D Y PATIL
RAMRAO ADIK INSTITUTE OF TECHNOLOGY
NAVI MUMBAI

Subject Name: Engineering Chemistry

Unit No:1

Water

Faculty Name : Mrs. Rupal Agme-Jadhav

IMPURITIES IN WATER

There are three types of impurities present in water.

1 Physical Impurities

2. Chemical Impurities

3.Biological Impurities

1.Physical Impurities

- **These include colour, turbidity, taste, odour etc.**
- **Colour in water is due to presence of metallic subtances like salts of iron,manganese, algae etc.**
- **Turbidity is due to colloidal matter.**

Notes by: : Mrs. Rupali Agme-Jadhav

IMPURITIES IN WATER

1.Physical Impurities

- **Different taste is due to the presence of metallic ions like iron, aluminium and manganese etc.**
- **Odour in water is undesirable for domestic as well as industrial purposes.**
- **Disagreeable odour is due to the presence of living organisms,bacteria, fungi and weeds etc.**

Notes by: : Mrs. Rupali Agme-Jadhav

IMPURITIES IN WATER

2Chemical Impurities

- **These include inorganic and organic chemicals released from dyes, paints, drugs, insecticides, pesticides, detergents and textiles etc.**
- **Acidity in water is harmful. Surface water and ground water attain acidity from industrial wastes like acid, mine, drainage etc.**
- **Acidity is caused by the presence of free CO_2.**

Notes by: : Mrs. Rupali Agme-Jadhav

IMPURITIES IN WATER

2.Biological Impurities

- **These are algae, pathogenic bacteria, fungi, viruses, parasites etc.**
- **The source of these contaminations is discharge of domestic and sewage wastes atc.**

HARDNESS OF WATER

- **Hardness of water is that characteristic which prevent the lathering of soap.**
- **Water is said to be hard when it does not produce lather readily with soap in contrast to soft water.**
- **Hardness of water is due to the presence of dissolved salts of calcium, magnesium and other heavy metals. These metal ions form insoluble precipitate with the fatty acid components of soap.**

HARDNESS OF WATER

- **Soap generally consists of sodium salts of long chain fatty acid such as oleic, palmetic and •Stearic acid. Hard water when treated with soap, sodium or potassium salt of higher fatty acid does not produce lather but forms precipitate.**
- **Typical reaction of soap (sodium stearate)with calcium chloride and magnesium sulphates can be written as follows:**

$$2C_{17}H_{35}COONa + CaCl_2 \rightarrow (C_{17}H_{35}COO)2Ca\downarrow + 2NaCl$$

Sodium stearate (Soap) Hardness Calcium stearate(Insoluble)

HARDNESS OF WATER

- **Typical reaction of soap (sodium stearate)with magnesium sulphates can be written as follows:**

$$2C_{17}H_{35}COONa + MgSO_4 \rightarrow (C_{17}H_{35}COO)_2Mg\downarrow + Na_2SO_4$$

Sodium stearate (Soap) Hardness Magnesium stearate(Insoluble)

UNITS OF HARDNESS

DIFFERENT UNITS OF HARDNESS

1. PPM: May be defined as the no. of parts (by wt) of $CaCO_3$ equivalent hardness +nt per million parts (by wt) of water

2. mg/L: It is the no of mg of $CaCO_3$ equivalent hardness present per liter of water

   1mg/L=1mg of $CaCO_3$ eq. hardness per liter of water

   As mass of 1 L water = 1 Kg = 1000g = 1000x1000mg = 10^6 mg;

   So, 1mg/L = 1mg of $CaCO_{3\ eq.}$ hardness per 10^6 mg of water=1ppm 1mg/L = 1ppm

One litre of water has a **mass** of almost exactly one kilogram when measured at its maximal density, which occurs at about 4 °C.

HARD AND SOFT WATER

- **Water which does not produce lather with soap solution readily but forms a white curd is called hard water.**
- **Water which produce lather easily with soap solution is called as soft water.**

TYPES OF HARDNESS OF WATER

There are two types hardness:

i) **Temporary Hardness**
ii) **Permanent Hardness**

DIFFERENCE BETWEEN T. H. & P. H. OF WATER

TEMPORARY HARDNESS	PERMANENT HARDNESS
It is due to bicarbonates & carbonates of Calcium, magnesium, iron and other heavy metals.	It is due to the chlorides, sulphates, nitrates of calcium, magnesium, iron and other than carbonates & bicarbonates.
It is known as carbonate or alkaline hardness.	It is known as non- carbonate or non-alkaline hardness.
Temporary hardness can be removed by simple technique such as boiling & filtering.	Permanent hardness can not be removed by simple technique such as boiling & filtering.
Temporary hardness leads to formation of loose deposits of carbonates & hydroxides of Ca & Mg respectively.	Permanent hardness leads to formation of adherent scales.

DIFFERENCE BETWEEN HARD & SOFT WATER

SR. NO.	HARD WATER	SOFT WATER
1.	Hard water is one which does not produce lather with soap solution readily but forms a white curd.	Soft water gives lather easily on shaking it with soap solution.
2.	Hard water contain dissolved calcium & magnesium salts.	Soft water does not contain dissolved calcium & magnesium salts in it.

