

Hardness of water



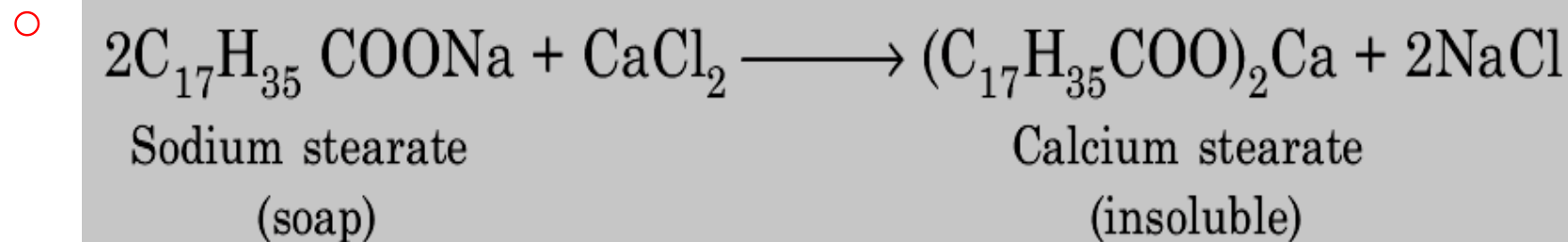
- Hardness of water is the characteristic of preventing lather formation of water with soap. Generally salts like chlorides, bicarbonates and sulfates of Ca^{2+} , Mg^{2+} and Fe^{2+} make water hard.



Hardness of water



- This hard water on treatment with soap which is stearic or palmitic acid salts of sodium or potassium causes white precipitate formation of calcium or magnesium stearate or palmitate.

