FUELS AND COMBUSTION – 4

(COMBUSTION NUMERICALS)

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Numerical 1

A solid fuel has C= 80%, H = 12%, S = 1%, N = 1%, Moisture = 1%, O = 5%. Calculate the minimum quantity of air required for complete combustion of 1 kg of fuel

Solution:

Constituent	% by weight	Weight per kg
C	80	0.80
H	12	0.12
S	1	0.01
O	5	0.05

$C + O_2 \longrightarrow CO_2$

12   32

0.8 ---- 2.13 kg

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

2   16

0.12 ---- 0.96 kg

$S + O_2 \longrightarrow SO_2$

32   32

0.01 ----- 0.01 kg

Total amount of oxygen required = 2.13 + 0.96 + 0.01 = 3.10 kg

Net amount of oxygen required = 3.10 – 0.05 = 3.05 kg

Air contains 23% oxygen by weight,

Amount of air required = (3.05) X 100/23

= 13.26 kg

Numerical 2

A solid fuel has C= 80%, H = 12%, S = 1%, N = 1%, Moisture = 1%, O = 5%. Calculate the minimum quantity of air required for complete combustion of 1 kg of fuel if 30% excess air is supplied.

Solution:

Constituent	% by weight	Weight per kg
C	80	0.80
H	12	0.12
S	1	0.01
O	5	0.05

$C + O_2 \longrightarrow CO_2$

12 32

0.8 ---- 2.13 kg

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

2 16

0.12 ---- 0.96 kg

$S + O_2 \longrightarrow SO_2$

32 32

0.01 ----- 0.01 kg

Total amount of oxygen required = 2.13 + 0.96 + 0.01 = 3.10 kg

Net amount of oxygen required = 3.10 – 0.05 = 3.05 kg

Air contains 23% oxygen by weight,

Amount of air required = (3.05) X 100/23 = 13.26 kg

If 30% excess air is supplied the amount of air required = 13.26 X 130/100

= 17.37 kg

Numerical 3

A solid fuel has C= 80%, H = 12%, S = 1%, N = 1%, Moisture = 1%, O = 5%. Calculate the weight and volume of air required for complete combustion of 1 kg of fuel. (Molecular weight of air = 28.94)

Solution:

Constituent	% by weight	Weight per kg
C	80	0.80
H	12	0.12
S	1	0.01
O	5	0.05

C + O2 ----> CO2

12 32

0.8 ---- 2.13 kg

H2 + 1/2 O2 ----> H2O

2 16

0.12 ---- 0.96 kg

S + O2 ----> SO2

32 32

0.01 ----- 0.01 kg

Total amount of oxygen required = 2.13 + 0.96 + 0.01 = 3.10 kg

Net amount of oxygen required = 3.10 – 0.05 = 3.05 kg

Air contains 23% oxygen by weight,

Amount of air required = (3.05) X 100/23 = 13.26 kg

For air, 28.94 = 22.4 m^3

Therefore, 13.26 kg = 13.26 X (22.4/28.94) m^3

= 10.26 m^3

Points to remember (For numericals on combustion of fuel)

1. When oxygen and air requirement for solid fuel combustion is calculated, the stoichiometric ratio of constituents and oxygen is considered by weight whereas for combustion of gaseous fuel the stoichiometric ratio by volume is considered.

2. When conditions at which combustion is carried out, are not mentioned the temperature and pressure are considered as 273^0K (0^0C) and 760 mm (1 atm) respectively.

3. At 273^0K (0^0C) and 760 mm (1 atm) – Air contains 23% oxygen by weight and 21% oxygen by volume

4. At 273^0K (0^0C) and 760 mm (1 atm) –

1 g mole of any gas = 22400 cm^3 = 22.4 L = 22.4 dm^3

OR 1 kg mole of any gas = 22400 X 1000 cm^3

i.e. 1 kg mole of any gas = 22.4 m^3

Numerical 4

A solid fuel has C= 80%, H = 12%, S = 1%, N = 1%, Moisture = 1%, O = 5%. Calculate the volume of air required at 20^0C and 750mm pressure for complete combustion of 1 kg of fuel. (Molecular weight of air = 28.94)

Solution:

$C + O_2 \longrightarrow CO_2$	$H_2 + 1/2\ O_2 \longrightarrow H_2O$	$S + O_2 \longrightarrow SO_2$
12 32	2 16	32 32
0.8 ---- 2.13 kg	0.12 ---- 0.96 kg	0.01 ----- 0.01 kg

Total amount of oxygen required = 2.13 + 0.96 + 0.01 = 3.10 kg

Net amount of oxygen required = 3.10 – 0.05 = 3.05 kg

Air contains 23% oxygen by weight,

Amount of air required = (3.05) X 100/23 = 13.26 kg

For air, 28.94 = 22.4 m^3

Therefore, 13.26 kg = 13.26 X (22.4/28.97) m^3 = 10.26 m^3 ----- (at 273^0K and 760 mm pressure)

At given temp & pressure, Volume of air can be calculated by, $P_1V_1/T_1 = P_2V_2/T_2$ ---- (Temp in degree Kelvin)

Therefore volume of air required at given temp & pressure = V_2 = (760 x 10.26) X 293/(273 X 750)

=11.16 m^3

Numerical 5

Calculate volume of air required for complete combustion of $1 m^3$ of fuel containing CH_4 = 35%, CO = 15%, H_2 = 40%, N_2 = 5% and O_2 = 5%

Solution:

Constituent	% by volume	volume per m^3
CH4	35	0.35
CO	15	0.15
H2	40	0.40
O2	5	0.05

