Page No.			
Date			

Numericals

1] A coal sample has following composition,

$C = 70\%$ $H = 5\%$ $O = 23\%$ $S = 1.50\%$

$N = 0.40\%$ $Ash = 0.10\%$

Calculat GCU & LCU ~~of~~ fuel.

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

$$= \frac{1}{100}\left[8080(70) + 34500\left(5 - \frac{23}{8}\right) + 2240 \times (1.50)\right]$$

$$GCV = \frac{642272.5}{100}$$

$$\therefore GCV = \underline{\underline{6422.725}} \text{ kcal/kg}$$

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

$$= 6422.725 - \left(\frac{9 \times 5}{100} \times 587\right)$$

~~LCV = 6187.925 kcal/kg~~

$LCV = 6158.575$ kcal/kg

Ans :- GCU :- 6422.725 kcal/kg

~~LCV = 6187.925 kcal/kg~~

LCU = 6158.575 kcal/kg

Teacher's Sign.:

Page No.
Date

2] A solid fuel containing 90% carbon, 8% hydrogen, 1.5% sulphur, 2% nitrogen, 5% oxygen & remaining ash. Calculate high & low calorific value of solid fuel.

→ $C = 90\%$ $H = 8\%$ $S = 1.5\%$ $N = 2\%$

$O = 5\%$

Gross/High calorific Value (GCV) $= \frac{1}{100}\left[8080C + 34500\left(H - \frac{O}{8}\right) + 2240S\right]$

$= \frac{1}{100}\left[8080 \times 90 + 34500\left(8 - \frac{5}{8}\right) + 2240(1.5)\right]$

$= \frac{984997.5}{100}$

GCV $=$ $\underline{\underline{9849.975}}$ kcal/kg.

Low calorific value (LCV) $=$ GCV $- \left(\frac{9H}{100} \times 587\right)$

$= 9849.975 - 0.09 \times 8 \times 587$

LCV $=$ 9427.335 kcal/kg.

Ans :- high calorific value $=$ 9849.975 kcal/kg.
low calorific value $=$ 9427.335 kcal/kg.

Teacher's Sign.:

Page No.
Date

3] 1 g of air dried sample of coal on heating at 110°C for 1 hour produced a residue 0.850 g & this residue on heating at 950°C for 7 minutes in absence of air left 0.72 g mass which on combustion left 0.1 g of non-combustible matter. Calculate the result of proximate analysis.

→

i] weight of coal taken = 1 g
ii] weight of coal after heating at 110°C = 0.850 g
iii] weight of coal after heating at 950°C = 0.72 g

∴ 1] Moisture % $= \frac{1 - 0.850}{1} \times 100$

$= 0.150 \times 100$

Moisture % = 15 %

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

$= \frac{0.850 - 0.72}{1} \times 100$.

Volatile matter % = 13 %.

3]. Ash % $= \frac{0.1}{1} \times 100$

∴ Ash % = 10 %.

4] Fixed carbon % = 100 − [Moisture % + Volatile matter % + Ash %]
= 100 − (15 + 13 + 10].
(%). Fixed carbon = 62 %

Teacher's Sign.:

Page No.
Date

4] A sample was analyzed for content of moisture, volatile matter & ash. Use the data & calculate the % of above quantities

i] weight of coal = 2.5 g
ii] weight of coal after heating at 110°C = 2.368 g
iii] weight of coal after heating covered crucible at 950°C = 1.75g
iv] const. weight obtained at the end of experiment = 0.95 g.

$\therefore$ Moisture % $= \dfrac{\text{loss in weight}}{\text{weight of coal sample}} \times 100$

$= \dfrac{2.5 - 2.368}{2.5} \times 100$

$= 0.0528 \times 100$

$= 5.28\%$.

Volatile matter % $= \dfrac{\text{loss in weight due to volatile matter}}{\text{weight of coal}} \times 100$

$= \dfrac{2.368 - 1.75}{2.5} \times 100$

$= 24.72\%$.

Ash % $= \dfrac{0.95}{2.5} \times 100$

$= 38\%$.

$\therefore$ Ans:- i] Moisture (%) in coal = 5.28 %
ii] % Volatile matter in coal = 24.72 %
iii] Ash (%) in coal = 38 %.

