetic petrol?

The conversion of solid **coal** into liquid fuel by heating with hydrogen to higher temperature under high pressure is called s**ynthetic petrol**.

15. Explain the term "knocking" of a petrol engine. (2009, 2013)

Knocking is a kind of explosion due to rapid pressure rise occurring in petrol engine.

This can be reduced by adding TEL. **Ex: Tetra ethyl lead**

16. Give the composition and uses of LPG. (or) What is LPG? Mention its composition and uses.

It is obtainted as a by-product during fractional distillation of crude petroleum oil or cracking of heavy oil.

Composition:

Constituents	%
n- Butane	38.5
Iso-Butane	37
propane	24.5

Calorific value is about 25,000 kcal/m^3 Uses:

 As a domestic and industrial fuel.
As a motor fuel.

17. What is power alcohol? Give its properties and uses.

When **ethyl alcohol** is **mixed** (or) blended with **petrol** (at conc. 5-10%), it is called as power alcohol.

Properties:

- Lower calorific value **7000 k.cal/kg**
- High octane number **(90)**
- Good anti-knocking properties ➢ Higher compression ratio.
- Generate **10%** more power than the gasoline of same quantity.

Uses: As a good fuel in motors.

18. What is difference between caking coals and coking coals?

Caking coal: When coals are heated strongly, the mass become soft, plastic and fuse to give a coherent mass. Such type of coals are called as caking coal.

Coking coals: When coals are heated strongly, the mass become **hard, porous and strong.**

19. Define Calorific value. Give its units.

Calorific Value: It is defined as the total amount of heat liberated, when a unit mass of fuel is burnt completely.

Units: 1. Cal 2. K.cal 3. B.T.U 4. C.H.U

20. Define GCV and NCV of a fuel.

Gross Calorific value: It is defined as the total amount of heat produced, when a unit quantity of the fuel is **completely burnt** and **combustion products are cooled** to room temperature.

Net Calorific Value: It is defined as the **net heat** produced, when a unit quantity of the fuel is **completely burnt** and **combustion products** are allowed **to escape.**

21. What is ignition temperature?

The Lowest temperature in which the fuel must be heated, so that it starts burning smoothly.

22. What is Spontaneous ignition temperature?

The minimum temperature at which the fuel **catches fire** (ignites) **Spontaneously** without external heating.

Part-B

1. Explain the proximate analysis of coal. Write its significance.

Proximate analysis: It involves the determination of % of

a. Moisture content b. Volatile content c. Ash content d. Fixed carbon

a. Moisture content :

- C

Air-dired Coal (1 gram) → Heated in an hot air -oven (1hour)

$$\% \text{ of moisture in coal} = \frac{\text{loss in weight of the coal}}{\text{weight of air-dried coal}} \times 100$$

b. Volatile matter:

→ After the analysis of moisture content,

$$\% \text{ of volatile matter in coal} = \frac{\text{loss in weight of the coal}}{\text{weight of air-dried coal}} \times 100$$

→ The loss in Wt. of the sample is found out.

c. Ash content:

→ After the analysis of volatile matter,

$$\% \text{ of ash content in coal} = \frac{\text{weight of ash formed}}{\text{weight of air-dried coal}} \times 100$$

→ The loss in Wt. of the sample is found out

d. Fixed carbon:

$$= \boxed{100 - \%\ \text{of (moisture content + volatile matter + ash content)}}$$

Significance:

a. Moisture content : High % of moisture is **undesirable** because

1. It **reduces calorific** value of coal.
2. It **consumes** more heat.
3. It **increases** transport cost.

b. Volatile matter:

High % of volatile matter is **undesirable** because, 1.

It **reduces calorific** value of coal.

2. Due to high % of volatile matter, coal **burns** with a long flame with **high smoke.**

3. Due to high % of volatile matter, coal **donot coke** well.

c. Ash content: High % of ash content is **undesirable** because,

1. It reduces the calorfic value of coal.
2. Ash causes hindrance to heat flow.
3. Ash causes hindrance to produce clinkers, which blocks the air supply.
4. It increases the transporting , handling costs.
5. It involves additional cost in ash disposal.

d. Fixed carbon: % of **fixed carbon is desirable** because,

1. Higher the **% of carbon** in coal, **greater its calorific value.** 2 % of carbon helps in designing the furnace.

2. **Explain the ultimate analysis of coal. Write its significance Ultimate analysis:** It involves the determination of % of **a.** Carbon and Hydrogen contents.
   - **b.** Nitrogen content
   - **c.** Sulphur content
   - **d.** Ash content
   - **e.** Oxygen content

a. Carbon and Hydrogen contents :

