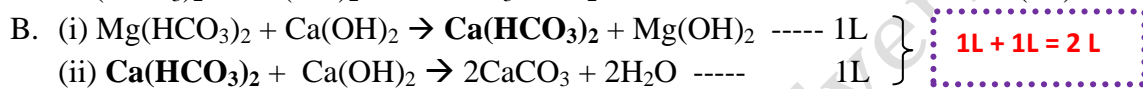
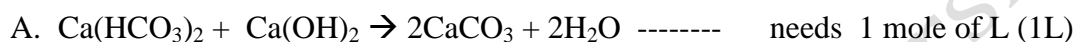


Chemicals required for various hardness constituents

Key Points:

1. Substances such as NaCl, Na₂SO₄, NaNO₃, KCl, K₂SO₄, KNO₃, SiO₂, Fe₂O₃, etc. do not consume any L & S and should therefore be excluded from the calculation of L & S requirements.
2. All substances must be converted into their respective CaCO₃ equivalents.
3. Ca-hardness is precipitated as CaCO₃, while Mg-hardness is precipitated as Mg(OH)₂.

Chemicals requirement for Temporary hardness constituents:



Or by combining eq. (i) and (ii) we get



✓ 1 mole of $\text{Ca}(\text{HCO}_3)_2$ needs 1 mole of Lime whereas 1 mole of $\text{Mg}(\text{HCO}_3)_2$ needs 2 moles of Lime.

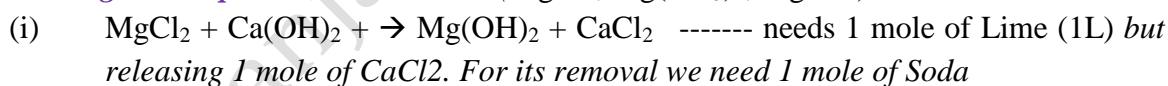
Chemicals requirement for Permanent hardness constituents:

A. **Calcium permanent hardness** (CaCl₂, Ca(NO₃)₂, CaSO₄)



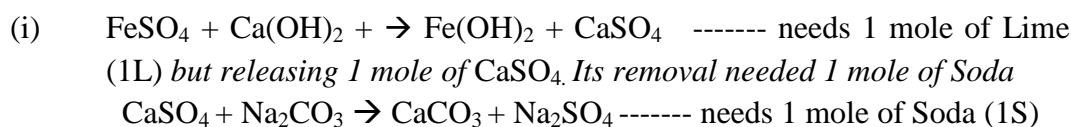
✓ *** All Calcium permanent hardness constituents [CaCl₂, CaSO₄, Ca(NO₃)₂] need only 1- mole of Soda (1S)

B. **Magnesium permanent hardness** (MgCl₂, Mg(NO₃)₂, MgSO₄)

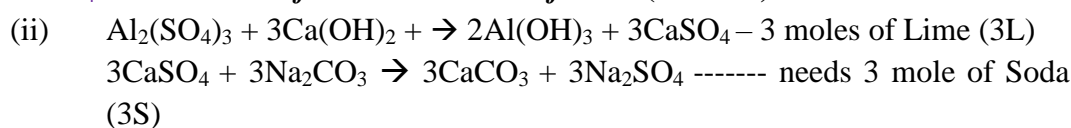


✓ So, 1 mole of Magnesium permanent hardness needs 1 mole of lime and 1 mole of Soda (1L + 1S).

Chemicals requirement for coagulants (FeSO₄, Al₂(SO₄)₃):



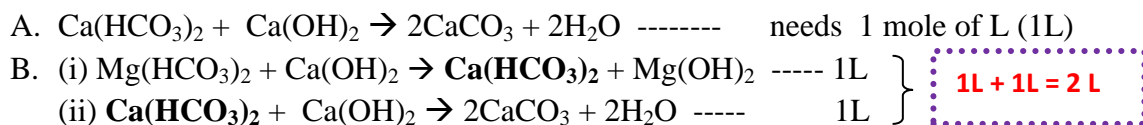
✓ So, FeSO₄ needs 1 mole of lime and 1 mole of Soda (1L + 1S).



✓ So, Al₂(SO₄)₃ needs 3 mole of lime and 3 mole of Soda (3L + 3S).

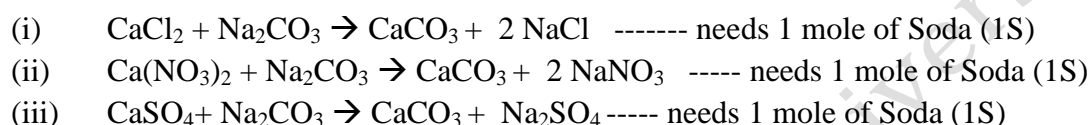
Q.1 Give reason that 1 mole of $\text{Ca}(\text{HCO}_3)_2$ needs 1 mole of Lime whereas 1 mole of $\text{Mg}(\text{HCO}_3)_2$ needs 2 moles of Lime. (write chemical reactions)

Ans.