Teacher's Sign.: ________

Page No.
Date

Q6] The analysis of coal found to ~~obtain~~ contain following constituents $C = 81\%$, $H = 6\%$, $O = 7\%$, $N = 1\%$. Calculate the weight of air required for combustion of 1 kg of air.

→

Components	% composition	weight of component per kg
C	81	0.81
H	6	0.06
N	1	0.01
O	7	0.07

Nitrogen do not participate in combustion.

$$\text{weight of air required} = \frac{100}{23}\left[2.67\,C + 8H + S - O\right] \text{kg.}$$

$$= \frac{100}{23}\left[2.67 \times 0.81 + 8\,(0.06) + 0 - 0.07\right]$$

weight of air required $= \underline{\underline{11.1856}}$ kg

Teacher's Sign.: ____________

Page No.
Date

Q7] Calculate the volume of air required for combustion of $1m^3$ of gaseous fuel which has following composition $CH_4 = 34\%$, $C_2H_4 = 4\%$, $CO = 10\%$, $H_2 = 45\%$ $N = 2\%$, water vapour $= 4\%$.

→ Volume of fuel $= 1 m^3$.
Volume of $CH_4 = 0.34 m^3$
Volume of $C_2H_4 = 0.04 m^3$.
Volume of water vapour $= 0.04 m^3$

Volume of $CO = 0.1 m^3$.
Volume of $H_2 = 0.45 m^3$.
Volume of $N = 0.02 m^3$

Reactions.	Volume of O_2 required
1] $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	$0.34 \times 2 = 0.68 m^3$
2] $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$	$0.04 \times 3 = 0.12 m^3$.
3] $2CO + O_2 \rightarrow 2CO_2$	$0.5 \times 0.1 = 0.05 m^3$.
4] Nitrogen (No reaction)	—
5) Water vapour (no reaction)	—
6] $2H_2 + O_2 \rightarrow 2H_2O$	$0.5 \times 0.45 = 0.225 m^3$.

∴ Total O_2 required $= 0.68 + 0.12 + 0.05 + 0.225$
Total O_2 required $= 1.075 m^3$.

∴ Volume of air $= \text{Volume of } O_2 \times \frac{100}{21}$

$= 1.075 \times \frac{100}{21}$

Volume of air. $= 5.119 m^3$ of air

Teacher's Sign.:

Page No.
Date

Q8] A gaseous fuel has following composition by volume $H_2 = 40\%$ $CH_4 = 30\%$ $C_3H_8 = 12\%$, $CO = 10\%$, $CO_2 = 3\%$, $N_2 = 3\%$ $O_2 = 2\%$. Calculate the volume & weight ~~of~~ required for combustion of $1 m^3$ of fuel.

→

Volume of fuel = $1 m^3$.
Volume of H_2 = $0.4 m^3$
Volume of CH_4 = $0.3 m^3$.
Volume of C_3H_8 = $0.12 m^3$

Volume of CO = $0.1 m^3$.
Volume of CO_2 = $0.03 m^3$.
Volume of N_2 = $0.03 m^3$.
Volume of O_2 = $0.02 m^3$.

Reactions.	Volume of O_2 required
1] $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	$2 \times 0.3 = 0.6 m^3$
2] $2H_2 + O_2 \rightarrow 2H_2O$	$\frac{1}{2} \times 0.4 = 0.2 m^3$.
3] $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$	$5 \times 0.12 = 0.6 m^3$.
4] $2CO + O_2 \rightarrow 2CO_2$.	$0.1 \times \frac{1}{2} = 0.05 m^3$.
5] O_2 in sample	$0.02 m^3$.

∴ Total O_2 required Volume $= [0.6 + 0.2 + 0.6 + 0.05] - 0.02$
$= \underline{\underline{1.43 m^3}}$.

∴ Volume of air required $= 1.43 \times \frac{100}{21} = \underline{\underline{6.809 m^3}}$

For weight of air,
$22.4 m^3$ requires 28.94 kg air
$6.809 m^3$ requires ?

Teacher's Sign.: ______

Page No.
Date

$\therefore$ weight of air (required) $= \left(\frac{28.94 \times 6.809}{22.4}\right)$ kg.

$= \underline{8.797}$ kg

Ans:- Volume of air required $= 6.809\ m^3$.
Weight of air required $= 8.797$ kg.

