Water softening methods

3. Ion-Exchange Process

Ion-Exchange Resin Process

- Ion-exchange resins are insoluble, cross-linked, long chain organic polymers with a microporous structure and the functional groups attached to the groups are responsible for the ion-exchanging properties.

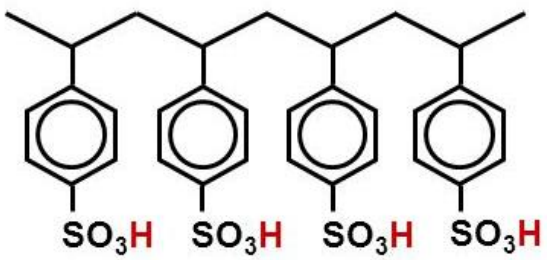
  - **Cation exchange resins** will exchange cations with H^+
  - **Anion exchange resins** will exchange anions with OH^-
  - Functional groups present are responsible for ion-exchange properties.
  - Acidic functional groups (-COOH, $-SO_3H$ etc.) exchange H^+ for cations
  - Basic functional groups ($-NH_2$, =NH etc.) exchange OH^- for anions.

Ion-Exchange Resin Process

A. Cation-exchange Resins (RH^+):

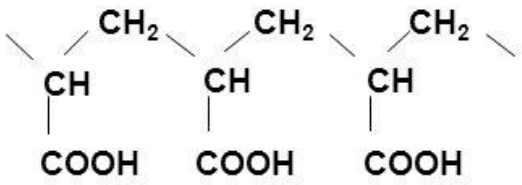
- Styrene divinyl benzene copolymers
- which on sulphonation or carboxylation, become capable to exchange their hydrogen ions with the cations in the water

Strongly acidic cation exchange resin



Sulphonic group

Weakly acidic cation exchange resin (WAC)



Polycarboxylic acid, polyacrylic acid

Amberlite IRC86

Ion-Exchange Resin

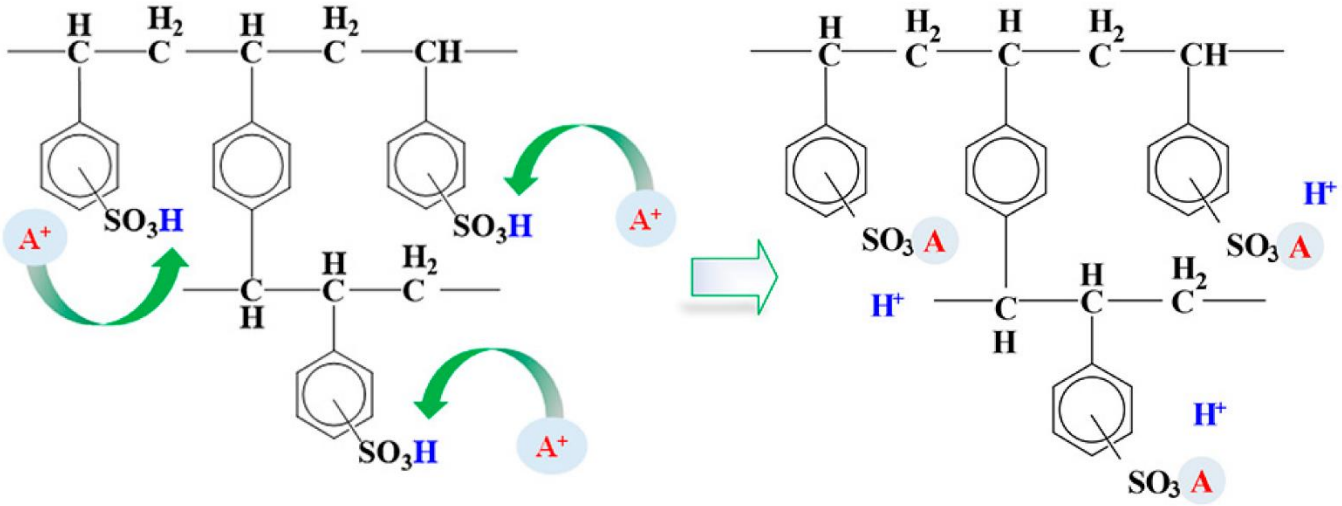
Cation-Exchange Resin

- Cations exchanged with H^+ ion

Sulphonated polystyrene

= strongly acidic cation exchange resin (SAC)

