



① Formula  $\text{CaCO}_3$  Hardness producing substance (T+P)

$$\frac{\text{weight of T+P} \times \text{equiv of } \text{CaCO}_3}{\text{equivalent weight of T+P}}$$

1. Calculate the temporary and permanent hardness of a water sample having the following analysis:

146  $\text{Mg}(\text{HCO}_3)_2 = 73 \text{ mg/L} \rightarrow \text{Temporary}$

162  $\text{Ca}(\text{HCO}_3)_2 = 162 \text{ mg/L} \rightarrow \text{Temporary}$

136  $\text{CaSO}_4 = 136 \text{ mg/L}$  ↗ Permanent  
95  $\text{MgCl}_2 = 95 \text{ mg/L}$

111  $\text{CaCl}_2 = 111 \text{ mg/L}$   
 $\text{NaCl} = 100 \text{ mg/L} \rightarrow \text{Unknown}$

Solving this by using an table

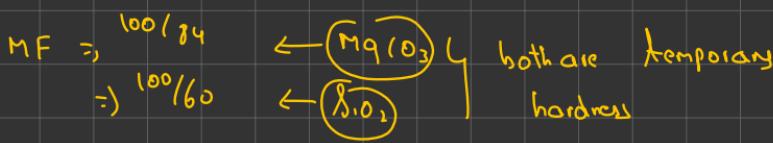
	Given stuff	MF	
$\text{Mg}(\text{HCO}_3)_2$	73 mg/L	100/146	$73 \times 100/146$
$\text{Ca}(\text{HCO}_3)_2$	162 mg/L	100/162	$162 \times 100/162$
$\text{CaSO}_4$	136 mg/L	100/136	$136 \times 100/136$
$\text{MgCl}_2$	95 mg/L	100/95	$95 \times 100/95$
$\text{CaCl}_2$	111 mg/L	100/111	$111 \times 100/111$
$\text{NaCl}$	100 mg/L		

1. A water sample contains 16.8 mg of  $\text{MgCO}_3$  and 6.0 g of  $\text{SiO}_2$  per litre. Calculate the temporary and permanent hardness of the sample.

Ans: Temporary hardness = 20 ppm and Permanent hardness = 0 ppm

$\text{MgCO}_3$  16.8 mg/L

$\text{SiO}_2$  6.0 g/L  $\rightarrow$  6000 mg/L



both are temporary hardness

$$\Rightarrow \frac{16.8 \times 100}{84}, \quad \text{S.O}_2 \text{ falls in neither categories}$$

(20)

Dulong's formula :-

Gross or high calorific value from chemical composition of fuel

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

for Net lower calorific value (Lcv)

$$Lcv = [HCV - 0.09H \times 587] \text{ kcal/kg}$$

## Question Solving

- The ultimate analysis of a coal gave the following results: C = 84%, S = 1.5%, N = 0.6%, H = 5.5% & O = 8.4%. Calculate the gross & net calorific value of the coal using Dulong's formula.

Gross calorific value of (HCV | GCV)

$$\begin{aligned} GCV &= \frac{1}{100} \left[ 8080C + 34500 \left( H - \frac{O}{8} \right) + 2240S \right] \\ &= \frac{1}{100} \left[ 8080(84) + 34500 \left( 5.5 - \frac{8.4}{8} \right) + 2240(1.5) \right] \end{aligned}$$

$$GCV = 8356.05$$

$$Lcv = GCV - 0.09H \times 587$$

$$\begin{aligned} &= 8356.05 - 0.09(5.5)587 = 8065.935 \\ Lcv &= 8065.935 \end{aligned}$$

- 2) A sample of coal was found to have the following percentage composition. C = 75%, H = 5.2%, O = 12.1%, N = 3.2%, & Ash 4.5% Calculate the higher calorific value & lower calorific value of coal sample.

