Lecture 4. The water in the chemical industry. Industrial water treatment. Water Purification.

- **Natural waters:**
- Atmospheric waters,
- Surface waters,
- Ground waters.

Classification of Impurities in water

- Physical Impurities - Dissolved Solids/Salts
- Chemical Impurities - Inorganic & Organic Chemicals
- Biological Impurities - Pathogens, algae, fungi,viruses...

1) Colour
2) Turbidity
3) Taste
4) Odour
5) Conductivity

1) Acidity (pH)
2) Gases (CO_2- O_2, NH_3)
3) Minerals
4) pH
5) Salinity
6) Alkalinity
7) Hardness

1) Microorganism
2) Water Bodies

Hardness

Type of Hardness:

– Temporary or Carbonate Hardness
– Permanent Hardness or non-carbonate Hardness.

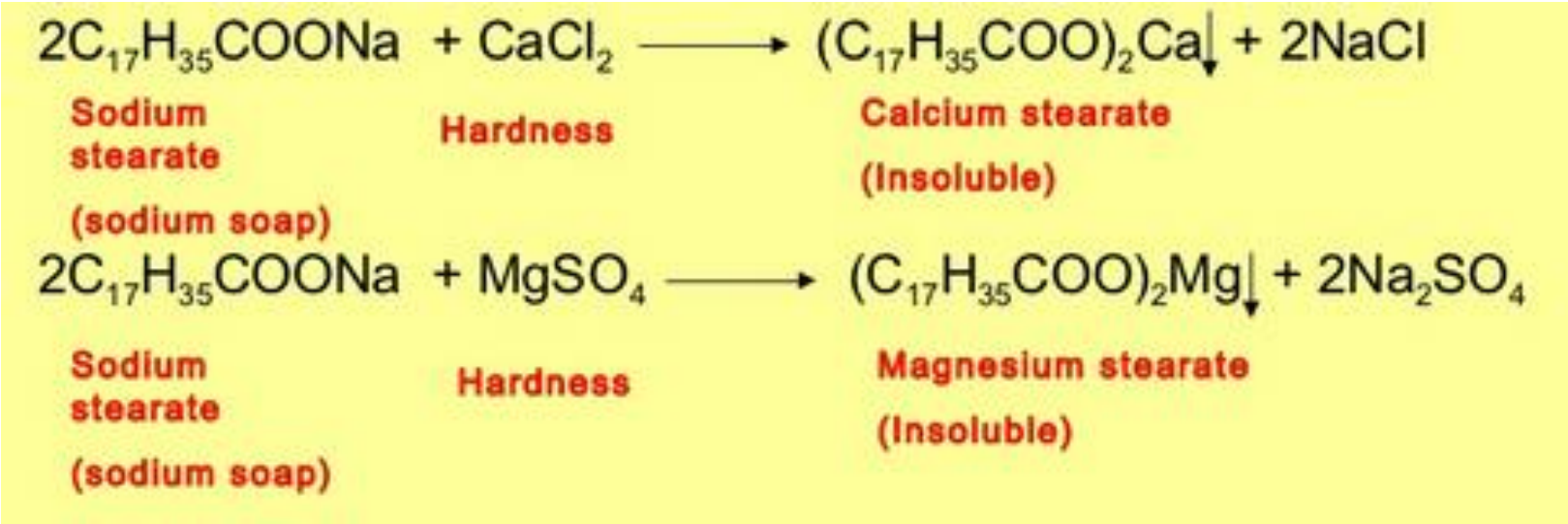
Total hardness includes both temporary and permanent hardness caused by calcium and magnesium compounds.

Temporary Hardness

- Temporary Hardness is caused by the presence of dissolved bicarbonate of calcium, magnesium and other heavy metals and the carbonate of iron. It is mostly destroyed by more boiling of water, when bicarbonates are decomposed yielding insoluble carbonates.