IMPURITIES IN WATER

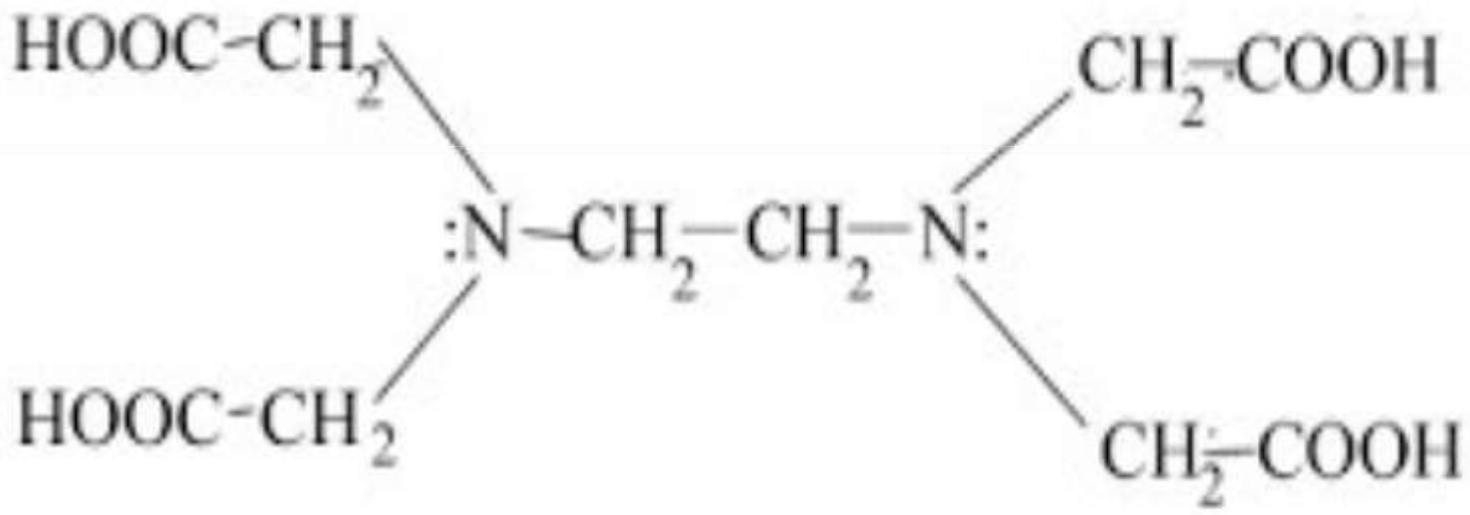
Table 3.9.1 Impurities in water

Name	Symbol	Common name	Effect
Calcium carbonate	$CaCO_3$	Chalk, limestone	Soft scale
Calcium bicarbonate	$Ca(HCO_3)_2$		Soft scale + CO_2
Calcium sulphate	CaSO4	Gypsum, plaster of paris	Hard scale
Calcium chloride	$CaCl_2$		Corrosion
Magnesium carbonate	$MgCO_3$	Magnesite	Soft scale
Magnesium sulphate	$MgSO_4$	Epsom salts	Corrosion
Magnesium bicarbonate	$Mg(HCO_3)_2$		Scale, corrosion
Sodium chloride	NaCl	Common salt	Electrolysis
Sodium carbonate	Na_2CO_3	Washing soda or soda	Alkalinity
Sodium bicarbonate	$NaHCO_3$	Baking soda	Priming, foaming
Sodium hydroxide	NaOH	Caustic soda	Alkalinity, embrittlement
Sodium sulphate	Na_2SO_4	Glauber salts	Alkalinity
Silicon dioxide	SiO_2	Silica	Hard scale

DETERMINATION OF HARDNESS OF WATER BY

EDTA METHOD

Hardness of water can be determined by EDTA method. The structure of Ethylene Diamine Tetra-acetic acid is as:

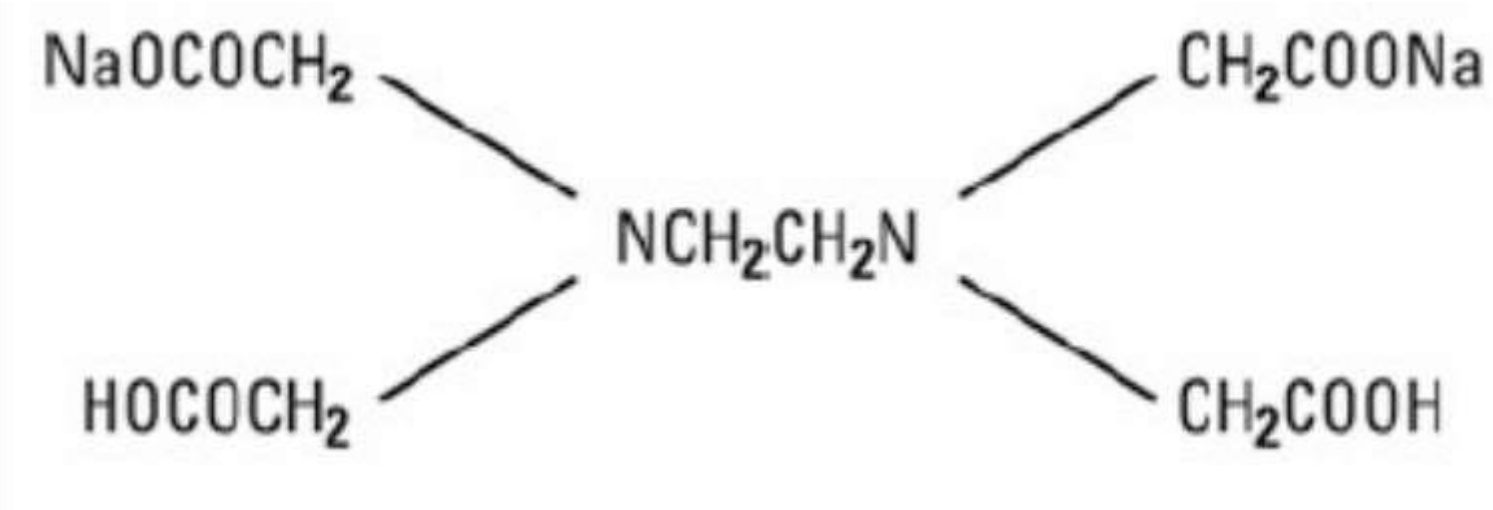


structure of EDTA

DETERMINATION OF HARDNESS OF WATER BY

EDTA METHOD

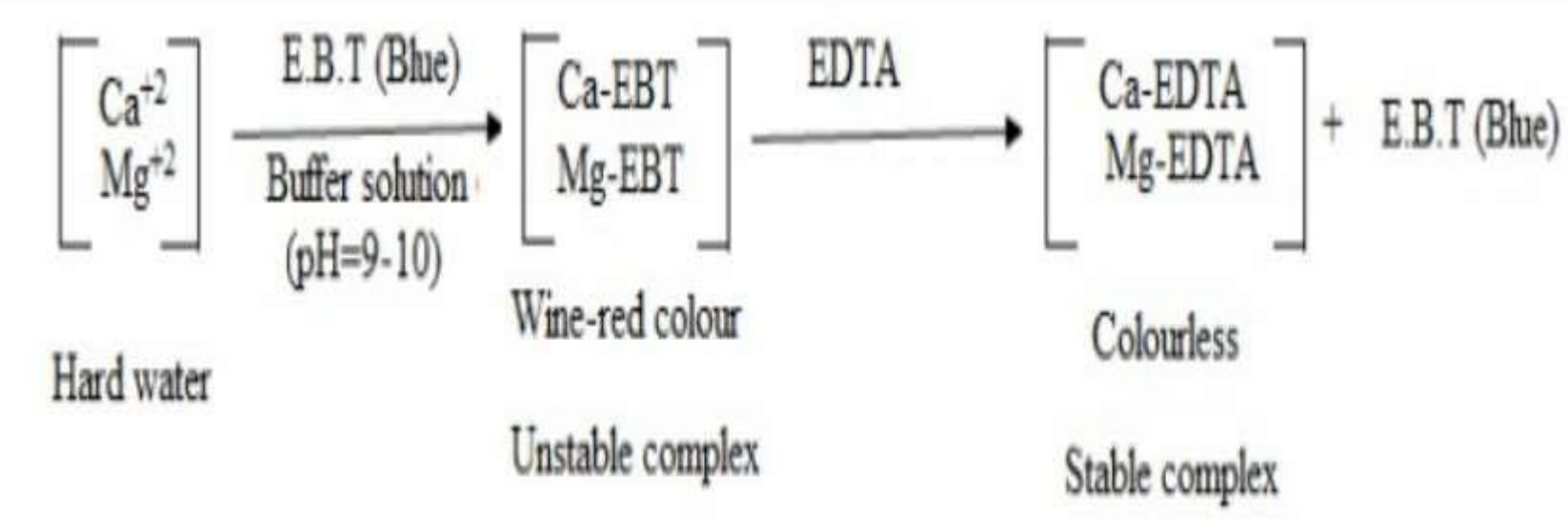
- **This is a complexometric method, as EDTA forms complex ions with hardness causing Ca2+ & Mg2+ ions present in water. It is accurate, convenient & rapid method.**
- **EDTA is used in the form of its disodium salt. It reacts quickly with hardness causing metal ions to form cyclic coordination complex.**



DETERMINATION OF HARDNESS OF WATER BY

EDTA METHOD

- **To determine the equivalent point, an indicator Eriochrome black-T IS used. It is an alcoholic solution of blue dye.**
- **It forms an unstable wine-red complex with Ca2+ & Mg2+ ions.**



DETERMINATION OF HARDNESS OF WATER BY

EDTA METHOD

- **This indicator is effective at pH of about 10. A buffer solution of NH_4OH & NH_4Cl is used to maintain pH = 10.**
- **When EBT indicator is added to hard water with buffer solution, few metals combine with EBT to give wine red unstable complex.**
- **During the course of titration against EDTA solution, EDTA combines with free metal ions to give stable complex of M-EDTA & The wine red colour changes to blue colour due to EBT. Thus the change of wine red colour to blue colour is the end point of titration.**