Q9] 1.5 gm of coal sample was Kjeldahlised & the ammonia evolved was absorbed in 50 ml of N/10 H_2SO_4. After absorbtion the excess H_2SO_4 required 35 ml of 0.1 N NaOH for netralization. 0.5 gm of the same coal sample was burnt in a bomb calorimeter & on treatment with $BaCl_2$ produced 0.08 gm of $BaSO_4$ precipitate. Calculate the percentage of nitrogen & sulphur in the given coal sample.

→

$$\%\ \text{Nitrogen} = \frac{1.4 \times (\text{volume of acid consumed}) \times \text{Normality}}{\text{weight of coal sample}}$$

$$\%\ N = \frac{1.4 \times (50-35) \times 0.1}{1.5}$$

$$\boxed{\%N = 1.4\ \%}$$

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

$$= \frac{32}{233} \times \frac{0.08}{0.5} \times 100$$

$$\boxed{\%S = 2.197\ \%}$$

Ans:- % of nitrogen = 1.4%
% of sulphur = 2.197%.

Teacher's Sign.: ____________

Page No.
Date

Q10] 2.2 gm of coal was heated in Kjeldahl's flask & ammonia gas evolved was absorbed in 45 ml of N/5 H_2SO_4. The excess acid required 35 ml of N/5 KOH for neutralization. Calculate % of nitrogen in coal sample.

→

$$\% N = \frac{1.4 \times \text{Volume of acid consumed} \times \text{Normality}}{\text{Weight of coal sample}}$$

$$= \frac{1.4 \times (45-35) \times 0.2}{2.2}$$

$$\% N = \frac{1.4 \times 10 \times 0.2}{2.2}$$

$$\% N = \frac{14 \times 2}{22}$$

$$\% N = 1.27\%$$

Ans:- 1.27 % of Nitrogen is present in 2.2 g of coal sample.

Q11] 2 gm of coal sample was taken for nitrogen estimated by Kjeldahl's method. The ammonial librated required 10 ml of 0.5 N H_2SO_4 for neutralization. Calculate % of nitrogen in coal sample.

→

$$\% N = \frac{1.4 \times \text{Volume of acid consumed} \times \text{Normality}}{\text{weight of coal sample}}$$

$$= \frac{1.4 \times 10 \times 0.5}{2}$$

$$\% N = 3.5$$

Ans :- 3.5 % of nitrogen is present in coal sample.

Teacher's Sign.:

Page No.
Date

Q12] 2 gm of coal sample was burnt in combustion tube & products of combustion were absorbed in previously weighted KOH bulb & $CaCl_2$ tube. The increase in weight of KOH bulb & $CaCl_2$ tube were found to be 3.5 gm & 1.5 gm respectively. Calculate % of carbon & hydrogen in the coal sample.

→ By formula,

$$\%C = \frac{\text{weight increase in KOH bulb}}{\text{weight of coal sample}} \times \frac{12}{44} \times 100$$

$$\%C = \frac{3.5}{2} \times \frac{12}{44} \times 100$$

$$\therefore \boxed{\%C = 47.27\,\%}$$
$$\boxed{\%C = 47.72\,\%}$$

$$\%H = \frac{\text{weight increase in } CaCl_2 \text{ tube}}{\text{weight of coal sample}} \times \frac{4}{36} \times 100$$

$$= \frac{1.5}{2} \times \frac{4}{36} \times 100$$

$$\boxed{\%H = 8.33\,\%}$$

Ans :- Carbon (%) in coal sample is 47.72 %.
Hydrogen (%) in coal sample is 8.33 %.

Teacher's Sign.:

Page No.
Date

Q13] 1.5 gm of coal sample was taken for estimation by combustion method. The increase in weight of KOH bulb & $CaCl_2$ tube was found to be 2.5 gm & 5.0 gm respectively. Calculate % of C & H.

→

By formula,

$$\% C = \frac{\text{weight increase in KOH bulb}}{\text{weight of coal sample}} \times \frac{12}{44} \times 100$$

$$\therefore \% C = \frac{2.5}{1.5} \times \frac{12}{44} \times 100$$

$$\therefore \boxed{\% C = 45.45 \%}$$

$$\% H = \frac{\text{weight increase in } CaCl_2 \text{ tube}}{\text{weight of coal sample}} \times \frac{4}{36} \times 100$$

$$= \frac{5}{1.5} \times \frac{4}{36} \times 100$$

$$\therefore \boxed{\% H = 37.037 \%}$$

Ans :- % of carbon in coal sample = 45.45 %.
% of hydrogen in coal sample = 37.037 %.