Q. 2. Give reason that Calcium permanent hardness constituents need only 1- mole of Soda (1S).

Ans.

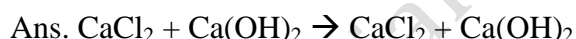


Q.3. Give reason that 1 mole of Magnesium permanent hardness needs 1 mole of lime and 1 mole of Soda (1L + 1S).

Ans. (i) $\text{MgCl}_2 + \text{Ca}(\text{OH})_2 \rightarrow \text{Mg}(\text{OH})_2 + \text{CaCl}_2$ ----- needs 1 mole of Lime (1L) but releasing 1 mole of CaCl_2 . For removal of CaCl_2 we need 1 mole of Soda as per the following reaction



Q.4. Give reason that lime is not consumed by CaCl_2 or any calcium-permanent hardness constituents.



See the above reaction, there is no change in reactant and product side. It means there is no reaction between these two constituents.

Solved Numerical

Note:

(A) Lime required for softening of 1L of hard water (mg) = $\frac{74}{100}$ (Lime consuming substances as CaCO_3 eq.) x Vol. of water x (100/% purity of lime)

(B) Soda required for softening of 1L of hard water (mg) = $\frac{106}{100}$ (Soda consuming substances as CaCO_3 eq.) x Vol. of water x (100/% purity of soda)

Solved numerical on Lime-soda Process

Example-1 A sample of water on analysis has been found to contain 100 mg/L of KHCO_3 and 200 mg/L of K_2SO_4 . Calculate the amount of lime and soda required for softening of 10,000 litres of hard water. (At. mass: K = 39, Ca = 40, H = 1, C = 12, O = 16, S = 32 g/mol)

Ans. The amount of lime and soda required = 0, as both are non hardness constituents.

Example-2 A sample of water on analysis has been found to contain 100 mg/L of $\text{Mg}(\text{HCO}_3)_2$ and 200 mg/L of K_2SO_4 . Calculate the amount of lime and soda required for softening of 10,000 litres of hard water. (At. mass: Na = 23, Mg = 24, H = 1, C = 12, O = 16, K = 39 g/mol, S = 32 g/mol)

Solution: Na_2SO_4 does not consume chemicals like lime and soda.

N.B: if purity of lime and soda is not mention then take % purity = 100

$\text{Mg}(\text{HCO}_3)_2$ as CaCO_3 eq. = $100 \times (100/146) = 68.493 \text{ mg/L}$

$\text{Mg}(\text{HCO}_3)_2$ require only 2L (no soda requirement, that is soda amount = 0)

So, lime required for softening of 10,000 L of hard water = $74/100(\text{Ca}(\text{HCO}_3)_2 \text{ CaCO}_3 \text{ eq.}) \times V \times (100/\% \text{ purity of lime})$

= $(74/100) \times 2 \times 68.493 \times 10,000 \text{ L} \times 100/100$ (here purity of lime 100%)

= 1013696.4 mg = 1.013 Kg (Ans.)

Example-3 A sample of water on analysis has been found to contain 150 mg/L of $\text{Ca}(\text{HCO}_3)_2$ and 100 mg/L of Na_2SO_4 . Calculate the amount of lime and soda required for softening of 15,000 litres of hard water after boiling the water for 20 min. (At. mass: Na = 23, Ca = 40, H = 1, C = 12, O = 16, S = 32 g/mol)

Solution: As boiling removes $\text{Ca}(\text{HCO}_3)_2$, lime and soda required will be zero.

Example-4 Calculate the amount of lime and soda required for softening of 100 L of hard water having 95 mg/L of MgCl_2 .

Solution: MgCl_2 needs 1L + 1S.

CaCl_2 as CaCO_3 eq. = $95 \times (100/95) = 100 \text{ mg/L}$

(A) Lime required = $74/100(\text{MgCl}_2 \text{ as } \text{CaCO}_3 \text{ eq.}) \times \text{Vol. of water} \times (100/\% \text{ purity of lime})$
= $(74/100) \times 100 \times 100 \times (100/100) = 7400 \text{ mg}$

(B) Soda required = $106/100(\text{MgCl}_2 \text{ as } \text{CaCO}_3 \text{ eq.}) \times \text{Vol. of water} \times (100/\% \text{ purity of soda})$
= $(106/100) \times 100 \times 100 \times (100/100) = 10600 \text{ mg}$

Example-6 Calculate the amount of lime required for softening of 100 L of hard water having 250 mg/L of CaCl_2 and 220 mg/L of KCl

Ans. KCl is a non hardness mass.