- A known amount of coal sample is burnt with the help of O_2 in a **combustion chamber.**
- If **C and H** is present in the coal sample, are converted into **CO_2 and H_2O** respectively.

$$C + O_2 \longrightarrow CO_2 \uparrow$$

$$H_2 + 1/2O_2 \longrightarrow H_2O \uparrow$$

- The liberated CO_2 and H_2O vapour are absorbed by **KOH and any, $CaCl_2$ tube of know weight .**
- The increase in wt. of KOH and any. $CaCl_2$ tube is due to the formation of **CO_2 and H_2O.**
- From the Wt. of CO_2 and H_2O formed, **% of C and H** can be calculated.

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

$$CaCl_2 + 7H_2O \longrightarrow CaCl_2 \cdot 7H_2O$$

Calculations:

a) % of Carbon:

$$\underset{12}{C} + O_2 \longrightarrow \underset{44}{CO_2}$$

44 gms of CO_2 contains, 12 gms of carbon

$$\therefore \text{ x gms of } CO_2 \text{ contains } = \frac{12 \times x}{44} \text{ gms of carbon}$$

$$\text{m gms of coal contains } = \frac{12 \times x}{44} \text{ gms of carbon}$$

$$\text{100 gms of coal contains } = \frac{12 \times x}{44} \times \frac{100}{m} \text{ gms of carbon}$$

$$\therefore \text{ \% of carbon in coal } = \frac{12 \times x}{44} \times \frac{100}{m}$$

(or)

$$\text{\% of carbon in coal } = \boxed{\frac{\text{Increase in weight of KOH tube}}{\text{weight of coal sample taken}} \times \frac{12}{44} \times 100}$$

(b) % of hydrogen

$$\underset{2}{H_2} + {}^{1}\!/_{2}O_2 \longrightarrow \underset{18}{H_2O}$$

18 gms of water contains 2 gms of hydrogen

(or)

$$\% \text{ of hydrogen} = \boxed{\frac{\textbf{Increase in weight of } CaCl_2 \textbf{ tube}}{\textbf{weight of coal sample taken}} \times \frac{\mathbf{2}}{\mathbf{18}} \times \mathbf{100}}$$

$$\therefore \text{ y gms of } H_2O \text{ contains } = \frac{2 \times y}{18} \text{ gms of hydrogen}$$

$$\text{m gms of coal contains } = \frac{2 \times y}{18} \text{ gms of hydrogen}$$

$$100 \text{ gms of coal contians } = \frac{2 \times y}{18} \times \frac{100}{m} \text{ gms of hydrogen}$$

$$\therefore \% \text{ of hydrogen in coal } = \frac{2 \times y}{18} \times \frac{100}{m}$$

b) Nitrogen content:

- The nitrogen content in coal was determined by Kjeldahl's method.

$$2N + 3H_2 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

$$(NH_4)_2SO_4 + 2NaOH \longrightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

$$NH_3 + HCl \longrightarrow NH_4Cl$$

- The volume of unused (or) unabsorbed $\frac{N}{10} Hcl$ is determined by titrating it against standard $\frac{N}{10} NaoH.$
- **% of Nitrogen** is calculated from the **amount of acid neutralized** by liberated ammonia from coal.

Calculation:

$$\text{Let, the weight of the coal sample taken } = \text{m gms}$$

$$\text{Initial volume of } \frac{N}{10} HCl = V_1 \text{ ml}$$

$$\text{Volume of unused } \frac{N}{10} HCl = V_2 \text{ ml}$$

$$\therefore \text{ The acid neutralised by ammonia } = (V_1 - V_2) \text{ ml}$$

we know that

$$1000 \text{ ml of } 1 \text{ N HCl} \equiv 1 \text{ mole of HCl} \equiv 1 \text{ mole of } NH_3$$

$$[\therefore \underset{1 \text{ mole}}{HCl} + \underset{1 \text{ mole}}{NH_3} \longrightarrow NH_4Cl]$$

$$\equiv 14 \text{ gms of } N_2 \text{ [or 17 gms of } NH_3]$$

$$\therefore (V_1 - V_2) \text{ ml of } \frac{N}{10} HCl = \frac{14 \times (V_1 - V_2) \times N/10}{1000 \times 1N} \text{ gms of } N_2$$

m gms of coal sample contains

$$= \frac{14 \times (V_1 - V_2) \times N/10}{1000 \times 1} \text{ gms of } N_2$$

100 gms of coal sample contains

$$= \frac{14 \times (V_1 - V_2) \times N/10}{1000 \times 1} \times \frac{100}{m} \text{ gms of } N_2$$