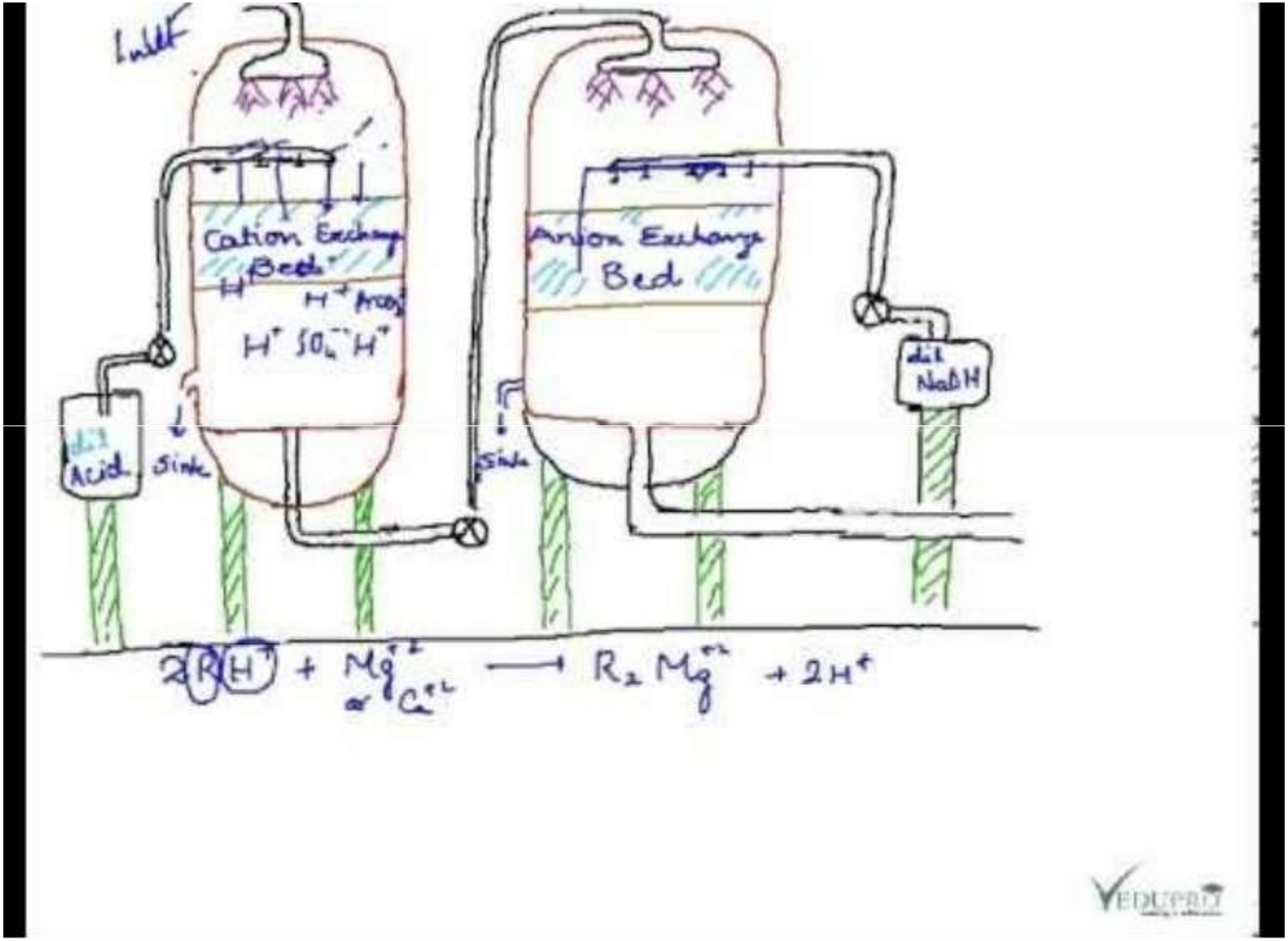
WATER TREATMENT (SOFTENING)