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

1 vol   2vol

0.35 m3 ---- 0.7 m3

$CO + 1/2 O_2 \longrightarrow CO_2$

1vol   0.5vol

0.15 m3 ----0.075 m3

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

1vol   0.5vol

0.40 m3 ---- 0.20 m3

Total volume of oxygen required = 0.70 + 0.075 + 0.20 = 0.975 m3

Net amount of oxygen required = 0.975 – 0.05 = 0.925 m3

Air contains 21% oxygen by volume,

Volume of air required = (0.925) X 100/21

= 4.40 m3

Numerical 6

Calculate volume and weight of air required for complete combustion of $1m^3$ of fuel containing CH_4 = 35%, CO = 15%, H_2 = 40%, N_2 = 5% and O_2 = 5%. (Mol. Weight of air = 28.94)

Solution:

Constituent	% by volume	volume per m^3
CH4	35	0.35
CO	15	0.15
H2	40	0.40
O2	5	0.05

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

1 vol 2vol

0.35 m3 ---- 0.7 m3

$CO + 1/2O_2 \rightarrow CO_2$

1vol 0.5vol

0.15 m3 ----0.075 m3

$H_2 + 1/2\ O_2 \rightarrow H_2O$

1vol 0.5vol

0.40 m3 ---- 0.20 m3

Total volume of oxygen required = 0.70 + 0.075 + 0.20 = 0.975 m3

Net amount of oxygen required = 0.975 – 0.05 = 0.925 m3

Air contains 21% oxygen by volume,

Volume of air required = (0.925) X 100/21 = 4.40 m3

For air, 22.4 m^3 = 28.94

Therefore, 4.40 m3 = 4.40 X (28.94/22.4) kg = 5.69 kg

Numerical 7

Calculate volume of air required at 25^0C and 730 mm pressure for complete combustion of $1m^3$ of fuel containing CH_4 = 35%, CO = 15%, H_2 = 40%, N_2 = 5% and O_2 = 5% if air contains 20% oxygen at this given temp & pressure

Solution:

Constituent	% by volume	volume per m^3
CH4	35	0.35
CO	15	0.15
H2	40	0.40
O2	5	0.05

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
1vol 2vol
0.35 m3 ---- 0.7 m3

$CO + 1/2O_2 \rightarrow CO_2$
1vol 0.5vol
0.15 m3 ----0.075 m3

$H_2 + 1/2\ O_2 \rightarrow H_2O$
1vol 0.5vol
0.40 m3 ---- 0.20 m3

Total volume of oxygen required = 0.70 + 0.075 + 0.20 = 0.975 m3

Net amount of oxygen required = 0.975 – 0.05 = 0.925 m3

At given temp & pressure, Volume of oxygen can be calculated by, $P_1V_1/T_1 = P_2V_2/T_2$ ---- (Temp in degree Kelvin)

Therefore volume of oxygen required at given temp & pressure = V_2 = (760 x 0.925) X 298/(273 X 730)

= $1.051\ m^3$

At given temp and pressure air contains 20% oxygen,

Volume of air required at given temp and pressure = 1.051 X 100/20 m3

= 5.256 m3

Numerical 8

Calculate volume of air required at 25^0C and 730 mm pressure for complete combustion of $1m^3$ of fuel containing C_2H_4 = 35%, CO = 15%, H_2 = 40%, N_2 = 5% and O_2 = 5% if air contains 20% oxygen at this given temp & pressure

Solution:

Constituent	% by volume	volume per m^3
C2H4	35	0.35
CO	15	0.15
H2	40	0.40
O2	5	0.05

C2H4 + 3O2 ---> 2CO2 + 2H2O
1 vol 3vol
0.35 m3 ---- 1.05 m3

CO + 1/2O2 ---> CO2
1vol 0.5vol
0.15 m3 ----0.075 m3

H2 + 1/2 O2 ---> H2O
1vol 0.5vol
0.40 m3 ---- 0.20 m3

Total volume of oxygen required = 1.05 + 0.075 + 0.20 = 1.325 m3

Net amount of oxygen required = 1.325 – 0.05 = 1.275 m3

At given temp & pressure, Volume of oxygen can be calculated by, $P_1V_1/T_1 = P_2V_2/T_2$ ---- (Temp in degree Kelvin)

Therefore volume of oxygen required at given temp & pressure = V_2 = (760 x 1.275) X 298/(273 X 730)

= $1.449m^3$

At given temp and pressure air contains 20% oxygen,

Volume of air required at given temp and pressure = 1.449X 100/20 m3

= 7.245 m3

Numericals for practice

1. Calculate weight & volume of air required for complete combustion of 5 m3 of gaseous fuel which possesses by volume H_2 = 50%, CH_4 = 30%, N_2 = 2%, CO = 7%, C_2H_4 = 3% , C_2H_6 = 5% and Water Vapour = 3%. (Mol. Wt. of air = 28.94)
2. Calculate weight and volume of air required for complete combustion of 5 kg of carbon if 25% excess air is supplied. (Mol. Wt. of air = 28.949)
3. Calculate volume of air required at 27^0C and 730 mm pressure for complete combustion of $10m^3$ of fuel containing CH_4 = 30%, C_3H_8 = 20%, CO = 20%, H_2 = 25%, N_2 = 1% and O_2 = 2% if air contains 20% oxygen at this given temp & pressure.
4. Calculate volume and weight of air required for complete combustion of $1m^3$ of fuel containing ethane = 35%, isobutane = 15%, H_2 = 40%, N_2 = 5% and O_2 = 5%. (Mol. Weight of air = 28.94)
5. Calculate volume of air required at 25^0C and 1 atm pressure for complete combustion of $5m^3$ of fuel containing acetylene = 35%, CO2 = 15%, H_2 = 40%, water vapour = 5% and O_2 = 5%.