% of N_2 in coal

$$= \frac{14 \times \text{Volume of acid consumed} \times \text{Normality}}{1000 \times \text{weight of coal sample}} \times 100$$

(or) % of N_2 in coal

$$= \boxed{\frac{\mathbf{1.4 \times Volume\ of\ acid\ consumed \times Normality}}{\mathbf{weight\ of\ coal\ sample}}}$$

C. Sulphur content:

$$\underset{32}{S} + 2O_2 \longrightarrow SO_4^{2-} \xrightarrow{BaCl_2} \underset{233}{BaSO_4} \downarrow$$

233 gms of $BaSO_4$ contains 32 gms of sulphur

$$\therefore \text{x gms of } BaSO_4 \text{ contains } = \frac{32 \times x}{233} \text{ gms of S}$$

$$\text{m gms of coal sample contains} = \frac{32 \times x}{233} \text{ gms of S}$$

$$\text{100 gms of coal sample contains} = \frac{32 \times x}{233} \times \frac{100}{m} \text{ gms of S}$$

$$\therefore \text{ \% of sulphur in coal} = \frac{32 \times x}{233 \times m} \times 100$$

$$\text{(or) \% of sulphur in coal} = \boxed{\frac{32 \times \text{weight of } BaSO_4 \text{ obtained}}{233 \times \text{weight of coal sample}} \times 100}$$

- From the wt of $Baso_4$ formed, the % of Sulphur in coal is calculated.

c) Ash Content:

Its is carried out as in **proximate analysis.**

d) Oxygen Content:

% of Oxygen = 100 - % (of C + H + N + S + ash)

Significance of Ultimate Analysis:

1. **Carbon and Hydrogen Contents:**

   Higher % of Carbon and hydrogen → better quality of coal → Higher Calorific value.
   % of carbon in coal **reduces size of combustion chamber** required.

2. **Nitrogen Content:**

   - Good quality coal should have very little nitrogen content.

3. **Sulphur Content:**

   - The Combustion products of Sulphur So_2 and So_3 are harmful and have corrison effect on equipments.
   - Coal containing Sulphur is not suitable for the preparation of metallurgical coke as it affects the properties of the metal.

4. **Oxygen Content:**

   - Lower the **% of Oxygen higher** is its calorific value.
   - As the **Oxygen content** increases its moisture holding capacity increases and **calorific value of the fuel** is reduced.

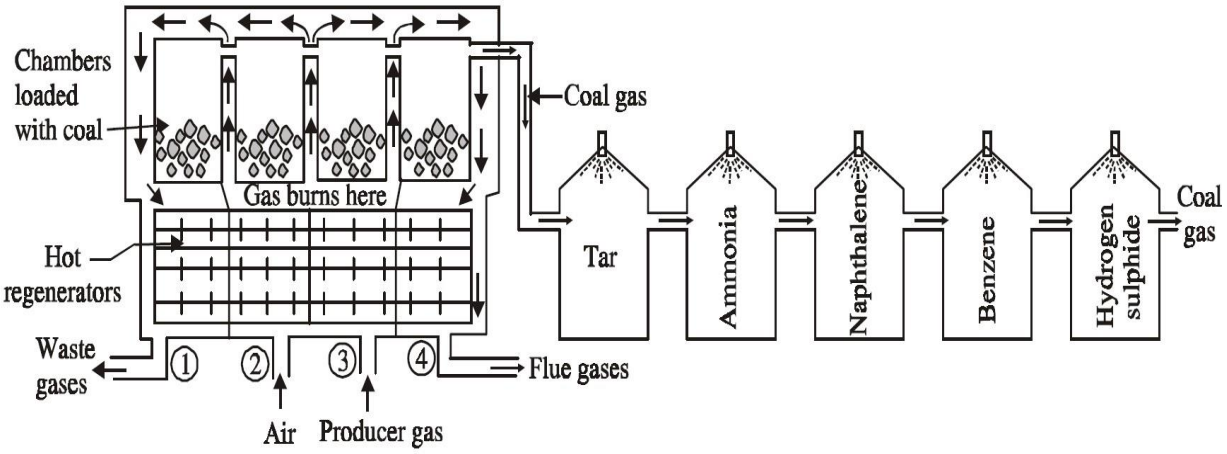
3. Describe the Otto – Hoffman method of coke manufacture and the recovery of various by product.

Otto – Hoffman's by – product oven:

1. To increase the thermal efficiency of the Carbonisation process.
2. To recover the by products like (Coal gas, ammonia benzol oil)
   Otto – Hoffman developed modern by product oven.