Teacher's Sign.: ____________

Page No.
Date

Q14] 1 gm of coal sample was burnt in bomb calorimeter produced 0.1 gm of $BaSO_4$. Calculate % of sulphur in Coal sample.

→

By formula,

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

$$\therefore \% S = \frac{32}{233} \times \frac{0.1}{1} \times 100$$

$$\therefore \boxed{\% S = 1.373 \%}$$

Ans :- % of sulphur in coal sample is 1.373 %

* Theory Questions *

Q1] What do you mean by unleaded petrol & Write the advantages of unleaded petrol.

→

Unleaded petrol is practically the zero lead quantity gasoline supplied for motor fuels.

1] In car exhaust, if catalytic converter is connected, leaded petrol cannot be used, because lead destroys the active sites of catalyst.

2] Two types of catalyst are used in catalytic converter.
 i] Reduction catalyst.
 ii] Oxidation catalyst.

Teacher's Sign.: ______

Page No.
Date

3. Catalyst helps to reduce emisssion of harmful gases by following reactions.
4. Reduction catalyst contains Pt or Rh, which can reduce NO_x as,

$$2NO_x \longrightarrow N_2 + xO_2.$$

5. Oxidation catalyst helps treating unburnt hydrocarbon oxidation catalyst unburnt hydrocarbons & carbon monoxide due to presence of Pd or Pt.

$$xCO + \frac{x}{2}O_2 \longrightarrow xCO_2.$$

$$xHC + xO_2 \longrightarrow \frac{x}{2}H_2O + \frac{x}{2}CO_2.$$

6. Engine is connected withe computerised oxygen sensors & signals are indicated to adjust the requirement of oxygen which is adjusted.

* Advantages of Unleaded petrol.

1] It is fuel without lead which is a heavy metal & very harmful.

2] The use of ULP helps is controlling knocking in engines as it supports the use catalytic converters attached to exhaust in automobiles.

3] Octane rating can be further improved by adding small amount of MTBE which supports combustion also.

4] ULP also allows use of catalysts like Rhodium which converts exhaust gases like CO & NO to CO_2 & N_2 Rhodium also converts unburnt hydrocarbons to CO_2 & H_2O.

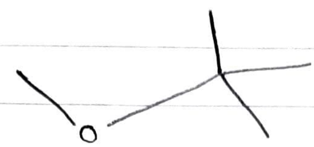
Teacher's Sign.:

2] What is MTBE. why is it preferably used? State its advantages & disadvantages.

→

A] MTBE is methyl tertiary butyl ether.

B ~~uses of~~ MATB



B] Uses of MTBE is prefered because,

1] It can be produced by simple reaction of iso-butelene & methanol.

2]. It helps to avoid disadvantages of methanol, rather provides alternative with safty & efficiency.

3] Industry does not depend on corn crop for production of MTBE.

C] Advantages :-

1] It contains "oxygen" in the form of ether group. It has low photochemical reaction with hydroxyl radical.

2] This oxygen in MTBE supports combustion of petrol in I.C. engine.

3] Due to presence of oxygen, formation of "peroxy" compound is reduced & thus "octane" rating" is enhanced.

4] Protection of environment is achieved.

D] Disadvantages :-

1] MTBE needs to be blended with gasoline at refinary. ~~(cannot~~

2] MTBE is poisonous, hence may contaminate ground waters if gasoline leaks.

Page No.
Date

3] Significance of proximate analysis & ultimate analysis
→

A] Significance of proximate analysis :-
1] Moisture :-
i] It decreases calorific value of coal largely as it does not burn & takes away heat in the form of latent heat.
ii] It increases ignition point of coal.
Hence, coal with lower moisture % is of better quality.

2] Volatile matter :-
i] It decreases the calorific value of coal.
ii] It elogates flame & decreases flame temprature.
iii]. It forms smoke & pollutes air.
iv]. Coal containing 15-25% of Volatile matter on carbonisation gives coke oven gas which is the source of various organic aromatic chemicals.
v] Such coals have good caking property & coke can be obtained from the coals.
vi] The coal with lesser V.M is better quality coal.

