MODULE - IV

Energy Resources.

Fuels:

Definition: A fuel is a combustible substance which on proper burning produces a large amount of heat energy. The heat evolved during combustion can be used economically for industrial and other uses.

Introduction: Coal is used in locomotives and as reducing agent in blast furnance.

* Right type of fuel can be selected depending on various factors such as storage, availability, handling, pollution and landed cost of fuel.

Combustion: Combustion is the process of chemical reaction between fuel and oxygen.

Fuel + Oxidizer (Oxygen) → Product of Combustion + Energy

Heating Value :-

Heating value of a fuel is the amount of energy or heat released per unit mass during combustion of that fuel.

Classification Of fuels:

Classification of fuels based on two factors

(i) based on Occurence (natural or primary and artifical or secondary).

(ii) physical state of fuel (solid, liquid, gas) or state of aggregation. Nuclear fuels are nowadays

used for power generation. It includes $_{92}U_{235}$ and $_{94}Pu_{239}$.

Natural Fuels (Primary fuels)

Some fuels are found in nature and are used in the same form. These are called natural fuels, eg: wood, coal, natural gas and petroleum.

Artificial Fuels (Secondary fuels)

The fuels that are derived from natural fuels (primary) are called artificial or secondary fuels, eg: petrol, producer gas and charcoal.

Classification of fuels based on physical state:

Types Of fuels:

Fuels are of three main types they are

(i) Solid fuels :- Eg: wood, coal, charcoal etc

(ii) Liquid fuels :- Eg: Kerosene, petrol, diesel etc.

(iii) Gaseous fuels :- Eg: CNG, LPG, biogas, hydrogen etc.

Comparison Of solid, liquid and gaseous fuels advantages and disadvantages.

Solid	Liquid.	Gas.
1) Cheap and easily available	Costly and available only in a few countries and obtained from mines.	Most costly than solid fuels.
2) Low risk of fire hazards	More risky as they are highly inflammable.	High risk of fire hazards.

3) Slow combustion	Quick combustion	Very fast combustion due to uniform mix of air & fuel
4) Ash content is more	No ash content	No ash content
5) Causes more pollution.	Less pollution	Least pollution due to uniform mixing of air & fuel
6) Low calorific value & low thermal efficiency	Higher calorific value	Higher calorific value

Characteristic of a good fuel

A good fuel has the following features:

1) It should be cheap and easily available
2) It ~~must have~~ should be dry & should have less moisture. Dry fuel increases its Caloritic Value
3) It should be easily tranportable, otherwise cost of fuel will increase.
4) It must have high calorific culure.
5) It must leave less ash after ~~combustion~~ combustion. In case of more ash, the fuel gives less heat
6) The combustion speed of a good fuel should be moderate

Ranking Of Coal.

- During coalification of wood, the first stage of coal is Peat. It is ranked the lowest among coals. Other coals are lignite, bituminous and anthracite. It has been reported that

(1.)

Proximate Analysis:

- Proximate analysis gives information regarding the practical utility of coal.

Moisture: A known mass of finely powdered air-dried coal

Volatile matter: Dried sample of coal left in the crucible is covered with a lid and placed in a muffle furnace maintained at 950°C exactly for 7 mins. The crucible is then taken out, cooled in the air and then in desiccator and weighed. The loss in weight is reported as the percentage of Volatile matter.

% of Volatile matter = $\frac{\text{Loss in wight due to removal of volatile matter}}{\text{weight of coal taken}} \times 100$

Ash content: Coal, free from moisture and volatile matter, is heated in crucible at about 700°C in a muffle furnace in presence of air. It undergoes combustion and results in the formation of ash.

% of ash = $\frac{\text{Mass of ash} \times 100}{\text{Mass of coal.}}$

Carbon: Since the main component of coal is carbon, it can be determined by subtracting the sum of the percentage of moisture, Volatile substance and ash content from 100.

Carbon % = 100 − [% of moisture + % of Volatile matter + % of ash).