Construction:

- The oven consists of a number of silica chambers.
- Each chamber is about **10 – 12 m** long, **3 – 4 m** height and **0.40 – 0.45 m** wide.
- Each chamber is provided with a charging hole at the top, it is also provided with a gas off take value and iron door at each end for discharging coke.



Process:

- Coal is introduced into the Silica chamber and the chambers are closed. The Chambers are heated to C by burning the preheated air and the producer gas mixture in the interspaces between the chambers.
- The air and gas are preheated by sending them through 2nd and 3rd hot regenerators. Hot flue gases produced during combustion are allowed to pass through 1st and 4th regenerators until the temperature has been raised to 1000º C.
- While 1st and 4th regenerators are being heated by **hot flue gases**, the 2nd and 3rd regenerators are used for heating the **incoming air** and **gas mixture.**
- The recycling of flue gases to produce heat energy is know as regenerative system of heat economy.
- When the process is complete, the **coke is removed** and **quenched** with water.
- Time taken for complete carbonization is about 12 – 20 hours. The yield of coke is **about 70%.**

- The Valuable by products like tar, ammonia, H_2S and benzol can be recovered from coal gas.

Recovery of by – products:

1. **Tar**

   The Coal gases are passed through a tower in which liquor ammonia is sprayed. Tar and dust get dissolved and collected in a tank below, which is heated by steam to recover the ammonia sprayed.

2. **Ammonia**

   The gases are passed through another tower in which **water is sprayed.** Here **ammonia** gets converted to **NH_4OH.**

3. **Naphthalene**

   The gases are passed through a tower in which cooled water is sprayed. Here naphthalene gets condensed.

4. **Benzene**

   The gases are passed through a tower, where petroleum is sprayed. Here benzene gets condensed to liquid.

5. **H_2S**

   The remaining gases are passed through a purifier packed with moist Fe_2O_3. Here **H_2S** is retained.

 The Final gas left out is pure coal gas, which is used as a gaseous fuel.

Advantages:

1. Valuable by- products like ammonia, coal gas, a gaseous fuel.
2. The Carbonisation time is less.
3. Heating is done by producer gas.

4. What is Synthetic petrol? How is it manufactured by Bergius process?

Synthetic Petrol:

If Coal is heated with hydrogen to high temperature under high pressure, it is converted to **gasoline**. The preparation of liquid fuels from solid coal is called hydrogenation of coal (or) Synthetic petrol.

Bergius Process (or) Direct method

In this process the finely powdered coal is made into a paste with heavy oil and a catalyst powder (tin or nickel oleate) is mixed with it.

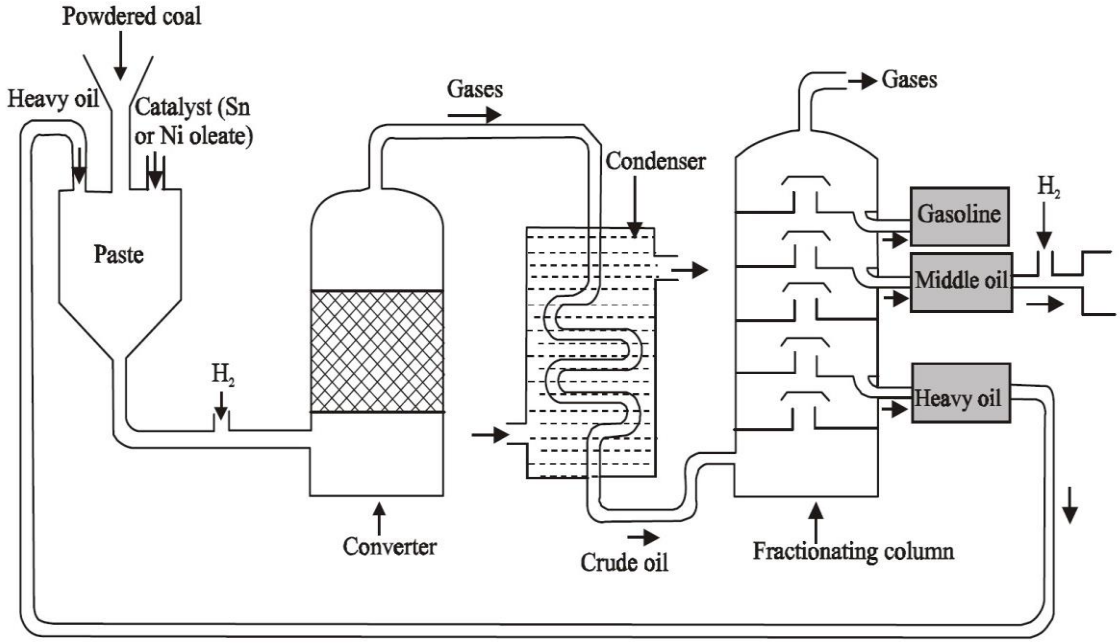
The paste is pumped along with hydrogen gas into the converter, where the paste is heated to 400-450º C under a pressure of **200-250 atm.**

During this process hydrogen combines with coal to form saturated higher hydrocarbons, which undergo further decomposition at higher temperature to yield mixture of lower hydrocarbons. The mixture is led to a condenser, where the crude oil is obtained.