Amberjet 1200 H, Amberlite IR120 H



Ion-Exchange Resin Process

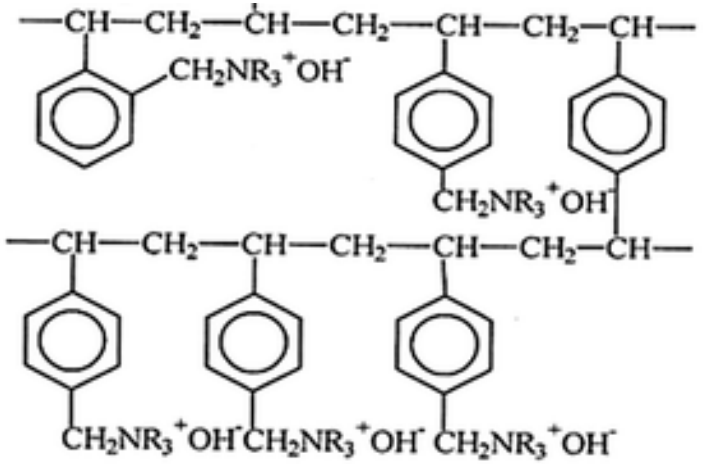
B. Anion-exchange Resins ($R'OH^-$):

- Styrene-divinyl benzene or amine-formaldehyde copolymers, which contain amino or quaternary ammonium or quaternary phosphonium or tertiary sulphonium groups as an integral part of the resin matrix.
- These after treatment with dil. NaOH solution capable to exchange their OH^- ions with the anions in the water

Quaternary ammoniated ST-DVB copolymer

Anion exchange resin

R' = CH_3 is known as Type-1 anion resin



Ion-Exchange Resin Process

The Process of Ion-exchange is:

$$2\,RH^{+} + Ca^{2+}/Mg^{2+} \longrightarrow R_2Ca^{2+}/R_2Mg^{2+} + 2\,H^{+} \quad \text{(Cation exchange)}$$

$$R'OH^{-} + Cl^{-} \longrightarrow R'^{+}Cl^{-} + OH^{-} \quad \text{(anion exchange)}$$

$$2\,R'OH^{-} + SO_4^{2-} \longrightarrow R'_2\,SO_4^{2-} + 2\,OH^{-} \quad \text{(anion exchange)}$$

$$2\,R'OH^{-} + CO_3^{2-} \longrightarrow R'2\,CO_3^{2-} + 2\,OH^{-} \quad \text{(anion exchange)}$$

Finally,

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

Regeneration of exhausted resins:

Saturated resins are regenerated by treating with strong mineral acid or alkali respectively

$$R_2Ca^{2+}/R_2Mg^{2+} + 2H^{+} \longrightarrow 2\,RH^{+} + Ca^{2+}/Mg^{2+} \quad \text{(Strong acid)}$$

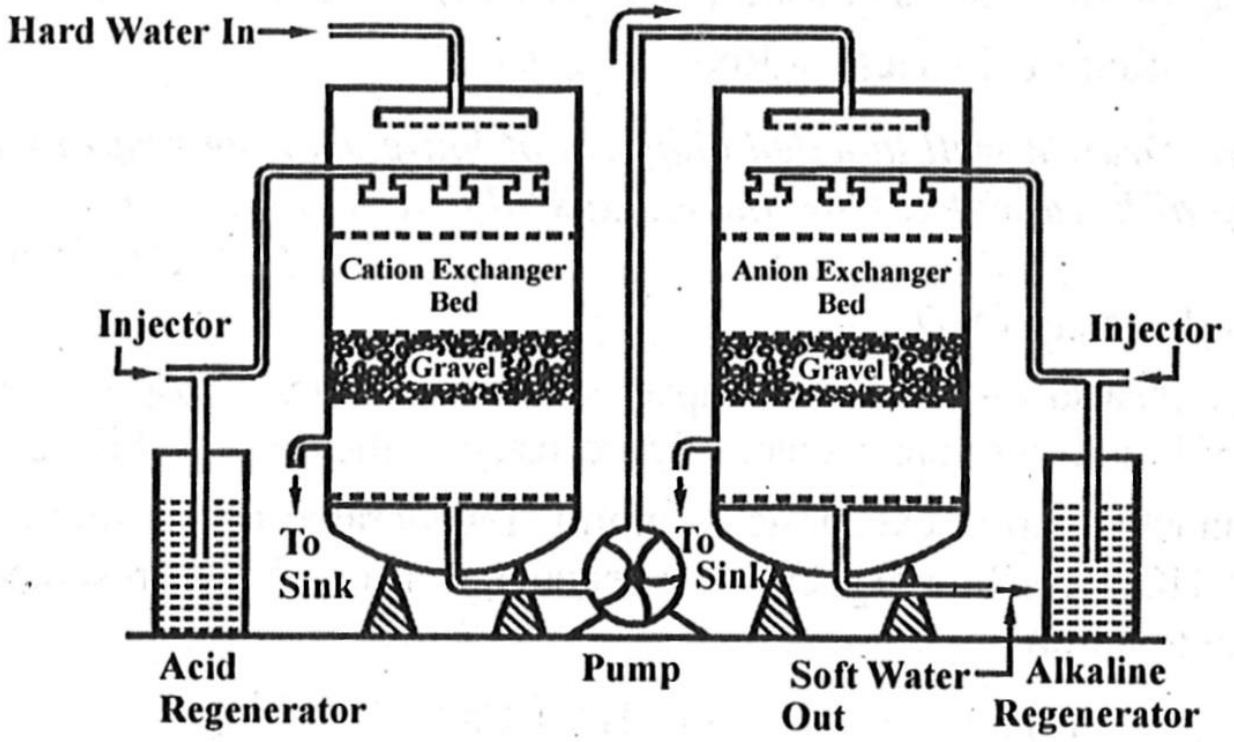
(washings)