Significance Of Proximate analysis:

→ ~~Proximate analysis give~~

Moisture: A high moisture content in the fuel takes some heat liberated in the form of latent heat, reduces the calorific value, increases the cost of

transportation and causes waste of heat. Hence, the lesser the moisture content, the better is the quality of fuel. But moisture up to 10% produces a

Volatile matter: It is due to combustible and non-combustible gases. A coal containing high volatile matter burns with long flame, high smoke and low calorific value. Volatile matter also influences the design of the furnace since the higher the volatile matter, the larger is the combustion space required.

Ash:

* Ash reduces heating value of coal.
* Ash content increases the cost of transportation, handling, storage and disposal.
* It determinis the quality of coal. Hence, the lesser the % of ash, the better is the quality of coal

Fixed Carbon:

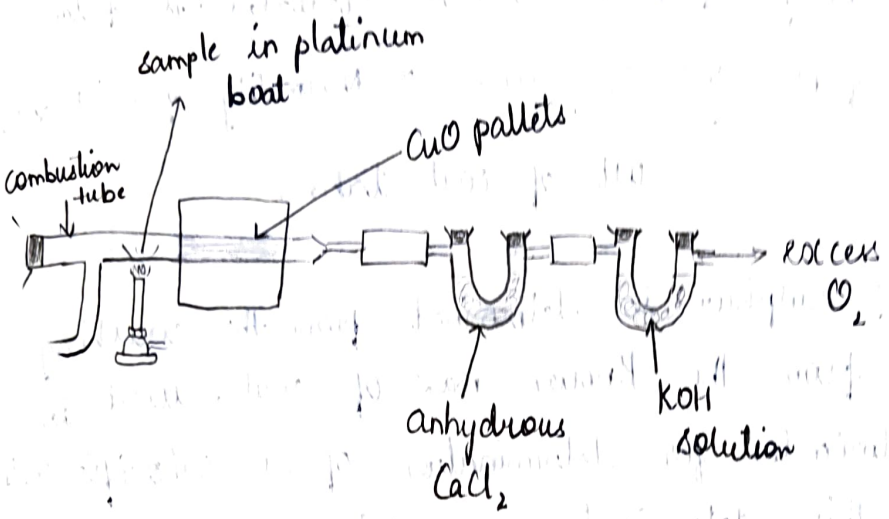
The higher the fixed carbon in a coal, the greater is its calorific value and better is the quality of coal. It helps in designing the furnace the shape of fire box. It increases from low ranking coals such as lignite to high ranking coals such as anthracite.

2) Ultimate Analysis:

It is the elemental analysis of coal. This analysis includes % of C, H, O, S, N and ash content in coal and better quality of CO. The two components can be determined in a single experiment.

i, Determination of Carbon & hydrogen

- About 0.2g of accurately weighed coal is burnt in oxygen in apparatus.
- KOH & $CaCl_2$ absorb CO_2 & H_2O respectively.
- Increase in weights of the tubes are noted.



$$C + O_2 \longrightarrow CO_2$$

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

$$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$$

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

% of carbon = $\frac{\text{increase in weight of KOH tube}}{\text{weight of coal}} \times \frac{12}{44} \times 100$

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

ii, Determination of Nitrogen:

Nitrogen: About 1 gram of accurately weighed powdered coal is heated with conc H_2SO_4 along with K_2SO_4 (catalyst) in a long-necked Kjeldahl's flask. After the soln becomes clear, it is treated

with excess of KOH. The liberated ammonia is distilled over & absorbed in a known volume of standard acid soln. The unused acid is then determined by back titration with standard NaOH soln. From the volume of acid by ammonia liberated the percentage of N in coal is calculated as follows

$$\% \text{ of } N = \frac{\text{Vol of acidic} \times \text{Normality of acid} \times 1.4}{\text{wt of coal taken.}}$$

iii) Sulphur: Sulphur is determined from the washings obtained from the known mass of coal, used in bomb calorimeter for determination of a calorific value. During this determination, sulphur is converted into sulphate. The washings are treated with Barium Chloride soln, when Barium sulphate is precipitated. This precipitate is filtered, washed and heated to const weight.