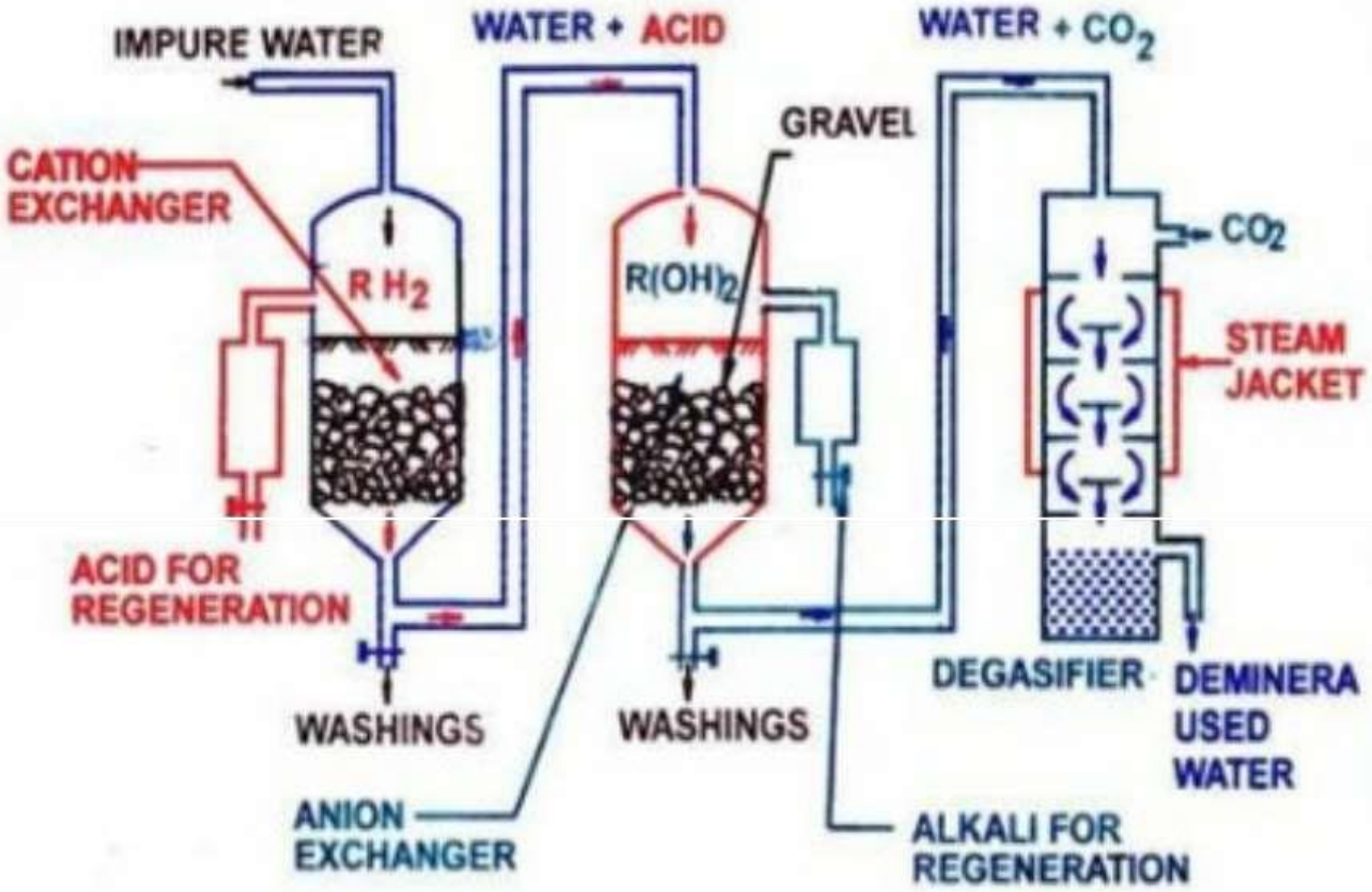
The process of removing or reducing the concentrations of hardness causing salts from water is called as softening of water.

The important methods generally employed for softening are:

A. Ion exchange Process

DEMINERALIZATION PROCESS





DEMINERAISATION PROCESS BY ION-EXCHANGE

ION EXCHANGE PROCESS

- **Ion exchange process is also called as Deionization or Demineralization Process Ion exchange resins are used for softening Of water.**
- **Ion exchange resins are long chain cross link**
- **Ion exchange resins are long chain cross link organic polymers having functional groups through which various ins are exchanged.**

There are two types of resins.

1. **Cation Exchange Resins**
2. **Anion Exchange Resins**

ION EXCHANGE PROCESS

1. Cation Exchange Resins

- **They are represented as RH^+ or RH_2**
- **The resins containing acidic functional groups (-COOH), -SO_3H etc. are capable of exchanging their H^+ ions with all the type of cations.**

2. Anion Exchange Resins

- **They are represented as $R'OH^-$ or $R(OH)_2$**
- **The resins containing basic functional groups -NH_2, = NH etc. are capable of exchanging their OH^- ions with all the type of anions.**

ION EXCHANGE PROCESS

Principle :

- **When hard water is first passed through the cation exchanger bed which remove all the type of cations like Ca, Mg , Na and releases hydrogen ion.**
- **After this the acidic hard water is passed through an anion exchanger bed which removes all the type of anions present in water, and equivalent amount of OH- ions are released from it to water.**
- **Finally H+ ions released from cation exchanger bed & OH- ions from anion exchange bed combine to produce water molecule.**
- **As the water is coming out is free from all the type of ions thats why the process is called as ion exchange process.**

ION EXCHANGE PROCESS

Reactions:

$$2RH^{+} + Ca^{+2} \rightarrow R_2Ca^{+2} + 2H^{+}$$

$$2RH^{+} + Mg^{+2} \rightarrow R_2Mg^{+2} + 2H^{+}$$

$$R'OH^{-} + Cl^{-} \rightarrow R'Cl^{-} + OH^{-}$$

$$2\,R'OH^{-} + SO_{4_{2-}} \rightarrow R'SO_{4_{2-}} + 2OH_{-}$$

$$H^{+} + OH^{-} \rightarrow H_2O$$

ION EXCHANGE PROCESS

Regeneration Reactions:

$$R_2Ca^{+2} + 2H^{+} \rightarrow 2RH^{+} + Ca^{+2} \text{ (washing)}$$

$$R_2\,SO_{42-} + 2\,OH^{-} \rightarrow 2R'OH^{-} + SO_{42-} \text{ (washing)}$$

ION EXCHANGE PROCESS

Regeneration :

- **When cation & anion exchangers are exhausted completely (i.e. They lost their capacity to exchange H+ & OH- ions) regeneration process is carried out.**
- **The exhausted cation exchanger is regenerated by passing a solution of dil. HCl or dil. H_2SO_4.**
- **The exhausted anion exchanger is regenerated by passing a solution of dil. NaOH.**

ION EXCHANGE PROCESS

Advantages :

- **It produces water of very low hardness about 2ppm.**
- **Highly acidic & alkaline water can be softened.**

Disadvantages :

- **The equipment is costly.**
- **More costly chemicals are needed.**

DIFFERENCE BETWEEN BOD & COD

BOD	COD
The biological oxygen demand (BOD) is defined as the amount of dissolved oxygen in parts per million required by the microbes for the decomposition of organic matter present in the sewage sample	The chemical oxygen demand (COD) is defined as the measure of oxygen in parts per million required for the oxidation of organic as well as inorganic compounds present in the sewage sample.
It is the basic parameter to determine the level of organic matter which can be oxidized biologically.	It is the basic parameter to determine the level of organic matter which can be oxidized chemically
Slow process.	Fast process.
It takes five days.	It takes 2-3 hours.
BOD values are generally less than COD values.	COD values are generally greater than BOD values.

