



① formula CaCO_3 Hardness producing substance (HPS)
weight of HPS \times eqwt of CaCO_3
 equivalent weight of HPS

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

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

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

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

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

$\text{NaCl} = 100 \text{ mg/L} \rightarrow$ 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	$162 \times 100/162$
CaSO_4	136 mg/L	100/136	$136 \times 100/136$
MgCl_2	95 mg/L	100/95	$95 \times 100/95$
CaCl_2	111 mg/L	100/111	$111 \times 100/111$
NaCl	100 mg/L		

1. A water sample contains 16.8 mg of MgCO_3 and 6.0 g of SiO_2 per litre. Calculate the temporary and permanent hardness of the sample.

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

MgCO_3 16.8 mg/L

SiO_2 6.0 g/L \rightarrow 6000 mg/L

$$MF \Rightarrow \frac{100}{84} \quad \leftarrow \text{Mg(OH)}_2 \quad \left\{ \begin{array}{l} \text{both are temporary} \\ \text{hardness} \end{array} \right.$$

$$\Rightarrow \frac{100}{60} \quad \leftarrow \text{SiO}_2$$

$$\Rightarrow \frac{168 \times 100}{84}, \quad \text{SiO}_2 \text{ falls in neither categories}$$

(20)

Dulong's formula :-

Gross or high calorific value from chemical composition of fuel

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

for Net/ lower calorific value (LCV)

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

Question Solving

- 1) 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)

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

$$\boxed{\text{GCV} = 8356.05}$$

$$\text{LCV} = \text{GCV} - 0.09H \times 587$$

$$= 8356.05 - 0.09(5.5) 587 = 8065.935$$

$$\boxed{\text{LCV} = 8065.935}$$

- 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.

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

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

$$\therefore \text{HCV} = 7332.1875 \text{ Kcal/Kg} \rightarrow \text{Unit is extremely Important.}$$

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

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

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

- 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

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

$$\text{LCV} = \text{GCV} - 0.09 H \times 587$$

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

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

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

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

- 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.

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

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

find using the GCV formula:-

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

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

$$7276.9825 - 345H$$

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

$$8925.28 = 7276.9825 - 397.83H$$

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

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

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

$$\% \text{ of volatile matter} = \frac{\text{loss of wt of coal sample at } 950 \pm 10^\circ\text{C}}{\text{wt of the coal sample}} \times 100$$

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

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

- 1) 1 gm of coal sample on heating at 110°C for 1 hour produced a residue 0.850 gm and this residue on heating at 950°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 = $1 - 0.850 \rightarrow$ wt of residue left.

$0.850 \xrightarrow{\Delta, 450^{\circ}\text{C} \pm 20^{\circ}\text{C} \text{ 7m}} 0.720 \text{ gm} \xrightarrow{\text{on combustion}} 0.1 \text{ gm} \rightarrow$ non combustible

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

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

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

$$\begin{aligned} \% \text{ age of ash content} &= \frac{\text{weight left in the crucible}}{\text{wt. of the coal sample}} \times 100 \\ &= \frac{0.1}{1} \times 100 = 10\% \end{aligned}$$

$$\therefore \% \text{ age of the fixed carbon} = 100 - (15 + 13 + 10) = 62\%$$

- 2) A coal sample was analyzed as follows: Exactly 2.500 gm was weighed into silica crucible. After heating for one hour at 110°C , the residue weighted 2.415 gm. The crucible next covered with lid of strongly heated for 7 mins. At $950 \pm 20^{\circ}\text{C}$. The residue weighed 1.528 gm. 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

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

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

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

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

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

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

- 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 gm \rightarrow Initial air dried weight.

2.9 gm $\xrightarrow{\text{volatile matter}}$ (2.9 - 1.96) gm

moisture content = 4.5%

It means it already has lost moisture content = $\frac{x - 2.9}{x} \times 100$
= 4.5

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

$$= 190 = 95.5x$$

$$= \frac{290}{95.5} = x = \underline{3.036 \text{ gm}} \rightarrow \text{Initial weight}$$

$$= \frac{296 - 1.96}{3.03} \times 100 = \underline{27.16\%}$$

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.

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

("O" is oxygen present in fuel)

$$= \left\{ \frac{2.67 \times C}{12} + \frac{8 \times H}{2} + \frac{S}{32} - O \right\} \times 100 / 23$$

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

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

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

- 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 = 28.94g}

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

Calculation of quantity of air required for combustion

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

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

"O" is the oxygen present in the fuel

This is the weight of O₂ required for the combustion of fuel.

now the weight of the air required = (nos of mol. of air) × 22.4 l
at STP

$$\therefore = \frac{\text{weight of air needed} \times 22.4 \text{ l at STP}}{28.94} = \frac{9.04 \times 22.4}{28.94} = 6.99 \text{ m}$$

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

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

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)

$$\begin{aligned} \text{weight of oil} &= \text{volume of oil} \times \text{Density of oil} \\ &= 7 \times 0.88 = 6.16 \text{ gm} \end{aligned}$$

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

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

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

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

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

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

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

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

Mg(HCO₃)₂ = 73 mg/L

Ca(HCO₃)₂ = 162 mg/L $40 + 2 + 12 \times 2 + 16 \times 6$

CaSO₄ = 136 mg/L

MgCl₂ = 95 mg/L

CaCl₂ = 111 mg/L

NaCl = 100 mg/L

Compound	Hardness type	analysis	MF	CaCO ₃ eq. (analysis × MF)
Mg(HCO ₃) ₂	Temporary	73 mg/L	100/146	$73 \times 100/146 = 50$
Ca(HCO ₃) ₂	Temporary.	162 mg/L	100/162	$162 \times 100/162 = 100$
CaSO ₄	Permanent	136 mg/L	100/136	$136 \times 100/136 = 100$
MgCl ₂	Permanent.	95 mg/L	100/95	$95 \times 100/95 = 100$
CaCl ₂	Permanent	111 mg/L	100/111	$111 \times 100/111 = 100$
NaCl	—	—	—	—

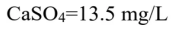
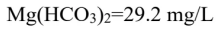
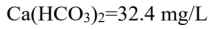
$$\begin{aligned} \therefore \% \text{age of temporary hardness} &= \text{Total of CaCO}_3 \text{ hardness eq. (Mg(HCO}_3)_2 + \text{Ca(HCO}_3)_2) \\ &= 50 + 100 \text{ mg/L} = 150 \text{ mg/L} \end{aligned}$$

$$\begin{aligned} \text{total of permanent hardness} &= \text{Total of CaCO}_3 \text{ hardness of CaSO}_4 + \text{MgCl}_2 \\ &\quad + \text{CaCl}_2 \end{aligned}$$

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

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

2. A water sample contains the following impurities:



Calculate temporary, permanent and total hardness of the sample