$$\% \text{ of sulphur} = \frac{\text{weight of } BaSO_4 \text{ obtained} \times 32 \times 100}{\text{wt of coal sample taken in bomb} \times 233}$$

iv) Ash: The residual coal taken in the crucible and then heated without lid in a muffle furnace at $700 \pm 50^\circ C$ for half-an-hour. The crucible is then taken out, cooled first in air, then in desiccators and weighed. Heating, cooling and weighing are repeated, till a const weight is obtained. The residue is repeated as ash on % basis

Thus,

$$\% \text{ of ash} = \frac{\text{wt of ash left} \times 100}{\text{wt of coal taken.}}$$

(v) Oxygen: It is determined indirectly by deducting the combined percentage of carbon, hydrogen, nitrogen, sulphur, & ash from 100.

$$\% \text{ of Oxygen} = 100 - \% \text{ of } (C + H + S + N + Ash)$$

Significance Of Ultimate analysis:

Carbon and Hydrogen: Greater the % of carbon & hydrogen better is the coal in quality and calorific value. However, hydrogen is mostly associated with the volatile matter & hence, it affects the use to which the coal is put.

Nitrogen: Nitrogen has no calorific value & hence, its presence in coal is undesirable. Thus, a good quality coal should have very little Nitrogen content.

Sulphur: Sulphur, although contributes to the heating value of coal, yet on combustion produces acids like SO_2, SO_3, which have harmful effects of corroding the equipments and also cause atmospheric pollution. Sulphur is, usually, present to the extent of 0.5% to 0.3% and derived from ores like iron, pyrites, gypsum, etc.. mines along with the coal. Presence of sulphur is highly undesirable in coal to be used for making coke for iron industry. Since it is transferred to the iron metal and badly affects the quality & properties of steel. Moreover, Oxides of

sulphur pollutes the atmosphere it leads to corrosion.

Ash: Ash is a useless, non combustible matter which reduces the calorific value of coal. Moreover, ash causes the hindrance to the flow of air & heat, thereby lowering the temp. Hence, lower the ash content, better the quality of coal.

Oxygen: Oxygen content decreases the calorific value of coal. High oxygen content coals are characterized by high inherent moisture, low calorific value, & low coking power. Moreover, Oxygen is combined form with hydrogen in coal and thus, hydrogen available for combustion is lesser than actual one. An increase in % oxygen content decreases the calorific value by about 1.7% and hence, oxygen is undesirable. Thus a good quality coal should have low % of oxygen.

Liquid fuels: [Petroleum]

Introduction:

* petroleum is one of the best primary liquid fuel. It is also known as crude oil. petrol, diesel, kerosene are main liquid fuels. They are secondary liquid fuels derived from Petroleum. These fuels are used for domestic works, auto vehicles & power generation.
* The word meaning of petroleum of is 'rock oil' (petra = rock, oleum = oil).

* Petroleum is dark-brown viscous liquid.

Petroleum is a mineral found deep in earth's crust. It is a mixture of number of hydrocarbons (paraffins, olefins, aromatics & naphthalene) nitrogen, sulphur, oxygen containing optically active compounds along with traces of compounds of heavy metals such as Fe, Co, Ni & V. The unpleasant odour of petroleum is due to the presence of some foul smelling sulphur compounds.

Origin of petroleum

Carbide theory:

This theory Metals inside the earth react with carbon & form metal carbides. These carbides are converted into hydrocarbons in the presence of moisture or steam which on further hydrogeneration polymerize to give a complex mixture of paraffins, olefins, & aromatic hydrocarbons.

Engler's theory or Organic theory:

According to this theory, organic matters, animals, vegetation and marine animals died and accumulated in sea. There, they were decomposed under high temperature & pressure by anaerobic bacteria to give a dark viscous liquid called Petroleum.

Refining Of Petroleum:

Refining can be defined as the process by which petroleum is made free of impurities, division of petroleum into different fractions having diff boiling points & their further treatment to impart specific properties.

Refining of petroleum is done in diff stages:

1) Removal of Solid Impurities: (Gravitational force).

The crude oil is a mixture of solid, liquid & gaseous substances. This is allowed to stand undisturbed for some time, when the heavy solid particles settle down and gases evaporate. The supernant liquid is then centrifuged where in the solids get removed.