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

$$\therefore \frac{1}{100} \left[ 8080(75) + 34500 \left( 5.2 - \frac{12.1}{8} \right) + 2240(0) \right]$$

$$\therefore HCV = 7332.1875 \text{ Kcal/kg} \longrightarrow \text{unit is extremely important.}$$

$$\text{formula for LCV is} = \left[ HCV - \frac{9}{100} H \times 587 \right] \text{ Kcal/kg}$$

$$\left[ 7332.1875 - \frac{9}{100} (5.2)(587) \right] \text{ Kcal/kg}$$

$$\Rightarrow 7057.4715 \text{ Kcal/kg}$$

- 3) A sample of coal contains C = 76%, O = 16.2%, H = 5%, N = 1.5%, S = 0.3%  
Ash = 1.0% Calculate the higher & lower calorific value of the coal

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

$$LCV = GCV - 0.09 H \times 587$$

$$\therefore GCV = \frac{1}{100} \left( 8080(76) + 34500 \left( 5 - \frac{16.2}{8} \right) + 2240(0.3) \right)$$

$$\therefore GCV = \underline{\underline{7173.895 \text{ Kcal/kg}}}$$

$$\text{now LCV} = 7173.895 - 0.09 \times 5 \times 587$$

$$= \underline{\underline{6909.745 \text{ Kcal/kg}}}$$

- 4) A coal is having the following composition by weight C = 90%, O = 0.3%, S = 0.5%, N = 0.5%, ash = 2.5%. Net calorific value was found to be 8925.28 kcal / kg . Calculate the % H , and gross calorific value.

Net Calorific value also goes by the name LCV.

$$NCV = GCV - 0.09 \times H \times 587$$

$$8925.28 = GCV - 0.09 \times H \times 587$$

first using the GCV formula:-

$$\frac{1}{100} \left\{ 8080(90) + 34500 \left( H - \frac{0.3}{8} \right) + 2240(0.5) \right\}$$

$$= \frac{1}{100} \left[ 727200 + 34500H - 34500 \left( \frac{0.3}{8} \right) + 2240(0.5) \right]$$

$$7276.9825 - 345H$$

$$8925.28 = 7276.9825 - 345H - 52.83H$$

$$8925.28 = 7276.9825 - 397.83H$$

$$8925.28 - 7276.9825 = -397.83(H)$$

$$\therefore H = \underline{\underline{4.143\%}} \quad \text{so } GCV = \underline{\underline{9222.28}}$$

$$\% \text{ of moisture in an coal sample} = \frac{\text{loss in wt of coal sample}}{\text{wt. of the coal sample}} \times 100$$

$$\% \text{ of volatile matter} = \frac{\text{loss at wt of coal sample at } 950 \pm 20^\circ C}{\text{wt of the coal sample}} \times 100$$

$$\% \text{age. of ash} = \frac{\text{weight of residue left in Crucible}}{\text{wt of the coal sample}} \times 100$$

%age of the fixed carbon =  $100 - (\% \text{ moisture} + \% \text{ ash} + \% \text{ volatile matter})$

- 1) 1 gm of coal sample on heating at  $110^{\circ}\text{C}$  for 1 hour produced a residue 0.850 gm and this residue on heating at  $950^{\circ}\text{C}$  for 7 mins. in absence of air, left 0.720 gm mass which on combustion left 0.1 gm of non-combustible matter. Calculate the results of proximate analysis.

Initial weight = 1 gm

moisture content =  $1 - \underline{0.850} \rightarrow$  wt of residue left.

0.850  $\xrightarrow{\Delta, 950^{\circ}\text{C} \pm 20^{\circ}\text{C}, 7\text{m}}$  0.720 gm  $\xrightarrow{\text{on combustion}}$  0.1 gm, non combustible

%age of moisture =  $\left( \frac{1 - 0.850}{1} \right) \times 100 = 15\%$ .

%age of volatile matter =  $\frac{0.850 - 0.720}{1} \times 100 = 13\%$ .

★ The weight of the coal sample always equals to 1 even when it seems to change it doesn't.

%age of ash content =  $\frac{\text{wt. of ash}}{\text{wt. of the coal sample}} \times 100$   
 $= \frac{0.1}{1} \times 100 = 10\%$ .

∴ %age of the fixed carbon =  $100 - (15 + 13 + 10) = 62\%$ .

- 2) A coal sample was analyzed as follows: Exactly 2.500gm was weighed into silica crucible. After heating for one hour at  $110^{\circ}\text{C}$ , the residue weighted 2.415gm. The crucible next covered with lid of strongly heated for 7 mins. At  $950 \pm 20^{\circ}\text{C}$ . The residue weighed 1.528gm. The crucible was then heated without cover, until a constant weight is obtained. The last residue was found to weight 0.245 gm. Calculate the results of proximate analysis.

