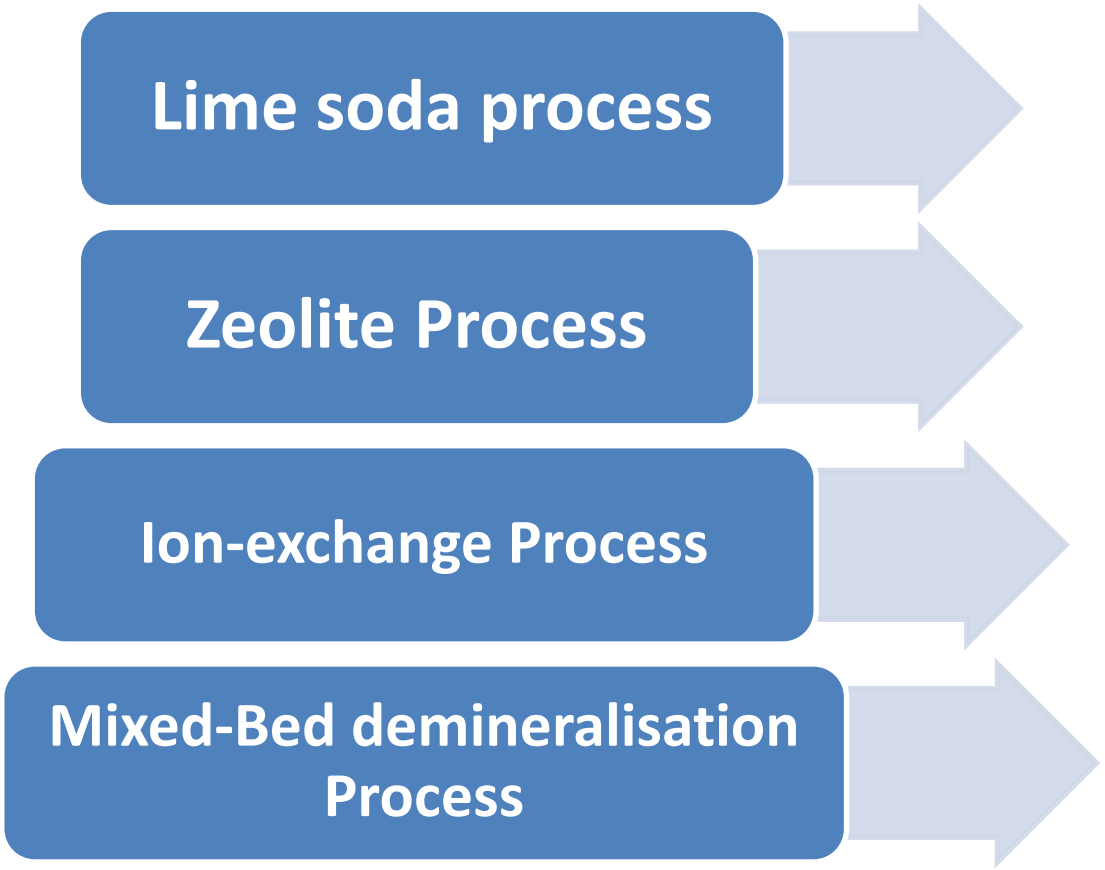
Softening of hard water – External treatment



Lime soda process

Very important method

Principle : The lime soda process involves the chemical conversion of all the soluble hardness causing salts by the addition of soda (Na_2CO_3) and lime [$Ca(OH)_2$]into insoluble precipitates which could easily be removed by settling and filtration

Functions of lime

Removes

1. temporary hardness

2.permanent Mg hardness

3.dissolved Fe, Al salts

4.Dissolved CO_2 and H_2S gases

5.Free mineral acids

Present in water

a) Removal of temporary Ca and Mg hardness

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$$

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + Mg(OH)_2\downarrow + 2H_2O$$