2) Removal Of Water (Cottrell's process):

The crude oil emulsion of oil obtained from the earth's crust is in the form of stable & brine. This mixture when passed b/w two highly charged electrodes will destroy the emulsion films & the colloidal water droplets coal escape into bigger drops & get separated out from the oil.

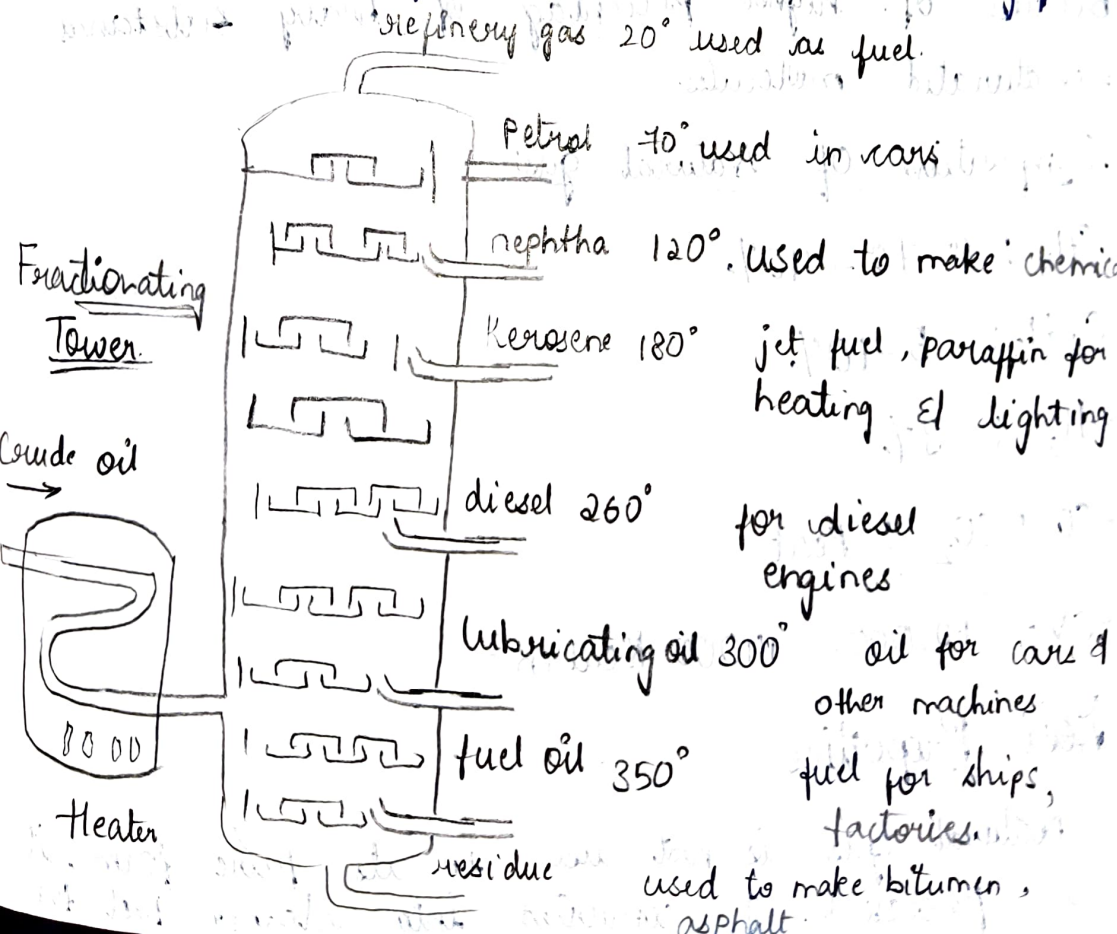
3) Removal Of harmful impurities:

In order to remove sulphur compounds in the crude oil. It is treated with copper oxide

The sulphur compounds get converted to insoluble copper sulphide, which can be removed by filtration. Substances like NaCl and $MgCl_2$ if present will corrode the refining equipment and result in scale formation. These can be removed by techniques like electrical desalting and dehydration.

