Water tutorial sheet-2

1. **How many grams of $MgCl_2$ dissolved per litre will give hardness of 76 ppm?**

Suppose A mg/L of $MgCl_2$ gives 76 ppm of hardness

M. W. of $MgCl_2$ = 95 g/mol

After applying the formula of hardness in equivalent of $CaCO_3$

76 = A x 100/95

A = 76 x 95/100 = 72.2 mg/L= **0.072 g/L**

2. **A water sample contains 168 mg of $MgCO_3$ per litre. Calculate hardness of the sample in ppm and in grains/gallon.**

Wt. of hardness causing substance i.e. $MgCO_3$ = 168 mg/L

M. W of $MgCO_3$ = 84

Hardness of water sample = 168 x 100/84 $CaCO_3$ eq.

= **200 ppm**

1 ppm = 0.07 grains/gallon or ^oC

200 ppm = 200 × 0.07 *grains/gallon or ^oC*

= **14 grains/gallon or ^oC**

3. **What role does "coagulants" play in lime soda process to remove hardness? Give an example.**

During cold "soda lime" process, the precipitates of $CaCO_3$ and $Mg(OH)_2$ are very fine particles and forms sludge like precipitates those do not settle easily. Small amount of coagulant is added which entraps the fine particles of $CaCO_3$ and $Mg(OH)_2$), as a result particle of $CaCO_3$ and $Mg(OH)_2$) becomes heavy and settled down at the bottom and filtered off easily.

Example of coagulants are: Alum, Aluminium sulfate, sodium aluminate etc.

4. **Calculate the quantity of lime and soda required for softening 50,000 litres of water containing the following salts per litre: Ca(HCO3)2 = 8.1 mg; Mg(HCO3)2 = 7.5 mg; CaSO4 = 13.6 mg; MgSO4 = 12.0 mg; MgCl2 =2.0 mg and NaCl = 4.7 mg.**

Lime required for the salts are = $Ca(HCO_3)$, $Mg(HCO_3)_2$, $MgCl_2$, $MgSO_4$

Soda required for the salts are = $CaSO_4$, $MgCl_2$, $MgCl_2$

Quantity of lime required for softening 1 liter of water is

$$= [Ca(HCO_3) + 2\ Mg(HCO_3)_2 + MgCl_2 + MgSO_4]$$

$$= \frac{74}{100}\left[8.1 \times \frac{100}{162}\right] + 2\left[7.5 \times \frac{100}{146}\right] + \left[2 \times \frac{100}{95}\right] + \left[12 \times \frac{100}{120}\right]$$

$$= \frac{74}{100}\left[5 + 2 \times (5.14) + 2.11 + 10\right]$$

Quantity of lime required for softening 1 liter of water is $= \frac{74}{100}$ [27.39] mg/l

Quantity of lime required for softening 50,000 liter of water is $= \frac{74}{100} \times 27.39 \times 50{,}000$

= **1.0134 kg/l**

Quantity of soda required for softening 1 liter of water is $= \frac{106}{100}[CaSO_4 + MgCl_2 + MgCl_2]$

$= \frac{106}{100}$ [5 + 10 + 2.11] mg/l

Quantity of soda required for softening 50,000 liter of water is $= \frac{106}{100} [17.11] \times 50{,}000$

= **0.9068 kg/l**

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5. **A sample of water on analysis gave the following results: Ca^{2+} = 30 mg/L; Mg^{2+} = 18 mg/L; K^+ = 19.5 mg/L; CO_2 = 11 mg/L; HCO_3^- = 122 mg/L; Cl^- =35.5 mg/L; SO_4^{2-} = 48 mg/L. Calculate total hardness and alkalinity present in water sample..**

$$Ca^{2+} = 30 \times \frac{100}{40} = 75 \text{ mg/l}$$

$$Mg^{2+} = 18 \times \frac{100}{24} = 75 \text{ mg/l}$$

$$CO_2 = 11 \times \frac{100}{44} = 25 \text{ mg/l}$$

$$HCO_3^- = 122 \times \frac{100}{122} = 100 \text{ mg/l}$$

Hardness causing substance are Ca^{2+} and Mg^{2+} only, Since K^+, CO_2, HCO_3^-, Cl^- and SO_4^{2-} do not cause any hardness

So Total hardness= (hardness due to Ca^{2+} + hardness due to Mg^{2+})

= 75+75= **150 ppm**

Alkalinity causing ions available here HCO_3^-, however there is CO_2 also available which cause acidity so total alkalinity will be = HCO_3^- – CO_2 = 100–25=**75 ppm**.

6. **The carbonate alkalinity of water sample was found to be 75 ppm $CaCO_3$ equivalent. After carrying out lime treatment, the alkalinity of water was found to increase to 300 ppm $CaCO_3$ equivalent. Calculate the excess amount of $Ca(OH)_2$ present in water after lime treatment. Express it in terms of mg/L of $Ca(OH)_2$.**

Alkalinity of water due to carbonate = 75 ppm

Which increase to 300 ppm after adding lime so total increment due to lime is

300 – 75 = 225 ppm

Suppose A mg of lime increase 225 ppm alkalnity

225 = A x 100/74 $CaCO_3$ eq.

A = **166.5 mg/L**

7. **Why calgon conditioning is better than phosphate conditioning?**

In calgon conditioning, the added calgon forms soluble complex with hardness causing ions which prevents the formation of scale and sludge in water.

$$Na_2[Na_4(PO_3)_6] \rightarrow 2Na+ + [Na_4P_6O_{18}]^{2-}$$

$$2CaSO_4 + [Na_4P_6O_{18}]^{2-} \rightarrow \underbrace{[Ca_2P_6O_{18}]^{2-}}_{\text{Soluble complex of calcium}} + 2Na_2SO_4$$

This soluble complex does not cause any problem in boilers.