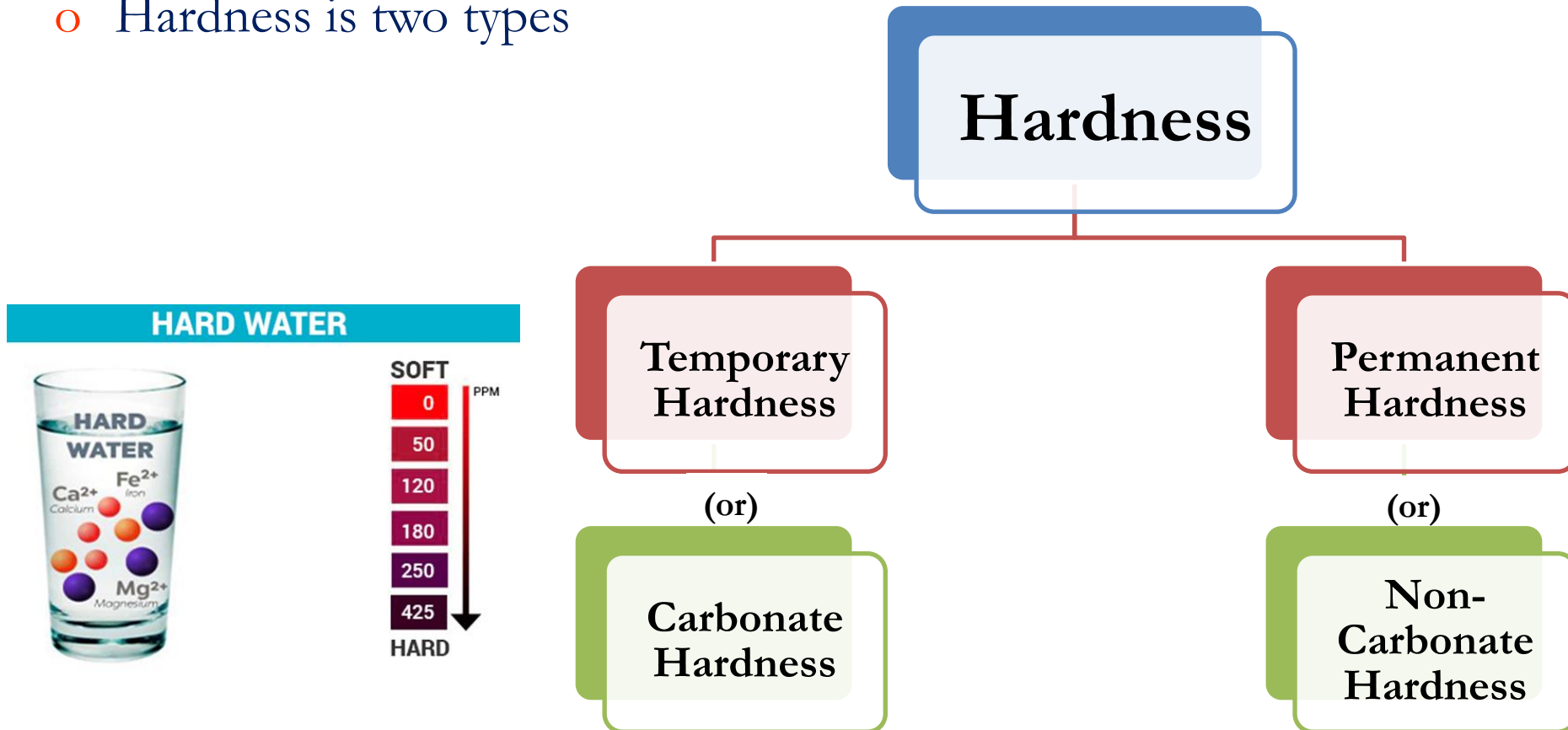


- Thus the cause of hardness is the precipitation of the soap and hence prevents lathering at first. When the hardness causing ions are removed as insoluble soaps, water becomes soft and forms lather.

Types of Hardness



- Hardness of water is due to dissolved salts of mainly calcium and magnesium as well as iron and other heavy metals.
- Hardness is two types

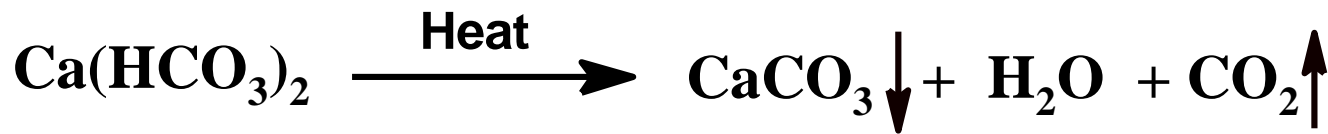


Types of Hardness



a) Temporary Hardness or Carbonate Hardness:

- Due to dissolved bicarbonates of calcium and magnesium and carbonates of iron and other heavy metals. Hence it is also called as carbonate hardness.
- Can be easily removed by boiling, where insoluble carbonates and hydroxides get precipitated at the bottom of the vessel, this it removes the hardness



Types of Hardness



a) Temporary Hardness or Carbonate Hardness:

- CaCO_3 is completely in-soluble in water.
- Whereas, MgCO_3 is slightly soluble in water but heating causes its hydrolysis into the much less soluble Mg(OH)_2 .



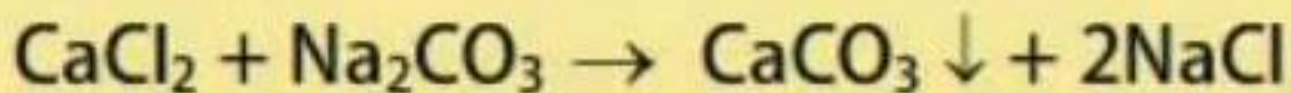
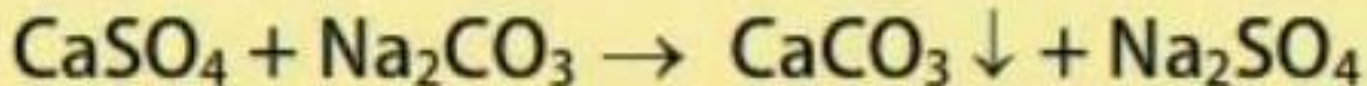
- So simple boiling and filtration of water remove temporary hardness.

Types of Hardness



b) Permanent Hardness or non-carbonate Hardness:

- This kind of hardness is due to the presence of dissolved chlorides and sulphates of calcium, magnesium, iron and other heavy metals.
- Permanent Hardness cannot be removed by simple boiling.
- Can be removed through zeolite, Lime-soda, ion-exchange processes.



Difference between Temporary Hardness and Permanent Hardness



Sr. No	Temporary hardness	Permanent hardness
1	Type of hardness which can be removed by simple techniques such as boiling is known as temporary hardness	Type of hardness which cannot be removed by simple techniques such as boiling is known as Permanent hardness
2	It is due to bicarbonates of <u>Ca, Mg</u> and carbonates of Mg hence known as carbonate hardness	It is due to other salts hence known as carbonate hardness
3	It is due to <u>Ca(HCO₃)₂</u> , Mg(HCO ₃) ₂ , MgCO ₃	It is due to CaCl ₂ , MgCl ₂ , CaSO ₄ , MgSO ₄ , Ca(NO ₃) ₂ , Mg(NO ₃) ₂ , FeCl ₂ , & FeSO ₄
4	It is known as alkaline hardness	It is known as <u>non alkaline hardness</u>
5	It is removed by boiling not by chemicals	It is removed by chemicals lime and soda
6	<u>Ca(HCO₃)₂</u> \rightarrow CaCO ₃ + CO ₂ + 2H ₂ O Mg(HCO ₃) ₂ \rightarrow Mg(OH) ₂ + 2CO ₂	CaSO ₄ + Na ₂ CO ₃ \rightarrow CaCO ₃ + Na ₂ SO ₄