4) Fractional distillation:

Heating of crude oil around 400°c in an iron retort ~~to~~ produces hot vapor which is allowed to pass through fractionating column. It is a tall cylindrical tower containing a number of horizontal stainless trays at short distances and is provided with small chimney covered with loose cap. As the vapors go up they get cooled gradually & fractional condensation takes place. Higher boiling fraction condenses first later the lower boiling fraction



Gaseous Fuels:

Introduction:

Natural gas is the primary gaseous fuel. A variety of secondary fuels are obtained from coal or petroleum.

1) Natural Gas: [Ex: methane gas]

Natural gas is primarily methane gas. It is a fossil fuel. It is formed in coal beds (coal bed methane). Other sources are town gas and biogas.

* Natural gas formed with petroleum & diesel is called wet gas and that formed with crude ore is called dry gas. The calorific value of wet gas is higher than the of dry gas because of higher percentage of heavy ~~substance~~ unsaturated molecules.

Composition Of Natural gas:

→ CH_4 : @ 70 - 90%.

→ C_2H_6 : 5-10%.

→ H_2 : 3%.

→ $CO + CO_2$: Reset

↑ (calorific value)

→ CV = 12,000 - 14000 Kcal m^{-3}

~~Post~~ Properties:

Natural gas is not use in its pure form. it is processed & converted into cleaner fuel for

consumption. Many by products are extracted by while processing of natural gas like propane, ethane, butane, carbon dioxide, nitrogen etc, which can be further used.

Applications Of natural Gas:

* It is used as a very good domestic fuel.
* It is used in the preparation of ammonia (used for urea manufacturing).
* It is used to prepare carbon-black which is used as fillers for rubber industry.

2) LPG [Liquified petroleum gas]: [ex: butane]

Now a days LPG has been a common fuel for domestic work & also in most of the industries.

* The main components of LPG or cooking gas are n-butane, isobutane, butylene, and propane (traces of propene and ethane).
* The hydrocarbon are in gaseous state at room temp & at atmospheric pressure but can be liquified under higher pressure. The gas can be compressed under pressure in containers and sold under trade names like Indane, Bharat petroleum gas, Hp gas etc.
* LPG has special odour due to the presence of organic sulphides which are added specially for safety measure.

Characteristics Properties of LPG:

→ It has high calorific value : 27800 Kcal/m³
→ It gives less CO and least unburnt hydrocarbons. So it causes least pollution.
→ It has the tendency to mix with air easily.
→ Its burning gives no toxic gases though it is highly toxic.
→ It is dangerous when leakage is there. It is highly knock resistant.
→ LPG can be extracted from natural gases and also from refining of crude oil. Cryogenic process is best for the extraction of natural gas.

Advantages Of LPG:

→ LPG is used as domestic fuel and as a fuel for internal combustion engines.
→ It is used as feedstock for the manufacture of various chemicals and olefins by pyrolysis.

Applications of LPG:

LPG is used in industries as portable blow lamps, welding, annealing, hardening, steel cutting etc.

Disadvantages Of LPG:

→ It is difficult to handle as fuel.
→ Engines working at low compression ratio cannot use LPG as fuel.

CNG [compressed natural gas]

Natural gas contains mainly CH_4. When natural gas is compressed at high pressure (1000 atm) or cooled to -160°C it is converted into CNG.

→ It is stored in cylinder made to steel. It is now replacing gasoline as it realises less pollution during its combustion.

→ In some of the metro cities, CNG vehicles are used to reduce pollution.

→ LNG is different from CNG. LNG is costlier than CNG.

Advantages Of CNG:

→ Green fuel commonly refered to as the green fuel because of its lead and sulphure free character, CNG reduces harmful emissions.

→ High auto ignition temp.

→ Low operational cost.

→ Dual facility.

Disadvantages:

→ Higher purchasing cost.

→ Limited availability.

→ Reduced storage space

→ lowered performance

→ Engine injector issues

→ Lesser fuel range.

Calorific Value:

Calorific value is defined as the "amount of heat produced by the combustion of unit mass or unit volume of a fuel."

→ It is characteristic of every substance and is imp for thermodynamic design and calculation of combustion system.

→ The calorific value is measured in several units of heat, they are calorie, kilocalorie, British thermal unit & Centigrate thermal unit.

Types of Calorific Value.