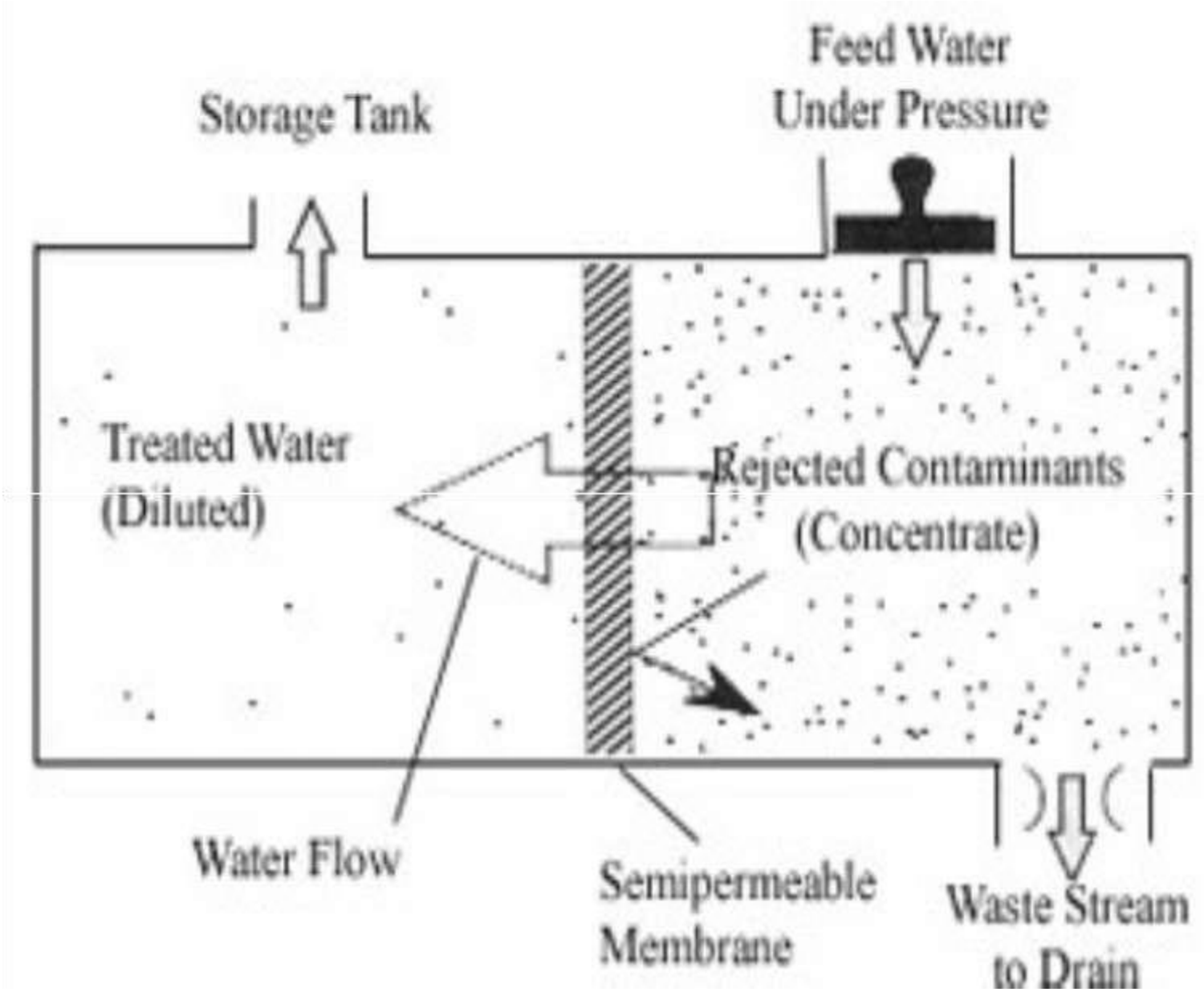
REVERSE OSMOSIS

- When two solution of different concentrations of the same solute are separated by a semi permeable membrane then solvent molecules flow from **lower concentration to higher concentration side, this is due to the osmotic pressure.**
- In reverse osmosis hydrostatic pressure, (external pressure) in excess of osmotic pressure is applied on the **(higher concentration to lower concentration)** side)concentrated side & it force only solvent molecule to pass through the semi permeable membrane from their contaminants. **This is called as reverse osmosis.**