CaCl_2 do not consume any lime. So, lime required = 0

Example-7 A sample of water on analysis has been found to contain 150 mg/L of $\text{Ca}(\text{HCO}_3)_2$, 100 mg/L of $\text{Mg}(\text{HCO}_3)_2$ and 100 mg/L of KCl . Calculate the amount of soda required for softening of 15,000 litres of hard water.

Ans. Soda required = 0

Example-8 A sample of water on analysis has been found to contain 150 mg/L of $\text{Ca}(\text{HCO}_3)_2$ and 100 mg/L of CaSO_4 . Calculate the amount of lime and soda required for softening of 15,000 litres of hard water after boiling the water for 20 min. (At. mass: $\text{Ca} = 40$, $\text{H} = 1$, $\text{C} = 12$, $\text{O} = 16$, $\text{S} = 32$ g/mol)

Solution: Boiling will remove the $\text{Ca}(\text{HCO}_3)_2$. So only CaSO_4 will be remain in the hard water after boiling.

CaSO_4 consumes only soda (Mol. mass = 136 g)

CaSO_4 as CaCO_3 eq. = $100 \times (100/136) = 73.529$ mg/L

Soda required = $106/100$ (CaSO_4 as CaCO_3 eq.) $\times V \times (100/\%$ purity of soda)

= $106/100 \times 73.529 \times 15,000 \times 100/100$ (purity of soda is 100%)

= 1169111.1 mg = 1.169 Kg (take 1 mg = 10^{-6} Kg).

Here, lime required = 0

Example-9 A sample of water on analysis has been found to contain 150 mg/L of $\text{Ca}(\text{HCO}_3)_2$ and 200 mg/L of $\text{Ca}(\text{NO}_3)_2$. Calculate the amount of lime required for softening of 15,000 litres of hard water after boiling the water for 20 min. (At. mass: $\text{Ca} = 40$, $\text{H} = 1$, $\text{C} = 12$, $\text{O} = 16$, $\text{N} = 14$ g/mol)

Solution: Lime required = 0

Example-10 Calculate the amount of Lime and soda needed for the softening of 10 litres of hard water having 146 mg/l of $\text{Mg}(\text{HCO}_3)_2$.

Solution: We know that $\text{Mg}(\text{HCO}_3)_2$ consumes 2 moles of lime and no soda.

$\text{Mg}(\text{HCO}_3)_2$ as CaCO_3 eq. = $146 \times 100/146 = 100$ mg/L or ppm

- (i) **Lime reqd.** = $74/100$ ($2 \times \text{Mg}(\text{HCO}_3)_2$ as CaCO_3 eq.) $\times \text{Vol. of hard water} \times (100/\%$ purity)
= $(74/100) \times 100 \text{ mg/L} \times 10 \text{ L} \times (100/100) = 1480 \text{ mg}$
- (ii) **Soda Req.** = 0 mg.

Example-11 Calculate the amount of Lime and soda needed for the softening of 50,000 litres of hard water having $\text{Mg}(\text{HCO}_3)_2 = 144$ ppm, $\text{Ca}(\text{HCO}_3)_2 = 25$ ppm, $\text{MgCl}_2 = 95$ ppm, $\text{CaCl}_2 = 111$ ppm, $\text{Fe}_2\text{O}_3 = 25$ ppm, and $\text{Na}_2\text{SO}_4 = 15$ ppm. Also find the cost of chemicals for softening. (Given that cost of lime = Rs.10 per Kg and cost of soda = Rs. 100 per Kg)

Solution:

As Fe_2O_3 and Na_2SO_4 are non-hardness constituents, they do not consume Lime (L) and Soda (S)

Constituents	Strength (ppm or mg/L)	Mol. Mass	Chemical Need	CaCO_3 eq. (mg/L)
$\text{Mg}(\text{HCO}_3)_2$	144	146	2L	$144 \times (100/146) = 98.63$
$\text{Ca}(\text{HCO}_3)_2$	25	162	1L	$25 \times (100/162) = 15.43$
MgCl_2	95	95	L + S	$95 \times (100/95) = 100$
CaCl_2	111	111	S	$111 \times (100/111) = 100$

**n-factor = 2 for all the salts

Remember that Lime is reqd. by $\text{Mg}(\text{HCO}_3)_2$, $\text{Ca}(\text{HCO}_3)_2$, and MgCl_2