$$R'_2\,SO_4^{2-} + 2\,OH^{-} \longrightarrow 2\,R'OH^{-} + SO_4^{2-} \quad \text{(Strong base)}$$

(washings)

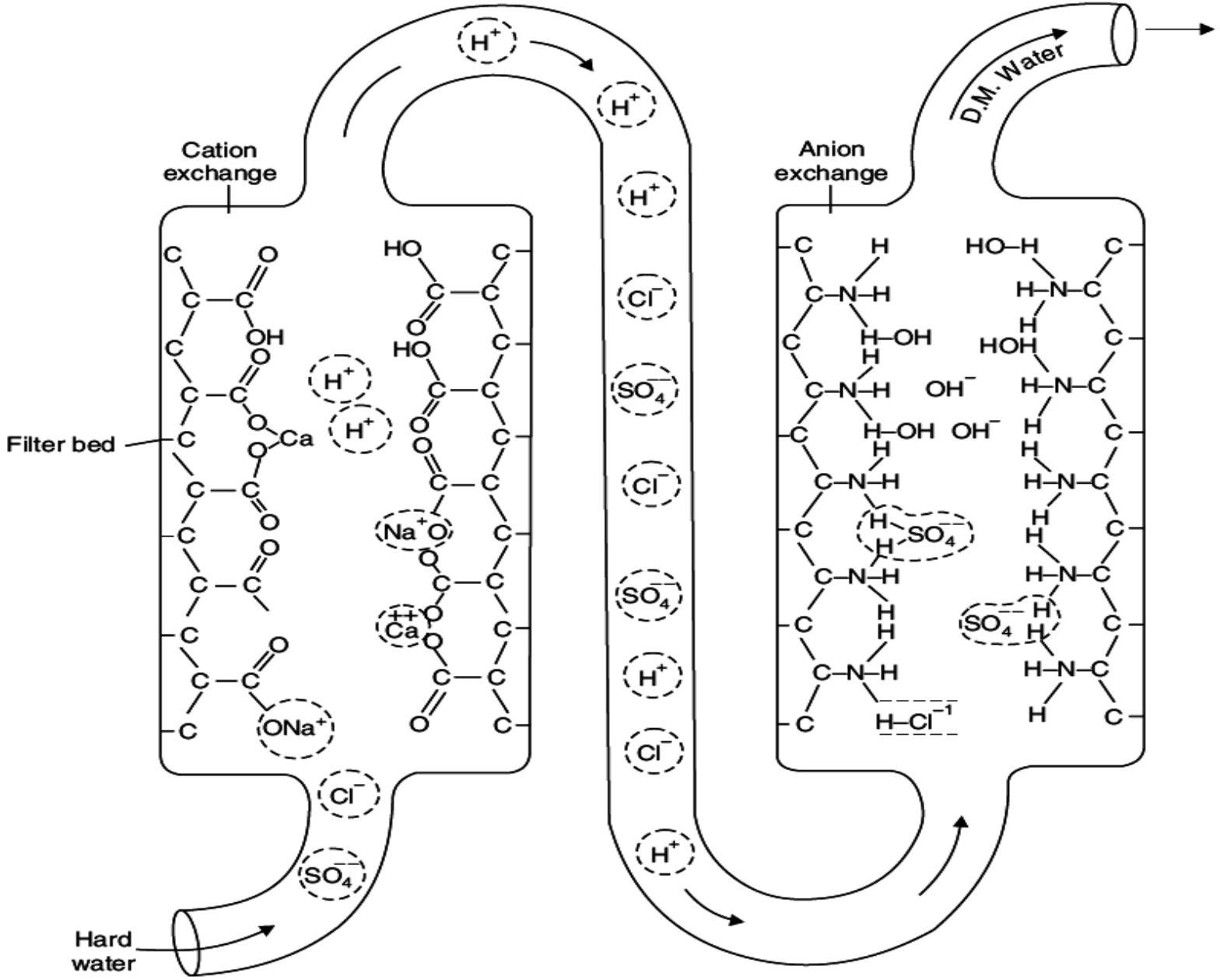
***R** = Resin; **RH^{+}** = Cation exchange resin; **$R'OH^{-}$** = anion exchange resin