High Calorific Value (HCV) or gross calorific value (GCV)

It is defined as the amount of heat energy produced by the combustion of unit mass (unit volume) of a fuel when the combustion products are allowed to cool at the room temp.

Lower Calorific Value (LCV) or Net calorific value (NCV)

It is defined as the amount of heat energy produced by the combustion of unit mass of fuel when the combustion products are allowed to escape out into the atmosphere. LCV does not include the latent heat of steam or water vapour formed.

Formula

Dulong - Petit Formula.

→ $HCV = \frac{1}{100}[8080C + 34500(H - O/8) + 2240S]$ K cal/kg.

→ $LCV = [HCV - (9/100)H \times 587]$ K cal/kg.

$[HCV - \left[\frac{9 \times H}{100}\right] \times 587]$ K cal/kg.

Problems:

1) Calculate the gross and net calorific values of a coal sample having the following composition carbon = 85%, Hydrogen = 6%, Oxygen = 2%, Sulphur = 3% Nitrogen = 1% & Ash = 3%

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

$= \frac{1}{100}[8080 \times 85 + 34500\left(\frac{6-2}{8}\right) + 2240 \times 3]$ cal/gm

$= \frac{1}{100}[6,86,800 + 198375 + 6720]$ cal/gm.

$= \frac{1}{100}(891895)$ cal/gm.

$HCV = 8,918.95$ cal/gm.

$LCV = HCV - \left(\frac{9 \times H}{100}\right) \times 587$

$= 8,918.95 - \left(\frac{9 \times 6}{100}\right) \times 587$

$= 8,918.95 - 316.98$

$= 8,601.97$ cal/gm.

2) A sample of coal contains carbon = 60%, Hydrogen = 6%, Oxygen = 33%, Sulphur = 0.5%, Nitrogen = 0.2% and Ash = 0.3%, Calculate the HCV and NCV calorific values of the fuel.

$$HCV = \frac{1}{100}\left[8080 \times 60 + 34500\left(\frac{6 - 33}{8}\right) + 2240 \times 0.5\right] \text{ cal/gm}$$

$$= \frac{1}{100}[4,84,800 + 64687.5 + 1120] \text{ cal/gm}$$

$$= \frac{1}{100}[5,50,607.5] \text{ cal/gm}$$

$$= 5,506.07 \text{ cal/gm}$$

$$LCV = HCV - \left(\frac{9 \times H}{100}\right) \times 587$$

$$= 5506.075 - \left(\frac{9 \times 6}{100}\right) \times 587$$

$$= 5506.075 - 316.98$$

$$= 5189.095 \text{ cal/gm.}$$

3) Calculate the gross and net calorific values of a coal sample having the following composition Carbon = 80%, Hydrogen = 7%, Oxygen = 3%, Sulphur = 3.5% Nitrogen = 2%, Ash = 5%.

$$\text{Gross} = \frac{1}{100}\left[8080 \times 80 + 34500\left(\frac{7 - 3}{8}\right) + 2240 \times 3.5\right] \text{ cal/gm}$$

$$= \frac{1}{100}[646400 + 17250 + 7840] \text{ cal/gm}$$

$$= \frac{1}{100}[671490] \text{ cal/gm.}$$

$$= 6714.9 \text{ cal/gm.}$$

net C.V = $6714.9 - \left(\frac{9 \times 7}{100}\right) \times 587$

= 6345.09 cal/gm //

4) A sample of coal contains the following composition carbon = 84%, Hydrogen = 12%, Oxygen = 2%, S = 1%, and the remainder being ash. Calculate the gross and net calorific values of fuel

Gross = $\frac{1}{100}\left[8080 \times 84 + 34500\left(\frac{12-2}{8}\right) + 2240 \times 1\right]$ cal/gm

= $\frac{1}{100}\left[678720 + 43125 + 2240\right]$ cal/gm

= $\frac{724085}{100}$ = 7240.85 cal/gm

Net C.V = $7240.85 - \left(\frac{9 \times 12}{100}\right) \times 587$

= 7240.85 − 633.96

= 6606.89 cal/gm //

Problems on analysis

5) A coal and hydrogen sample weighing 1.98 gm, on heating at 110°C for one hour left a residue of 1.78 gms. The residue was heated in a suitable crucible with a lid at 950°C for exactly 7 min. at and the residue weighed 1.59 gms. The residue was heated in presence of air till a constant weight was obtained. The residue weighed 0.231 gms. Calculate Proximate analysis of coal