Initial weight = 2.500 gm

2.500 gm  $\xrightarrow[\text{removal}]{\Delta, \text{ moisture}}$  2.500 - 2.415 gm  $\xrightarrow{\Delta 950 \pm 20^{\circ}\text{C}, 7\text{m}}$  2.415 - 1.528

1.528  $\xrightarrow{\Delta \text{ for ash}}$   $(1.528 - 0.245)$  gms

$$\% \text{age of the moisture content} = \frac{2.500 - 2.415}{2.500} \times 100 = \underline{\underline{3.40\%}}$$

$$\% \text{age of volatile matter} = \frac{2.415 - 1.818}{2.500} \times 100 = \underline{\underline{35.48\%}}$$

$$\% \text{age of Ash Content} = \frac{0.245}{2.500} \times 100 = \underline{\underline{9.8\%}}$$

$$\% \text{age of fixed carbon} = 100 - (3.40 + 35.48 + 9.8) = \underline{\underline{51.32\%}}$$

- 3) An air-dried sample of coal weighing 2.9 gm whose weight after losing volatile matter was 1.96 gm. If it contains 4.5% moisture find the percentage of volatile matter in it.

Initial weight = 2.9 gms Initial air dried weight.

$$2.9 \text{ gms} \xrightarrow[\text{matter}]{\text{volatile}} (2.9 - 1.96) \text{ gms}$$

$$\text{moisture content} = 4.5\%$$

$$\text{If mean it already has lost moisture content} = \frac{(x - 2.9)}{x} \times 100 \\ = 4.5$$

$$= 4.5x = 100x - 2.9 \times 100$$

$$= 1.90 = 95.5x$$

$$= \frac{2.90}{95.5} = x = \underline{\underline{3.036 \text{ gm}}} \quad \text{Initial weight.}$$

$$= \frac{2.96 - 1.96}{3.03} \times 100 = \underline{\underline{27.16\%}}$$

**Some important formulae & hints to solve problems on calculation of quantity of air required for combustion of fuel.**

- 1) First write the appropriate chemical reaction with oxygen and find their relation between the elements or compound on weight or volume basis.
- 2) Calculate the oxygen required on the basis of unit quantity of fuel.
- 3) Calculate the total oxygen, which is already present in the fuel.
- 4) The oxygen calculated should be converted into air by knowing that air contains 23 part by weight of oxygen or 21 parts by volume of Oxygen.
- 5) The average molecular weight of air is 28.94 gm
- 6) Calculation for quantity of air required for combustion of coal.

a) Weight of air needed =  $\left\{ \frac{32C}{12} + \frac{16H}{2} + \frac{32S}{32} - O \right\} \times \frac{100}{23}$

(<sup>O</sup> is oxygen present in fuel)

$$= \left\{ 2.67 \times C + 8 \times H + S \right\} \times 100 / 23$$

b) Volume of air required = (No. of mol. of air)  $\times 22.4$  litres at STP

$$= \frac{\text{wt. of air needed in gm}}{28.94} \times 22.4 \text{ litre at STP}$$

$$= \frac{\text{wt. of air needed in kg}}{28.94} \times 22.4 \text{ m}^3 \text{ at STP}$$

28.94

- 1) Calculate volume of air required for complete combustion of 1kg of coal containing C = 60%, H = 7%, O = 8%, N = 5% & moisture = 13.8% remaining being ash.  
{Mol. wt. of air = 28.949g}

Compound	Total wt. / wto 1kg
C	0.60
H	0.07
O	0.08
N	0.05
moisture	0.138

Calculation of quantity of air required for combustion

$$\text{Weight of the air needed} = \left( \frac{32C}{12} + \frac{16H}{2} + \frac{32S}{32} - O \right) \times \frac{100}{23}$$

$$\Rightarrow \left( \frac{32(0.60)}{12} + \frac{16(0.07)}{2} + \frac{32(0)}{32} - 0.08 \right) \times \frac{100}{23} = \underline{\underline{9.04}}$$

"O" is the oxygen present in the fuel

This is the weight of O<sub>2</sub> required for the combustion of fuel.