Units of Hardness



- Both temporary and permanent hardness are expressed in mg/L (ppm) as equivalent of CaCO_3
- The choice of CaCO_3 is due to the fact that
 - It is the most insoluble salt in water
 - Besides, its molecular weight is 100 and equivalent weight is 50

Hardness

$$\text{Equivalent of } \text{CaCO}_3 = \frac{\text{Mass of hardness producing substance}}{\text{Molecular weight of hardness producing substance}} \times \frac{\text{Molecular weight of } \text{CaCO}_3}{100}$$



A sample hard water contains,

8.1 mg/L $\text{Ca}(\text{HCO}_3)_2$; 7.5 mg/L $\text{Mg}(\text{HCO}_3)_2$; 13.6 mg/L CaSO_4 ;
12.0 mg/L MgSO_4 and 2.0 mg/L MgCl_2 .

To calculate the hardness and express in CaCO_3 equivalents:

Constituent	Multiplication factor	CaCO_3 equivalents	Hardness
$\text{Ca}(\text{HCO}_3)_2 = 8.1 \text{ mg/L}$	100/162	$8.1 \times 100/162 = 5.0 \text{ mg/L}$	Temporary
$\text{Mg}(\text{HCO}_3)_2 = 7.5 \text{ mg/L}$	100/146	$7.5 \times 100/146 = 5.14 \text{ mg/L}$	
$\text{CaSO}_4 = 13.6 \text{ mg/L}$	100/136	$13.6 \times 100/136 = 10.0 \text{ mg/L}$	Permanent
$\text{MgSO}_4 = 12.0 \text{ mg/L}$	100/120	$12.0 \times 100/120 = 10.0 \text{ mg/L}$	
$\text{MgCl}_2 = 2.0 \text{ mg/L}$	100/95	$2.0 \times 100/95 = 2.11 \text{ mg/L}$	



Temporary hardness of water

$$\begin{aligned} \text{due to } \text{Ca}(\text{HCO}_3)_2 \text{ and } \text{Mg}(\text{HCO}_3)_2 &= 5.0 + 5.14 \\ &= \mathbf{10.14 \text{ mg/L or ppm CaCO}_3 \text{ eq.}} \end{aligned}$$

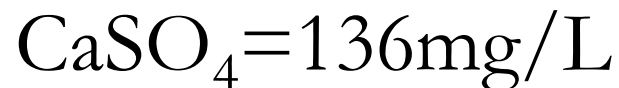
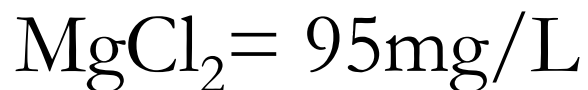
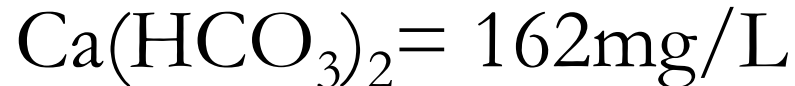
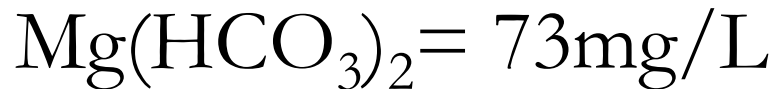
Permanent hardness of water

$$\begin{aligned} \text{due to } \text{CaSO}_4, \text{MgSO}_4 \text{ and } \text{MgCl}_2 &= 5.0 + 10.0 + 2.11 \\ &= \mathbf{17.11 \text{ mg/L or ppm CaCO}_3 \text{ eq.}} \end{aligned}$$

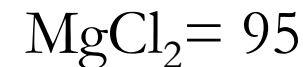
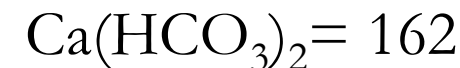
$$\begin{aligned} \text{Total hardness of water} &= 10.14 + 17.11 \\ &= \mathbf{27.25 \text{ mg/L or ppm CaCO}_3 \text{ eq.}} \end{aligned}$$