REVERSE OSMOSIS

- **The semi-permeable membrane are specially prepared from polyamide polymers & polymethacrylate, it permits only solvent molecules but not the ionic or molecular solutes.**
- **It also prevents the entrance of the colloidal compounds, high molecular weight organic compounds etc.**
- **Thus, in reverse osmosis, pure solvent (water) is separated from its contaminates, rather than removing contaminants from the water.**
- **This membrane filtration is sometimes also called “super-filtration” or “hyper-filtration”.**

REVERSE OSMOSIS



REVERSE OSMOSIS

Advantages :

- **The process is very easy, simple & fast to operate.**
- **It removes the suspended silica.**
- **It removes ionic as well as non ionic,**
- **It removes ionic as well as non ionic, colloidal & high molecular weight organic compounds.**
- **The lifetime of membrane is quite high, about 2 years.**

ULTRAFILTRATION

- **It is cross – flow separation process.**

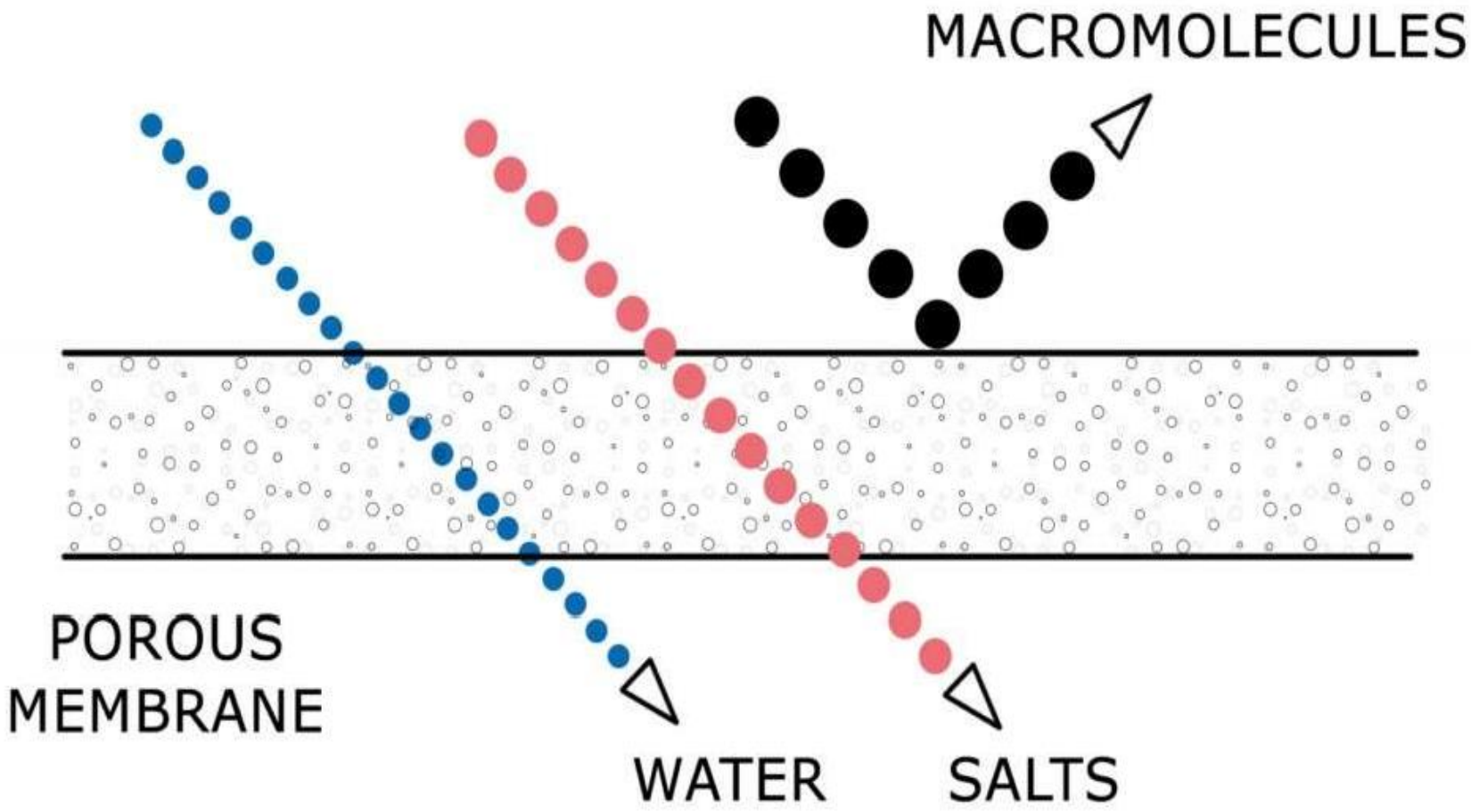
Thus in the process of reverse osmosis pure solvent is separated from its contaminants, rather than removing contaminants from water is called as ultra filtration, super filtration or hypo-filtration.

Ultra filtration is a separation process using membranes with pore size in range of 0.1 to 0.01 micron.

Here liquid stream to be treated flows tangentially along the membrane surface, thereby producing two streams.

The stream of liquid that comes through the membrane is called as permeate, the other liquid stream is called as concentrate.

