

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 $\text{MgCl}_2 = 95 \text{ g/mol}$

After applying the formula of hardness in equivalent of CaCO_3

$$76 = A \times 100/95$$

$$A = 76 \times 95/100 = 72.2 \text{ mg/L} = 0.072 \text{ g/L}$$

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. $\text{MgCO}_3 = 168 \text{ mg/L}$

M. W of $\text{MgCO}_3 = 84$

$$\begin{aligned} \text{Hardness of water sample} &= 168 \times 100/84 \text{ CaCO}_3 \text{ eq.} \\ &= 200 \text{ ppm} \end{aligned}$$

$$1 \text{ ppm} = 0.07 \text{ grains/gallon or } ^\circ\text{C}$$

$$\begin{aligned} 200 \text{ ppm} &= 200 \times 0.07 \text{ grains/gallon or } ^\circ\text{C} \\ &= 14 \text{ grains/gallon or } ^\circ\text{C} \end{aligned}$$

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: $\text{Ca(HCO}_3)_2 = 8.1 \text{ mg}$; $\text{Mg(HCO}_3)_2 = 7.5 \text{ mg}$; $\text{CaSO}_4 = 13.6 \text{ mg}$; $\text{MgSO}_4 = 12.0 \text{ mg}$; $\text{MgCl}_2 = 2.0 \text{ mg}$ and $\text{NaCl} = 4.7 \text{ mg}$.

Lime required for the salts are = $\text{Ca(HCO}_3)_2$, $\text{Mg(HCO}_3)_2$, 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

$$= [\text{Ca(HCO}_3)_2 + 2 \text{ Mg(HCO}_3)_2 + \text{MgCl}_2 + \text{MgSO}_4]$$

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

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

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

$$\begin{aligned} \text{Quantity of lime required for softening 50,000 liter of water is} &= \frac{74}{100} \times 27.39 \times 50,000 \\ &= 1.0134 \text{ kg/l} \end{aligned}$$

$$\begin{aligned} \text{Quantity of soda required for softening 1 liter of water is} &= \frac{106}{100} [\text{CaSO}_4 + \text{MgCl}_2 + \text{MgCl}_2] \\ &= \frac{106}{100} [5 + 10 + 2.11] \text{ mg/l} \end{aligned}$$

$$\begin{aligned} \text{Quantity of soda required for softening 50,000 liter of water is} &= \frac{106}{100} [17.11] \times 50,000 \\ &= 0.9068 \text{ kg/l} \end{aligned}$$

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5. A sample of water on analysis gave the following results: $\text{Ca}^{2+} = 30 \text{ mg/L}$; $\text{Mg}^{2+} = 18 \text{ mg/L}$; $\text{K}^+ = 19.5 \text{ mg/L}$; $\text{CO}_2 = 11 \text{ mg/L}$; $\text{HCO}_3^- = 122 \text{ mg/L}$; $\text{Cl}^- = 35.5 \text{ mg/L}$; $\text{SO}_4^{2-} = 48 \text{ mg/L}$. Calculate total hardness and alkalinity present in water sample..

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

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

$$\text{CO}_2 = 11 \times \frac{100}{44} = 25 \text{ mg/l}$$

$$\text{HCO}_3^- = 122 \times \frac{100}{122} = 100 \text{ mg/l}$$

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+})
 $= 75 + 75 = 150 \text{ ppm}$

Alkalinity causing ions available here HCO_3^- , however there is CO_2 also available which cause acidity so total alkalinity will be $= \text{HCO}_3^- - \text{CO}_2 = 100 - 25 = 75 \text{ ppm}$.

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

$$300 - 75 = 225 \text{ ppm}$$

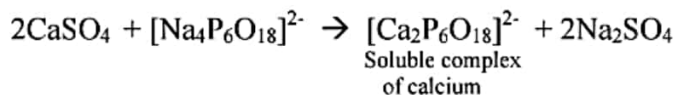
Suppose A mg of lime increase 225 ppm alkalinity

$$225 = A \times 100/74 \text{ CaCO}_3 \text{ eq.}$$

$$A = 166.5 \text{ mg/L}$$

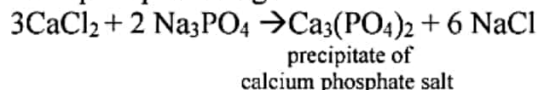
7. Why calgon conditioning is better than phosphate conditioning?

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



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.



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 = $100 \times 125 = 12500$ g NaCl

In the equivalent of $\text{CaCO}_3 = 12500 \times 50/58.5$ 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 = $8 \times 150 = 1200$ g NaCl

In the equivalent of $\text{CaCO}_3 = 1200 \times 50/58.5$ 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

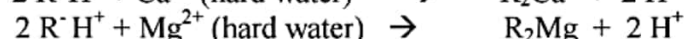
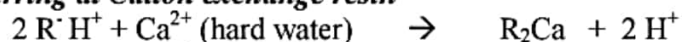
= 0.1 g/L of CaCO_3 eq.

= 100 mg/L or ppm

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

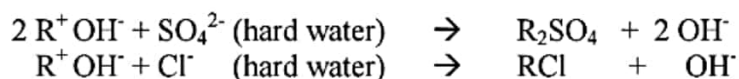
Demineralization process:

Reactions occurring at Cation exchange resin



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Reactions occurring at anion exchange resin



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 filtration 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.