- (i) **Lime reqd.** = $74/100 [(2 \times \text{Mg}(\text{HCO}_3)_2 + \text{Ca}(\text{HCO}_3)_2 + \text{MgCl}_2); \text{all as } \text{CaCO}_3 \text{ eq.}] \times \text{Vol. of hard water} \times (100/\% \text{ purity})$
 $= (74/100) \times [2 \times 98.63 + 15.43 + 100] \text{ mg/L} \times 50,000 \text{ L} \times (100/100)$
 $= 11569530 \text{ mg} = 11569530 \times 10^{-6} \text{ Kg} = 11.5695 \text{ Kg}$

Soda is reqd. by only CaCl_2 and MgCl_2

Cost of lime = $11.5695 \times 10 = \text{Rs. } 115.695$

- (ii) **Soda reqd.** = $106/100 [(\text{CaCl}_2 + \text{MgCl}_2); \text{all as } \text{CaCO}_3 \text{ eq.}] \times \text{Vol. of hard water} \times (100/\% \text{ purity})$
 $= (106/100) \times [100 + 100] \text{ mg/L} \times 50,000 \text{ L} \times (100/100)$
 $= 10600000 \text{ mg} = 10600000 \times 10^{-6} \text{ Kg} = 10.6 \text{ Kg}$

Cost of soda = $10.6 \times 100 = \text{Rs. } 1060$

Total cost of chemicals for softening of 50,000L of hard water = $115.695 + 1060 = \text{Rs. } 1175.695$

Example-12 20,000 L of hard water to be softens by a chemist using a lime-soda softener. The budget allocated for the said purpose is Rs.500. Do you think the allocated amount is sufficient to get the job done? The sample contains $\text{Mg}(\text{HCO}_3)_2 = 73$ ppm, $\text{Ca}(\text{HCO}_3)_2 = 81$ ppm, $\text{MgCl}_2 = 95$ ppm, $\text{CaSO}_4 = 68$ ppm, and $\text{Na}_2\text{SO}_4 = 30$ ppm. The purity of lime is 95% and that of soda is 90%. The costs per 1 Kg of lime and soda are Rs. 100 and Rs. 100, respectively.

Solution: As Na_2SO_4 is a non-hardness constituent, it does not consume Lime (L) and Soda (S)

Constituents	Strength (ppm or mg/L)	Mol. Mass	Chemical Need	CaCO_3 eq. (mg/L)
$\text{Mg}(\text{HCO}_3)_2$	73	146	2L	$73 \times (100/146) = 50$
$\text{Ca}(\text{HCO}_3)_2$	81	162	1L	$81 \times (100/162) = 50$
MgCl_2	95	95	L + S	$95 \times (100/95) = 100$
CaSO_4	68	136	S	$68 \times (100/136) = 50$

Lime is reqd. by $\text{Mg}(\text{HCO}_3)_2$, $\text{Ca}(\text{HCO}_3)_2$, and MgCl_2

- (i) **Lime reqd.** = $74/100 [(2 \times \text{Mg}(\text{HCO}_3)_2 + \text{Ca}(\text{HCO}_3)_2 + \text{MgCl}_2); \text{all as } \text{CaCO}_3 \text{ eq.}]$
 $\times \text{Vol. of hard water} \times (100/\% \text{ purity})$
 $= (74/100) \times [2 \times 50 + 50 + 100] \text{ mg/L} \times 20,000 \text{ L} \times (100/95)$
 $= 3894736.842 \text{ mg} = 3894736.842 \times 10^{-6} \text{ Kg} = 3.894 \text{ Kg}$
 $(1 \text{ mg} = 10^{-6} \text{ Kg})$

Cost of lime = $3.894 \times 100 = \text{Rs. } 389.4$

Soda is reqd. by only MgCl_2 and CaSO_4

- (i) **Soda reqd.** = $106/100 [(\text{CaSO}_4 + \text{MgCl}_2); \text{all as } \text{CaCO}_3 \text{ eq.}] \times \text{Vol. of hard water}$
 $\times (100/\% \text{ purity})$
 $= (106/100) \times [50 + 100] \text{ mg/L} \times 50,000 \text{ L} \times (100/90)$
 $= 3533333.333 \text{ mg} = 3533333.333 \times 10^{-6} \text{ Kg} = 3.533 \text{ Kg}$

Cost of soda = $3.533 \times 100 = \text{Rs. } 353.3$

Now, total cost of chemicals = Rs. 389.4 + Rs. 353.3 = **Rs. 742.7**

No, the allocated amount is not sufficient to get the job done.

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