b) Removal of permanent Mg hardness

$$MgCl_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaCl_2$$

$$MgSO_4 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaSO_4$$

c) Removal of dissolved Fe and Al salts

$$FeSO_4 + Ca(OH)_2 \longrightarrow Fe(OH)_2\downarrow + CaSO_4$$

$$2Fe(OH)_2 + H_2O + 1/2O_2 \longrightarrow 2Fe(OH)_3\downarrow$$

$$Al_2(SO_4)_3 + 3Ca(OH)_2 \longrightarrow Al(OH)_3\downarrow + 3CaSO_4$$

d) Removal of dissolved CO_2 and H_2S gases

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + 2H_2O$$

$$H_2S + Ca(OH)_2 \longrightarrow CaS\downarrow + 2H_2O$$

e) Removal of free mineral acid

$$2HCl + Ca(OH)_2 \longrightarrow CaCl_2\downarrow + 2H_2O$$

$$H_2SO_4 + Ca(OH)_2 \longrightarrow CaSO_4\downarrow + 2H_2O$$

Functions of Soda

During the removal of Mg^{2+}, Fe^{2+}, Al^{3+}, HCl and H_2SO_4 by lime, permanent calcium hardness is introduced in the water due to formation of calcium salts
The permanent calcium hardness thus introduced on account of the treatment of water with lime and the permanent calcium hardness already present in water before lime treatment are removed by soda

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2NaCl$$

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + Na_2SO_4$$

The chemical reactions involved in the lime soda process are quite slow. Moreover, the precipitates formed particularly of $CaCO_3$ and $Mg(OH)_2$ are fine and have a tendency to form supersaturated solutions. This results in after deposition of these precipitates later in the pipes and boiler tubes leading to their clogging and corrosion.

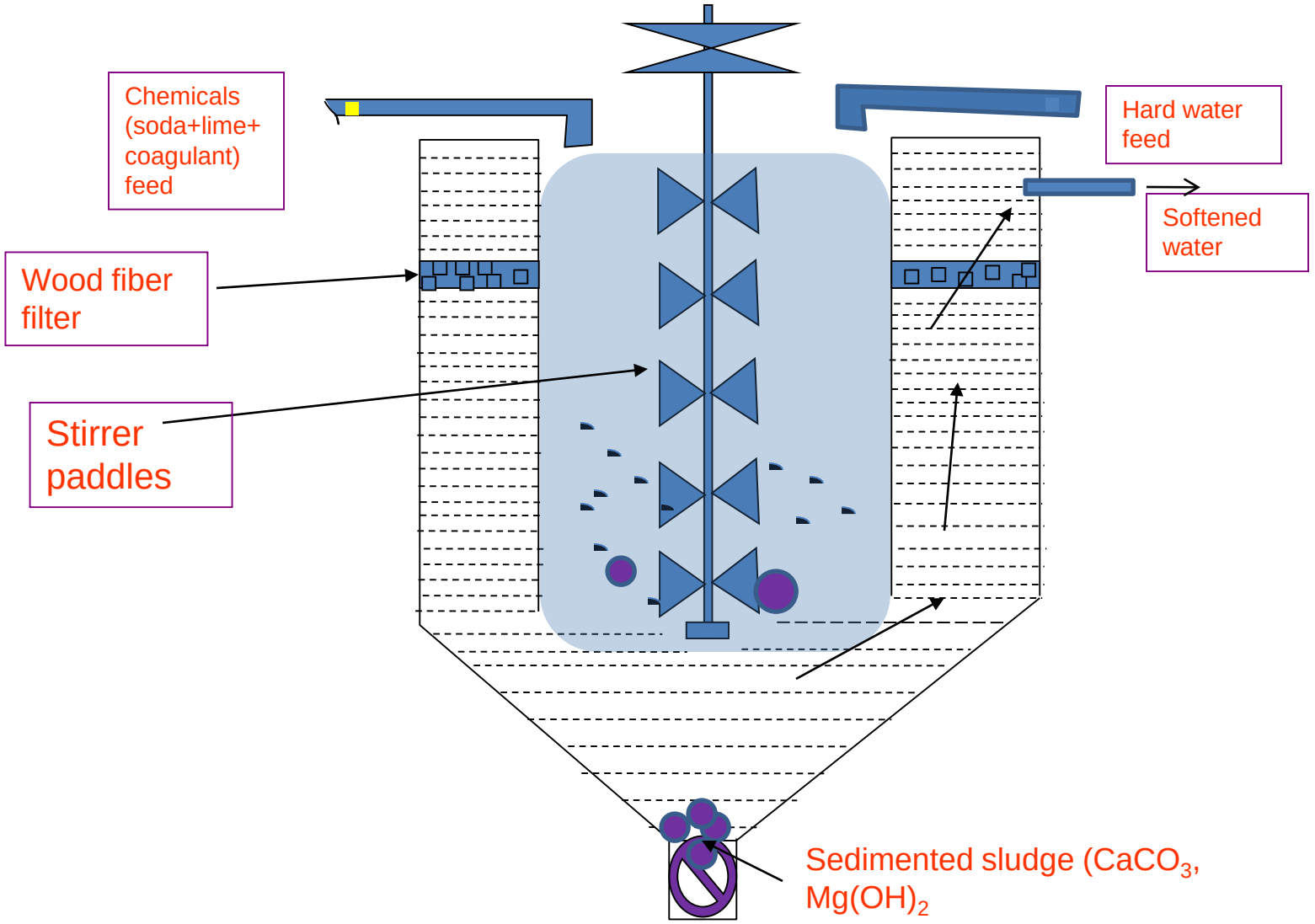
Some essential points to overcome above problem