Calculate the temporary and total hardness of a water sample containing



Molecular weight





Solution: calculation of CaCO_3 equivalents:

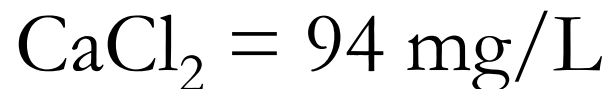
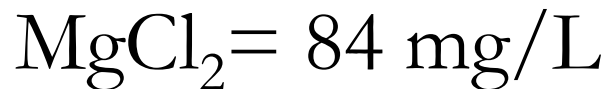
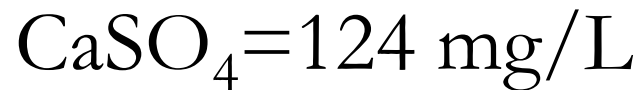
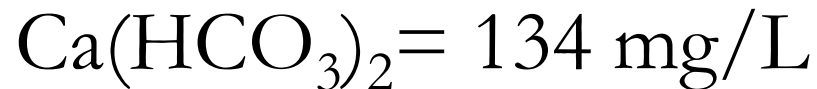
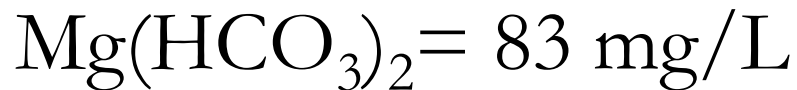
Constituent	Multiplication factor	CaCO_3 equivalent
$\text{Mg}(\text{HCO}_3)_2 = 73\text{mg/L}$	$100/146$	$73 \times 100 / 146 = 50\text{mg/L}$
$\text{Ca}(\text{HCO}_3)_2 = 162\text{mg/L}$	$100/162$	$162 \times 100 / 162 = 100\text{mg/L}$
$\text{MgCl}_2 = 95\text{mg/L}$	$100/95$	$95 \times 100 / 95 = 100\text{mg/L}$
$\text{CaSO}_4 = 136\text{mg/L}$	$100/136$	$136 \times 100 / 136 = 100\text{mg/L}$

\therefore Temporary hardness of water due to $\text{Mg}(\text{HCO}_3)_2$ and $\text{Ca}(\text{HCO}_3)_2 =$
 $= 100 + 50 = 150\text{mg/L}$ or ppm.

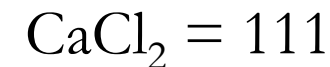
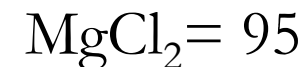
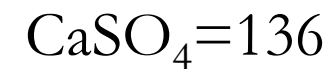
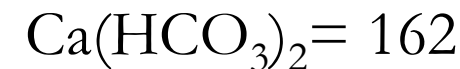
Total hardness of water = $50 + 100 + 100 + 100 = 350\text{ mg/L}$ or ppm.



Calculate the temporary and total hardness of a water sample containing



Molecular weight





Constituent	Multiplication factor	CaCO ₃ equivalent
Mg(HCO ₃) ₂ = 83 mg/L	100/146	56.8
Ca(HCO ₃) ₂ = 134 mg/L	100/162	82.7
CaSO ₄ = 124 mg/L	100/136	91.2
MgCl ₂ = 84 mg/L	100/95	88.4
CaCl ₂ = 94 mg/L	100/111	84.7

- **Temporary hardness** = 56.8 + 82.7 = **139.5 mg/L or ppm CaCO₃ equiv.**
- **Permanent hardness** = 91.2 + 88.4 + 84.7 = **264.3 mg/L or ppm CaCO₃ equiv.**
- **Total hardness** = 139.5 + 264.3 = **403.8 mg/L or ppm CaCO₃ equiv.**



Calculate total, carbonate and non-carbonate hardness of 1L water sample which contains

$\text{CaCl}_2 = 25.4 \text{ ppm}$; $\text{MgSO}_4 = 23.6 \text{ ppm}$; $\text{MgCl}_2 = 32 \text{ ppm}$; $\text{Ca}(\text{HCO}_3)_2 = 33.9 \text{ ppm}$; $\text{Mg}(\text{HCO}_3)_2 = 12.7 \text{ ppm}$ and $\text{NaCl} = 17 \text{ ppm}$.

(Atomic masses of $\text{Ca} = 40$; $\text{Cl} = 35.45$; $\text{S} = 32$; $\text{O} = 16$; $\text{C} = 12$; $\text{Mg} = 24$ and $\text{Na} = 23$)



Total hardness = 105.8 ppm

Permanent hardness = 76.2 ppm

Temporary hardness = 29.6 ppm