On the other hand, in phosphate conditioning, sodium phosphate is added to the boiler water which forms the precipitates e.g.

$$3CaCl_2 + 2\,Na_3PO_4 \rightarrow \underbrace{Ca_3(PO_4)_2}_{\text{precipitate of calcium phosphate salt}} + 6\,NaCl$$

Hence calgon conditioning is better than phosphate conditioning.

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8. **Why water softened by zeolite process is unfit for use in boilers?**
   It replaces only Ca^{2+} and Mg^{2+} with Na^+ but leaves all the other ions like HCO_3^- and CO_3^{2-} in the softened water. Those may form $NaHCO_3$ and Na_2CO_3 whereas sodium bicarbonate decomposes producing CO_2 which causes corrosion, and sodium carbonate hydrolysis to sodium hydroxide to cause caustic embrittlement.

9. **The hardness of 25,000 litres of a sample of water was removed by passing it through a zeolite softener. The softener then required 100 litres of NaCl solution, containing 125 gm/L of NaCl for regeneration. Calculate the hardness of the sample of water.**
   1 liters of NaCl solution contain 125 gm of NaCl
   100 liters of NaCl solution contain= 100 x 125= 12500 g NaCl
   In the equivalent of $CaCO_3$ = 12500 x 50/58.5 g of $CaCO_3$ eq.
   = 10683.76 g of $CaCO_3$ eq.
   25000 L of sample water has hardness = 10683.76 g of $CaCO_3$
   1 L of sample water has hardness = 10683.76 / 25000 = 0.427 g/L
   = **427 mg/L or ppm**

10. **A zeolite bed was exhausted after completely removing the total hardness of 10,000 L of hard water. The zeolite bed was regenerated using 8 L of NaCl containing 150 gm/L of NaCl. Calculate the hardness of water.**
    1 liters of NaCl solution contain 150 gm of NaCl
    8 liters of NaCl solution contain= 8 x 150= 1200 g NaCl
    In the equivalent of $CaCO_3$ = 1200 x 50/58.5 g of $CaCO_3$ eq.
    = 1025.64 g of $CaCO_3$ eq.
    10, 000 L of sample water has hardness = 1025.64 g of $CaCO_3$
    1 L of sample water has hardness = 1025.64 / 10,000 = 0.102 g/L
    = **102 mg/L or ppm**

11. **After treating 10,000 L of water by ion exchanger, the cationic resin required 200 L of 0.1 N HCl and anionic resin required 200 L of 0.1 N NaOH solutions. Find the hardness of the water sample.**

    Hardness of 10000 L of water = 200 L of 0.1 N HCl
    = 200 L of 0.1 N $CaCO_3$ eq.
    = 20 L of 1 N $CaCO_3$ eq.
    = 20 × 50 g of $CaCO_3$ eq.
    = 1000 g $CaCO_3$ eq.

    Hardness in 1L in water = 1000 / 10,000 g of $CaCO_3$
    = 0.1 g/L of $CaCO_3$ eq.
    = 100 mg/L or ppm

12. **In demineralization process, water is usually first passed through the cation-exchanger and then through anion-exchanger. Why?**

    Demineralization process:
    Reactions occurring at Cation exchange resin
    $$2\,R^- H^+ + Ca^{2+} \text{ (hard water)} \rightarrow R_2Ca + 2\,H^+$$
    $$2\,R^- H^+ + Mg^{2+} \text{ (hard water)} \rightarrow R_2Mg + 2\,H^+$$

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Reactions occurring at anion exchange resin

$$2\,R^{+}OH^{-} + SO_4^{2-}\ (\text{hard water}) \rightarrow R_2SO_4 + 2\,OH^{-}$$
$$R^{+}OH^{-} + Cl^{-}\ (\text{hard water}) \rightarrow RCl + OH^{-}$$

If water first pass through an anion exchanger all the cations will convert to hydroxides e.g $Ca(OH)_2$, $Mg(OH)_2$. Because of hydroxide the water pH will be high as a result hydroxide will be precipitated and block to the ion exchanger.

13. **Why is demineralization process preferred over zeolite process for softening of water for use in boilers?**

    Demineralized water is free from all ions (cations and anions); whereas zeolite process for softening of water replaces only Ca^{2+} and Mg^{2+} with Na^{+} but leaves all the other ions like HCO_3^{-} and CO_3^{2-} in the softened water those form $NaHCO_3$ and Na_2CO_3 (sodium bicarbonate decomposes producing CO_2, which causes corrosion and sodium carbonate hydrolysis to sodium hydroxide which causes caustic embrittlement). Therefore, demineralization process preferred over zeolite process for softening of water for use in boilers.

14. **Name the important discovery that has helped using the principle of reverse osmosis for the purification of water on commercial scale.**
    The innovation in the **membranes technology** with small pore size has helped principle of reverse osmosis to go on commercial scale. Although, a number of membranes (like micro filtration, ultra filration and nano filtration) are available, it the membrane of pore size 0.1 to 1.0 nm which used in reverse osmosis. This particular membrane prevents even bacteria and viruses to be present in drinking water.
15. **Why commercial RO technique as available today is not recommended by environmental agencies?**
    Commercial RO technique, as available today, wastes a tremendous amount of water for making it drinkable. Also, reverse osmosis not only removes harmful contaminants present in the water, but it also may strip many of the good, healthy minerals from the water. Therefore, not recommended by environmental agencies.