a) **Thorough mixing of chemicals and water;**
b) **Allowing proper time for the completion of reactions**
c) **The use of accelerators such as active charcoal; and**
d) **The use of coagulants such as alum or $NaAlO_2$.**

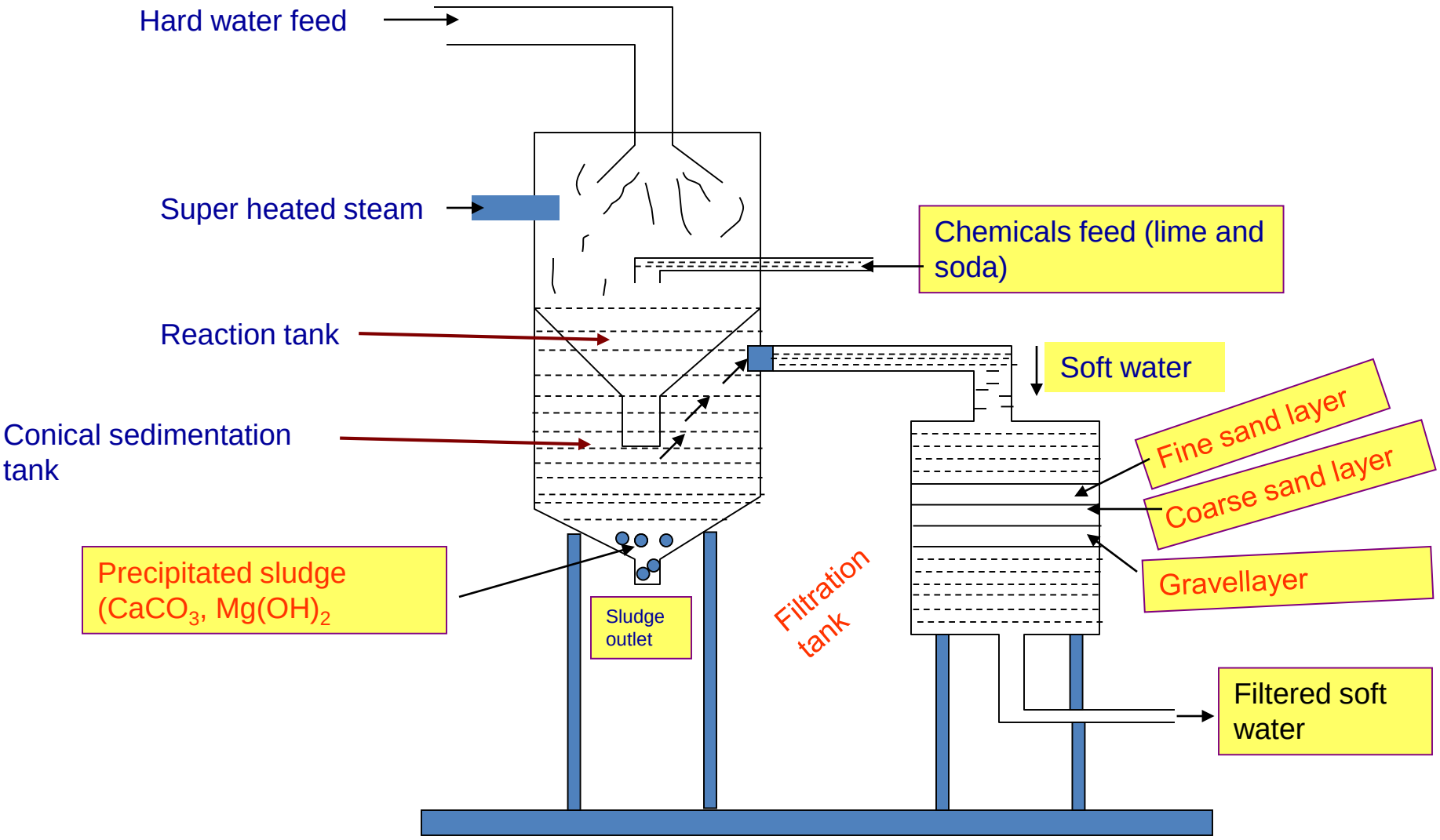
Process is further divided in to two types