Weight of coal sample (W_1) = 1.98 gm

Wt of coal after heating (W_2) = 1.78 gm

$$\% \text{ of Moisture} = \frac{W_1 - W_2}{W_1} \times 100$$

$$= \frac{1.98 - 1.78}{1.98} \times 100$$

$$= 10.1\%$$

Weight of coal (W_3) = 1.59 gm

$$\% \text{ VM} = \frac{W_2 - W_3}{W_1} \times 100$$

$$= \frac{1.78 - 1.59}{1.98} \times 100$$

$$= 9.6\%$$

Weight of coal sample (W_4) = 0.231 gm

$$\% \text{ Ash} = \frac{W_4}{W_1} \times 100 = \frac{0.231}{1.98} \times 100$$

$$= 11.6\%$$

$$\% \text{ FC} = 100 - (\% \text{ Moisture} + \% \text{ VM} + \% \text{ Ash})$$

$$= 100 - (10.1 + 9.6 + 11.6)$$

$$= 68.7\%$$

Alternative energy Resources:-

This means that energy produced from alternative sources does not contribute to greenhouse effect that causes climate change. These energy sources are reffered to as "alternative" bcoz they represent the alternative to coal, oil & natural gas

which have been the most common sources of energy since the Industrial revolution.

Solar Energy.

→ Solar energy is the technology used to harness the sun's energy and make it useable.

→ Many people are familiar with so-called photovoltaic (PV) cells, or solar panels, found on things like spacecraft, rooftops, handheld, calculators etc...

→ When sunlight hits the cells, it knocks electrons loose from their atoms (Einstein's photoelectric effect). As the electrons flow through the cell, they generate electricity.

→ On a much larger scale, solar thermal power plants employ various employ various techniques to concentrate the sun's energy as a heat source (solar heat collectors).

Advantages:

→ Solar energy is lauded as an unexhaustable fuel source that is pollution and often noise free.

→ Renewable and eco friendly energy source.

→ Available for free of cost

Disadvantaages:

→ Solar energy doesn't work at night without a storage device such as battery.

→ Cloudy weather can make the technology unreliable during the day

→ Solar technologies are also very expensive

→ Skilled manpower required for unskallation.

2) Wind energy.

→ Wind energy is a source of renewable power which comes from our current flowing across the earth's surface.

→ Wind turbines harvest this kinetic energy and convert it into renewable power which can provide electricity for domestic, industrial and agriculture sectors.

Advantages:

→ The electricity produced from wind power is said to be eco-friendly because the generation produces no pollution or greenhouse gases.

→ It is good for health and environmental sage.

→ Available for free of cost.

→ Wind is a renewable energy resource, it is inexhaustible.

Disadvantages:

→ Generates noise pollution.

→ The amount of electricity generated depends on the strength of the wind. If there is no wind there is no electricity.

→ Wind mill kills birds

→ Tornados, hurricanes & cyclones cause heavy damage

Hydropower Energy.

Due to the solar heat, water evaporates or water is lost to the atmosphere as vapour from the seas/oceans which is then precipitated back in the form of rain, snow, frost etc the evaporation

and ppt continues forever, and thereby a balance is maintained b/w the two. This process is known as Hydrologic cycle.

→ Evaporation, condensation and precipitation are the main processes involved in water cycle.

→ Solar radiation and earths gravitational pull are the main during forces of water cycle.

1) Ground water
2) surface water
3) Rain water

Uses

Two major types of uses of water are consumption use

→ In consumptive use of water, it is fully utilized and it is not reused.

Ex: Domestic, industrial and irrigation purpose.

Non consumptive use.

In this use of water, it is not fully utilized and it is reused

Ex: Hydropower application.

Advantages.

1) Available free of cost
2) Renewable energy resource
3) Eco friendly

Disadvantages

1) floods
2) Constructing dams would leads to an environmental degradation.
3) Constructing dam results in displacement of several villages, communities, loss of agriculture land.