ULTRAFILTRATION



ULTRAFILTRATION

ADVANTAGES :

- **Ultra filtration removes high molecular weight substances, colloidal materials, organic & inorganic polymeric molecules.**

DISADVANTAGES :

- **Low molecular weight ions such as sodium, calcium, magnesium chloride & sulphate are not removed.**

INDUSTRIAL APPLICATIONS :

- **Removal of colloids.**
- **It is used in industry to separate suspended solids from the solution.**

ELECTRODIALYSIS

- **This is the method in which the ions of salts present are polled out of salt water by passing direct current , using electrodes & thin rigid plastic membrane pair (synthetic or natural).**
- **When a direct electric current is passed through saline water , the sodium ions (Na+) start moving towards negative pole (cathode) , while the chloride ions (Cl-) start moving towards the positive pole (anode) , through membrane.**

ELECTRODIALYSIS

- As a result the concentration of brine solution decreases in central compartment , while increases in two side compartments.
- Desalined or pure water is removed from the central compartment from time to time , while concentrated brine is replaced by fresh brine or sea water.

- For more efficient separation usually ion – selective membranes are employed. Which has permeability for only one kind of ions.
- Eg. Cation selective membrane is permeable to cations only, because of the presence of functional groups like RSO_3^- or $RCOO^-$.

  They reject anions having the same charges as that of fixed functional groups, similarly anion selective membranes has positively charged fixed functional groups such as $R_4N^+Cl^-$.

ELECTRODIALYSIS

ADVANTAGES:

- It is most compact unit.
- The cost of instalation of plant & its operation is economical.

ELECTRODIALYSIS

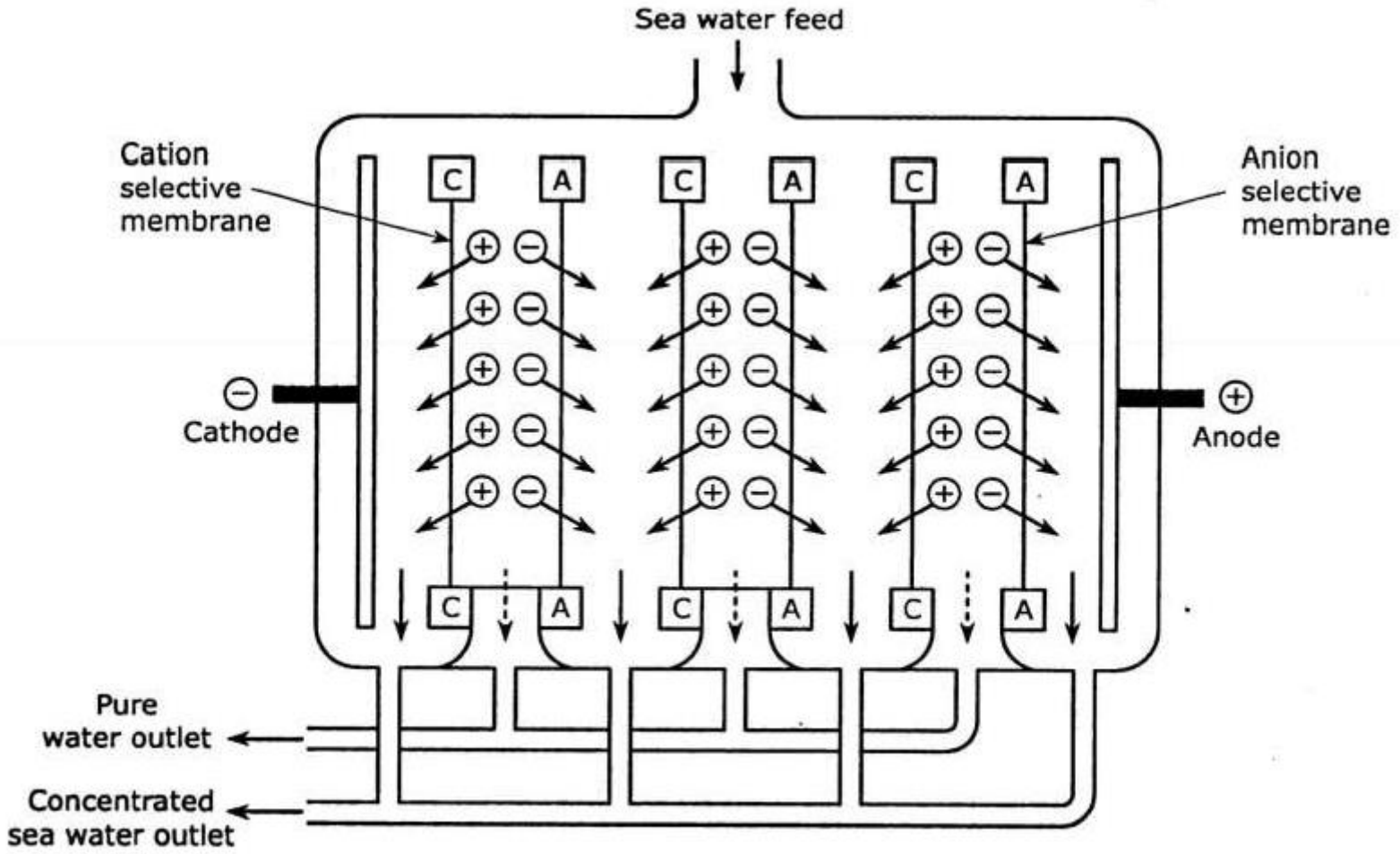


Fig. 1.13 : Electrodialysis cell

Notes by: : Mrs. Rupali Agme-Jadhav