3] Ash :-
i] Ash reduces calorific value of coal as ash is non-burning part in coal.
ii] Ash disposal is a problem.
iii] Ash fuses to form clinker at high temprature, obstructing the air supply to coal burning in furnace
Hence, lesser the ash % better is quality of coal.

3] Fixed Carbon :- i] Carbon is the burning part of coal. Therefore, higher the FC % higher is calorific value.

Teacher's Sign.:

Page No.
Date

B] Significance of Ultimate analysis :-

1] Carbon % :- Greater the % of carbon in coal, better is the coal quality & higher calorific value.

2] Hydrogen % :- most of the hydrogen in the coal is in the form of moisture & volatile matter. Only a small percentage of hydrogen is combustible. It decreases calorific value of coal. Smaller the H % better is coal quality.

3] Nitrogen % :- Nitrogen does not burn during coal combustion therefore it has no calorific value. % nitrogen should be negligible in coal.

4] Sulphur % :- Although sulphur can burn & increase calorific value of coal but it causes SOx pollution & cause acid rain, corrosion of metallic equipment. Hense, lower the % of sulphur better is the quality of coal.

5] Oxygen % :- Most of oxygen in coal is in the form of moisture. It decreases calorific value of coal. Hence, lower the oxygen %, better is coal quality.

Teacher's Sign.:

Page No.
Date

4] Differences between octance number & cetance number.

→

Octance number	Cetane number.
1] "Octane number" expresses knocking character of petrol.	1] "Cetane Number" expresses knocking characte of diesel.
2] It is the % of isooctane in the mixture of iso-octance & n-heptane, which has similar knocking to petrol sample.	2] It is % of hexadecane in the mixture of n-hexadecane & 2-methyl napthalene which has same ignition character of diesel.
3]. Octance number of good petrol should be atleast 85 for motor cycles & cars and 100 for aeroplance & helicoptors.	3]. Cetnce number of good diesel should be 25 for low speed engine & 35 for medium speed engine. & 45 for high speed engine.
4]. Octance number of petrol can be increased by adjusting compression ratio suitable or by adding benzene or toulene or alkylate fraction	4]. Cetane number of diesel can be increased by adding organic compounds containing oxygen atom. eg. ethyl nitrate, nitrite, isonaxy, acetone peroxide.

Teacher's Sign.:

Q5) What is knocking of petrol & why does it occur ? How does it related to structure of hydrocarbons present in petrol?

→ A] Knocking :-

1] Knocking is a term related to internal combustion engine working on petrol.

2] In an internal combustion engine, mixture of air & petrol vapour is compressed & then ignited by spark plug & the chemical reaction is oxidation of hydrocarbon molecule where gases are evolved through exhaust.

3]. Due to combustion, gases are produces which move the piston down the cylinder.

4] Rate of combustion depends upon composition of fuel, temperature & design of the engine.

5] Movement of piston must be uniform without any vibration.

6]. But sometimes, the rate of combustion is so great that mixture detonates before the ignition of spark plug, which causes uneven moving of piston producing a sound called "knocking".

B] Reation of knocking with structure of hydrocarbons.

1] Petrol is a mixture of various hydrocarbons & knocking of engine depend ~~upo~~ upon structure of hydrocarbons present in petrol.

2] Sudden burning of hydrocarbons, which produces a large volume ~~of~~ in short time, causes knocking.

3] Straight ~~ca~~ chain saturated hydrocarbons have more tendency of knocking than unsaturated hydrocarbons.

Knocking tendency :- Straight chain > branch chain > olefins > cyclo parafins > aromatic.

Teacher's Sign.: ____________

Page No.
Date

Q6] Significance of Octane & Cetane Number.
→

A] Significance of Octane Number :-
i] Octane Number is a standard measure of ~~an engine~~ the fuel against compression.
ii] Higher the octane number, the more compression of fuel happens before detonating.
iii] Fuels with higher octane number are used in higher compression gasoline engines.

B] Significance of Cetane Number :-
i] ~~Cent~~ Cetane Number refers to compression- ignition engine.
ii] Gasoline engines rely on ignition of air & fuel compressed together as a mixture, which is ignited near the end of compression stroke using spark plug.
iii]. High compressibility of fuels matters mainly for gasoline engines.
iv]. Gasoline with lower cetane numbers may lead to knocking.

Teacher's Sign.: ____________