now the weight of the air required = (nos of mol of air)  $\times 22.4$  at STP

$$\therefore \text{weight of oil needed at STP} = \frac{0.004 \times 22.4}{28.04} = 6.99 \text{ ml}$$

The formula for acid value =  $\frac{\text{volume of KOH in ml} \times \text{normality of KOH} \times 56}{\text{weight of oil in grams}}$

$$\text{weight of oil} = \text{volume of oil} \times \text{Density}$$

- 1) Find the acid value of an used oil sample whose 7 ml. required 3.8 ml. of N/50 KOH during titration. (Density of oil = 0.88g/cc)

$$\text{weight of oil} : \text{volume of oil} \times \text{Density of oil}$$

$$= 7 \times 0.88 = 6.16 \text{ gm}$$

$$\text{formula} = \frac{\text{volume of KOH in ml} \times \text{normality of KOH} \times 56}{\text{weight of the oil in grams}}$$

$$= \text{normality of KOH} = \frac{1}{50} = N=1 = \frac{1}{50}$$

$$= \frac{3.8 \times \frac{1}{50} \times 56}{6.16} = 0.6909 \text{ mg of KOH/g of oil}$$

1. A sample of vegetable oil purchased was tested for acid value. 10 gm. of the oil was titrated against N/40 KOH and burette reading was found 2.6 ml, state whether the oil is proper for lubrication or not from acid-value.

Here the mass of the oil is already given = 10gm

# Water numericals

$\text{CaCO}_3$  equivalent for hardness producing =  $\frac{\text{weight of hps} \times \text{equivalent wt. of CaCO}_3}{\text{equivalent weight of hps}}$

$$1 \text{ ppm} = 1 \text{ mg/L}$$

(At.Wt.: Ca = 40, Mg = 24, H = 1, C = 12, O = 16, S = 32)

- Calculate the temporary and permanent hardness of a water sample having the following analysis

$$\text{Mg}(\text{HCO}_3)_2 = 73 \text{ mg/L}$$

$$\text{Ca}(\text{HCO}_3)_2 = 162 \text{ mg/L}$$

$$\text{CaSO}_4 = 136 \text{ mg/L}$$

$$\text{MgCl}_2 = 95 \text{ mg/L}$$

$$\text{CaCl}_2 = 111 \text{ mg/L}$$

$$\text{NaCl} = 100 \text{ mg/L}$$

Compound	Hardness type	analysis	MF	$\text{CaCO}_3$ eq. (analysis $\times$ MF)
$\text{Mg}(\text{HCO}_3)_2$	Temporary	73 mg/L	100/166	$73 \times 100/166 = 50$
$\text{Ca}(\text{HCO}_3)_2$	Temporary.	162 mg/L	100/162	$162 \times 100/162 = 100$
$\text{CaSO}_4$	Permanent	136 mg/L	100/136	$136 \times 100/136 = 100$
$\text{MgCl}_2$	Permanent.	95 mg/L	100/95	$95 \times 100/95 = 100$
$\text{CaCl}_2$	Permanent	111 mg/L	100/111	$111 \times 100/111 = 100$
NaCl	-	-	-	-

$$\therefore \% \text{age of temporary hardness} = \text{Total of } \text{CaCO}_3 \text{ hardness eq. } (\text{Mg}(\text{HCO}_3)_2 + \text{Ca}(\text{HCO}_3)_2) \\ = 50 + 100 \text{ mg/L} = 150 \text{ mg/L}$$

$$\text{Total of permanent hardness} = \text{Total of } \text{CaCO}_3 \text{ hardness of } \text{CaSO}_4 + \text{MgCl}_2 \\ + \text{CaCl}_2$$

$$= 100 + 100 + 100 = 300 \text{ mg/L}$$

$$\therefore \text{Total hardness} = \text{Temporary hardness} + \text{Permanent hardness} = 150 + 300 = 450 \text{ mg/L}$$

2. A water sample contains the following impurities:

$$\text{Ca}(\text{HCO}_3)_2 = 32.4 \text{ mg/L}$$

$$\text{Mg}(\text{HCO}_3)_2 = 29.2 \text{ mg/L}$$

$$\text{CaSO}_4 = 13.5 \text{ mg/L}$$

Calculate temporary, permanent and total hardness of the sample