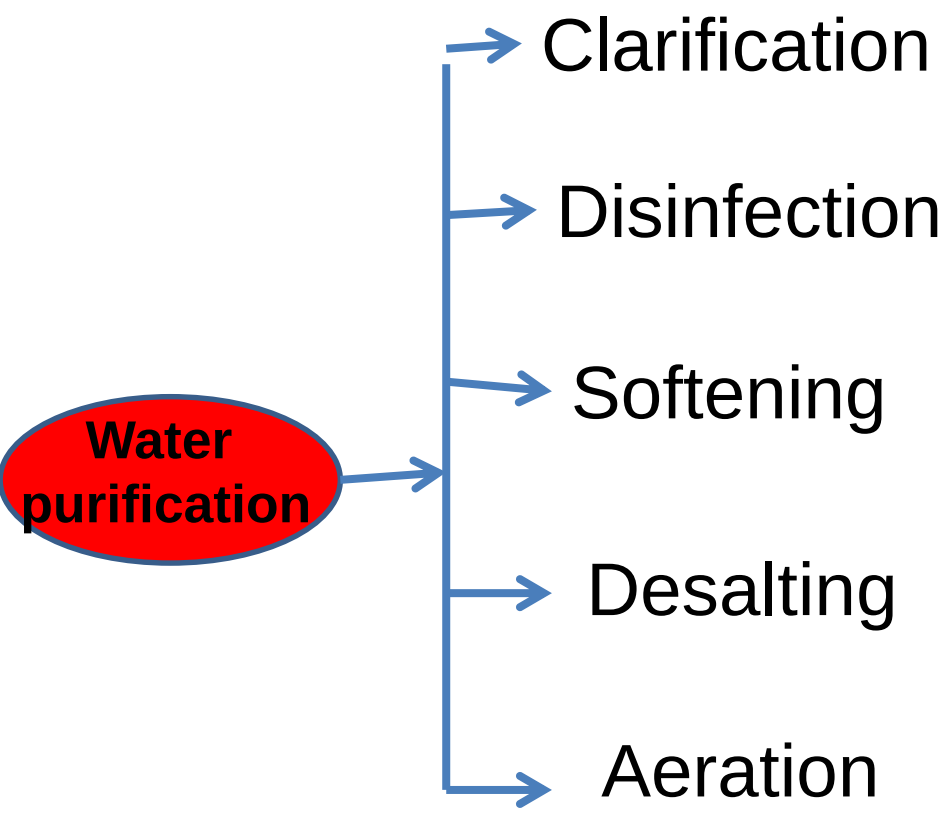
Permanent Hardness

Non Carbonate Hardness is due to the presence of chlorides, sulfates of calcium, Magnesium, iron and other heavy metals.



Water Hardness Scale		
Grains/Gal	**mg/L & ppm**	**Classification**
Less than 1	Less than 17.1	**Soft**
1 – 3.5	17.1 - 60	**Slightly Hard**
3.5 - 7	60 - 120	**Moderately Hard**
7 - 10	120 - 180	**Hard**
Over 10	Over 180	**Very Hard**

Industrial water treatment



Clarification

- **Clarification –coagulation-flocculation, sedimentation, and filtration**

Disinfection

Current Methods of Disinfection • Large-Scale: – Chlorination – Ozone – UV irradiation • Small Scale: – Boiling – Iodine tablets – Filters

Water softening

- **Water softening - the replacement of "hard" ions such as Ca^{2+} and Mg^{2+} by Na^{+}**

Water softening

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

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

2) $MgSO_4 + Na_2CO_3 = MgCO_3\downarrow + Na_2SO_4$

$CaSO_4 + Na_2CO_3 = CaCO_3\downarrow + Na_2SO_4$

$MgCl_2 + Na_2CO_3 = MgCO_3\downarrow + 2NaCl$

3) $3Ca(HCO_3)_2 + 2Na_3PO_4 = Ca_3(PO_4)_2\downarrow + 6NaHCO_3$

$MgCl_2 + 2Na_3PO_4 = Mg_3(PO_4)_2\downarrow + 6NaCl$

Desalting

- 1) **Ion Exchange;**
- **2) Distillation;**
- **3) Electrodialysis**.

Ion Exchange

Ion exchange materials are insoluble substances containing loosely held ions which are able to be exchanged with other ions in solutions which come in contact with them.

Ion exchangers are insoluble acids or bases which have salts which are also insoluble, and this enables them to exchange either positively charged ions (**cation exchangers**) or negatively charged ones (**anion exchangers**).