The crude oil is fractional to yield

i) Gasoline ii) Middle oil iii) Heavy oil.

The middle oil is further hydrogenated in vapour phase to yield more gasoline. The heavy oil is recycled for making paste with fresh coal dust. The yield of gasoline is about 60 % of the coal used.



- The heavy oil is **recycled** for making **paste** with fresh **coal dust.** The Yield of gasoline is about **60%**

Combustion

5. With a neat diagram explain the analysis of flue gas by ORSAT METHOD. Flue gas:

The mixture of gases **(CO_2, O_2 and CO)** Coming out from the combustion chamber is called as flue gas.

The analysis of flue gases is carried out by using **ORSAT'S apparatus.** The analysis of flue gas would give an idea about the **complete** (or) **incomplete** combustion process.

Description:

- It Consist of a horizontal tube.
- At **one end** of horizontal tube is connected to U – tube containing fused $CaCl_2$ and also connected to **3-way stop cock.**

- The **other end** of horizontal tube is connected with a graduated burette.
- The burette is surrounded by a water-jacket to keep temperature of gas constant.
- The lower end of the burette is connected to a water reservoir by means of a rubber tube.
- The level of water in the burette can be **raised (or) lowered** by raising **(or)** lowering the reservoir.
- The horizontal tube is connected with three different **absorption bulbs 1, 2 and 3** for absorbing **CO_2, O_2 and CO.**

Working:

- The 3-way Stop-cock is opened to the atmosphere.
- The reservoir is raised till the burette is filled completely with water and air is excluded from the burette. The 3-Way stop-cock is connected to the flue gas supply.
- The flue gas is sucked into the burette and the volume of the flue gas is adjusted to **100 cc (or) 100 ml** by raising and lowering the reservoir.
- Then the 3-way stop-cock is closed.

a) Absorption of CO_2:

- The stopper of the absorption bulb-1 having KOH solution is opened.

→ All the flue gas is passed into this bulb-1 by raising the level of water in the burette.

- The gas enters into the bulb-1, where CO_2 present in the flue gas is absorbed by KOH.
- The gas is again sent to the burette. This process is repeated several times to ensure the complete absorption of CO_2.
- The decreases in Volume of the flue gas in the burette gives the volume of CO_2 in 100ml of the flue gas.

a) Absorption of O_2.:

→ Stop cock of bulb-1 is closed and stop cock bulb-2 is opened.

→ The gas is again sent into the absorption bulb-2 where O_2 present in the flue gas is absorbed by alkaline pyrogallol.

→ The decrease in the volume of the flue gas in the burette gives the volume of O_2.

c) Absorption of CO:

- Now stop cock bulb -2 is closed and stop cock of bulb-3 is opened.
- The remaining gas is sent into the absorption bulb-3.
- Here CO present in the flue gas is absorbed by **ammonical cuprous chloride.**
- The remaining gas in the burette after the absorption **CO_2, O_2 and CO** is taken as **nitrogen.**

Bulb	Reagent	Function
1	KOH solution	Absorbs only CO_2
2	Alkaline pyrogallol solution	Absorbs CO_2 and O_2
3	Ammonical cuprous chloride	Absorbs CO_2 O_2 and CO

Significance:

1. Idea about **complete (or) incomplete** combustion process.
2. Flue gas contain considerable **amount of CO,** it is indicates that **incomplete** combustion is occurring and it indicates that the short supply of O_2
3. Flue gas contain considerable **amount of O_2** it indicates that **complete combustion** is occurring and also it indicates that the **excess of O_2** is supplied.

Precautions:

1. Care must be taken in such a way that, the reagent in the absorption bulb, 1,2 and 3 should be brought to the etched marked level one by one by **raising** and **lowering** reservoir bottle.
2. All the air from the reservoir bottle is expelled to atmosphere by lifting the reservoir bottle.
3. It is essential that **CO_2, O_2 and CO** are absorbed in that order only.
4. As the **CO content** in the flue gas is **very small,** it should be measured quite carefully.