1. Cold lime soda process
2. Hot lime soda process

Continuous cold lime soda softener



Continuous Hot Lime soda Process



Advantages

1. Economical
2. Hot lime soda process is much faster than the cold lime soda process
3. During this process pH value of water is increased hence the corrosion of pipe is reduced
4. Besides the removal of hardness, the quantity of minerals in water is also reduced
5. Due to alkaline nature of water, amount of pathogenic bacteria in water are also removed
6. Requires less amount of coagulants

Disadvantages

1. The softened water is not completely free from hardness (15-30ppm of hardness still remains)
2. Disposal of large amount of sludge is a problem
3. Careful operation and skilled supervision is required for efficient treatment of water

Differences between the cold and hot lime-soda processes

S.No	Cold lime soda process	Hot lime soda process
1	It is done at room temperature(25-30^{o} C)	It is done at elevated temperature(94-100^{o}C)
2	It is a slow process	It is a rapid process
3	The use of coagulants is must	Coagulants not needed
4	Filtration is not easy	Filtration is easy as the viscosity of water becomes low at elevated temperatures
5	Softened water has residual hardness around 60ppm	Softened water has residual hardness of 15-30ppm
6	Dissolved gases are not removed	Dissolved gases such as CO_2 are removed to some extent
7	Low softening capacity	High softening capacity

NUMERICAL PROBLEMS

1. First of all calculate the amount of all substances present in the water sample in terms of $CaCO_3$ equivalent
2. Add all $CaCO_3$ equivalent of substances to get total hardness
3. Substances like NaCl, KCl, Na_2SO_4, SiO_2, Fe_2O_3 etc do not impart any hardness, therefore , these do not consume any soda or lime. Hence these should not be taken into consideration for calculating the lime and soda requirements.
4. When the impurities are given as $CaCO_3$ or $MgCO_3$.The amount expressed as $CaCO_3$ does not require any further conversion. However the amount of $MgCO_3$ should be converted into $CaCO_3$ equivalent

Lime requirement

The amount of lime required for softening of water =

74/100 (temporary Ca hardness + 2 X temporary Mg Hardness + Permanent Mg hardness + CO_2 + HCl + H_2SO_4 + Fe^{2+} + Al^{3+} + HCO_3^- - $NaAlO_2$); All expressed in terms of $CaCO_3$ equivalents

The amount of lime required for softening of water = 106/100 (permanent Ca hardness + Permanent Mg hardness + HCl + H_2SO_4 + Fe^{2+} + Al^{3+} - HCO_3^- - $NaAlO_2$) All expressed in terms of $CaCO_3$ equivalents

Following points are to be noted-

1 equivalent of HCO_3 require 1 equivalent of lime which simultaneously produces 1 equivalent of CO_3^{2+}, which may be regarded as equal to 1 equivalent of soda.

$Ca(OH)_2 + 2HCO_3 \rightarrow \mathbf{CaCO_3} + H_2O + CO_3^{2+}$

This is why corresponding quantity of HCO_3 in equivalent has been substracted in the calculation of soda requirement.

2. $NaAlO_2$ require neither lime nor soda . 1 equivalent = 1 equivalent of OH^-