Cation exchange:

Na_2 [Cat] + $Ca(HCO_3)_2$ = Ca[Cat] + $2NaHCO_3$

Na_2 [Cat] + $MgSO_4$ = Mg[Cat] + Na_2SO_4

H_2 [Cat] + $MgCl_2$ = Mg[Cat] + 2HCl

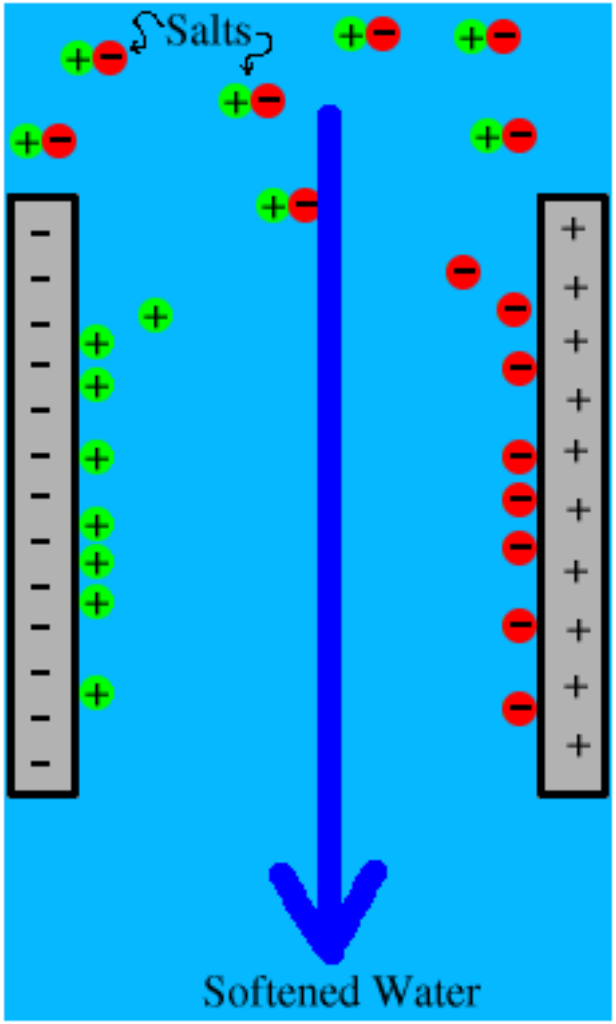
H_2 [Cat] + NaCl = Na[Cat] +HCl

Anion exchange:

[An]Cl + NaOH = [An]OH + NaCl

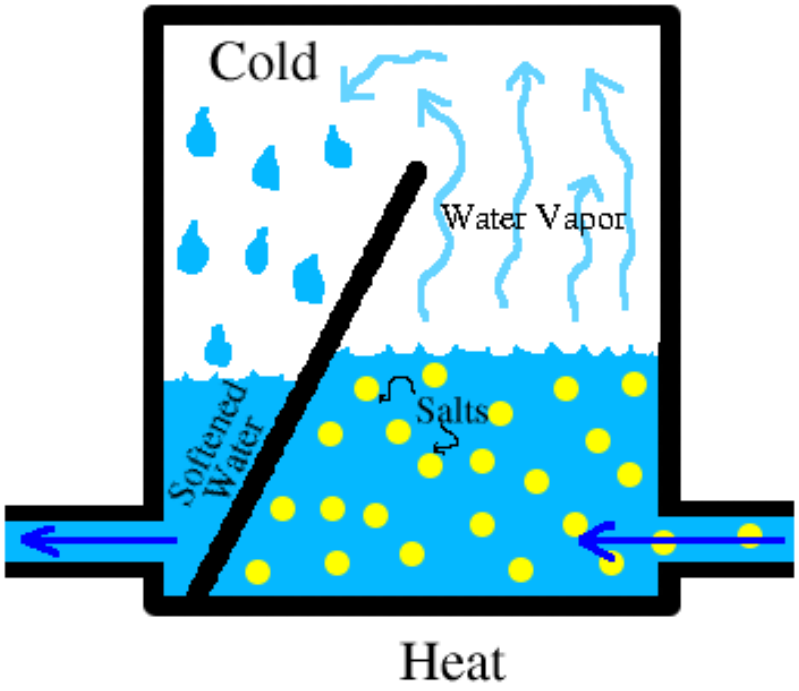
Electrodialysis

Electrodialysis involves passing water between two plates with opposite electrical charges. The metals in the water are attracted to the plate with the negative charge while the non-metals are attracted to the plate with the positive charge. Both types of ions can be removed from the plates and discarded. Electrodialysis is used on very hard water, with a hardness of more than 500 mg/L as calcium carbonate.



Distillation

Distillation involves the evaporation of water. The evaporated water leaves behind all hardness compounds, softening the water.



Aeration

Aeration is the process to remove dissolved gases, such as carbon dioxide, hydrogen sulfide, and to oxidize dissolved metals such as iron. It can also be used to remove volatile organic chemicals (VOC).

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$$