Ion-Exchange Resin Process



Demineralisation of water

Note: Hard water should be first passed through the cation exchanger and then anion exchanger to avoid hydroxides of Ca^{2+} and Mg^{2+} getting formed



Cation exchange reaction:

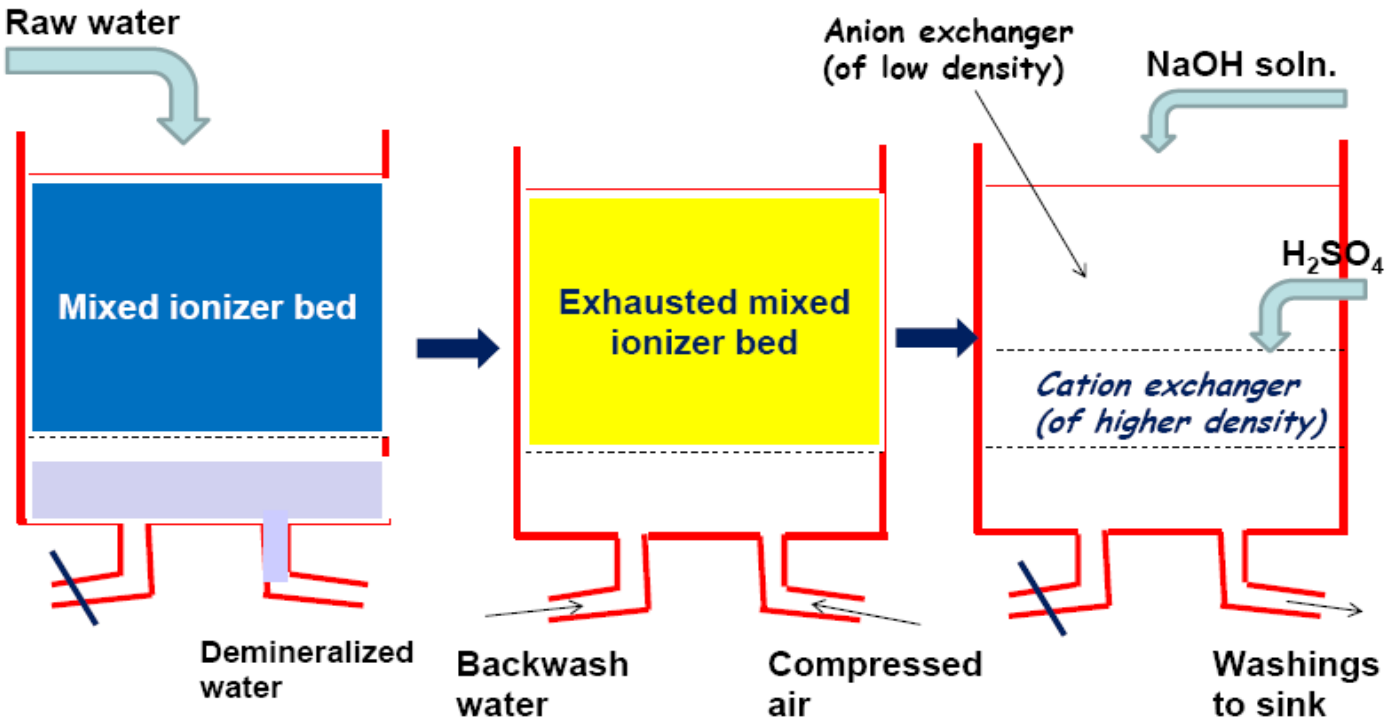
$$2R^{-}H^{+} + Ca^{+2} \rightleftharpoons CaR_2 + 2H^{+}$$

Anion exchange reaction:

$$RNH_2 + H_2O \rightleftharpoons R\overset{+}{N}H_3OH^{-}$$

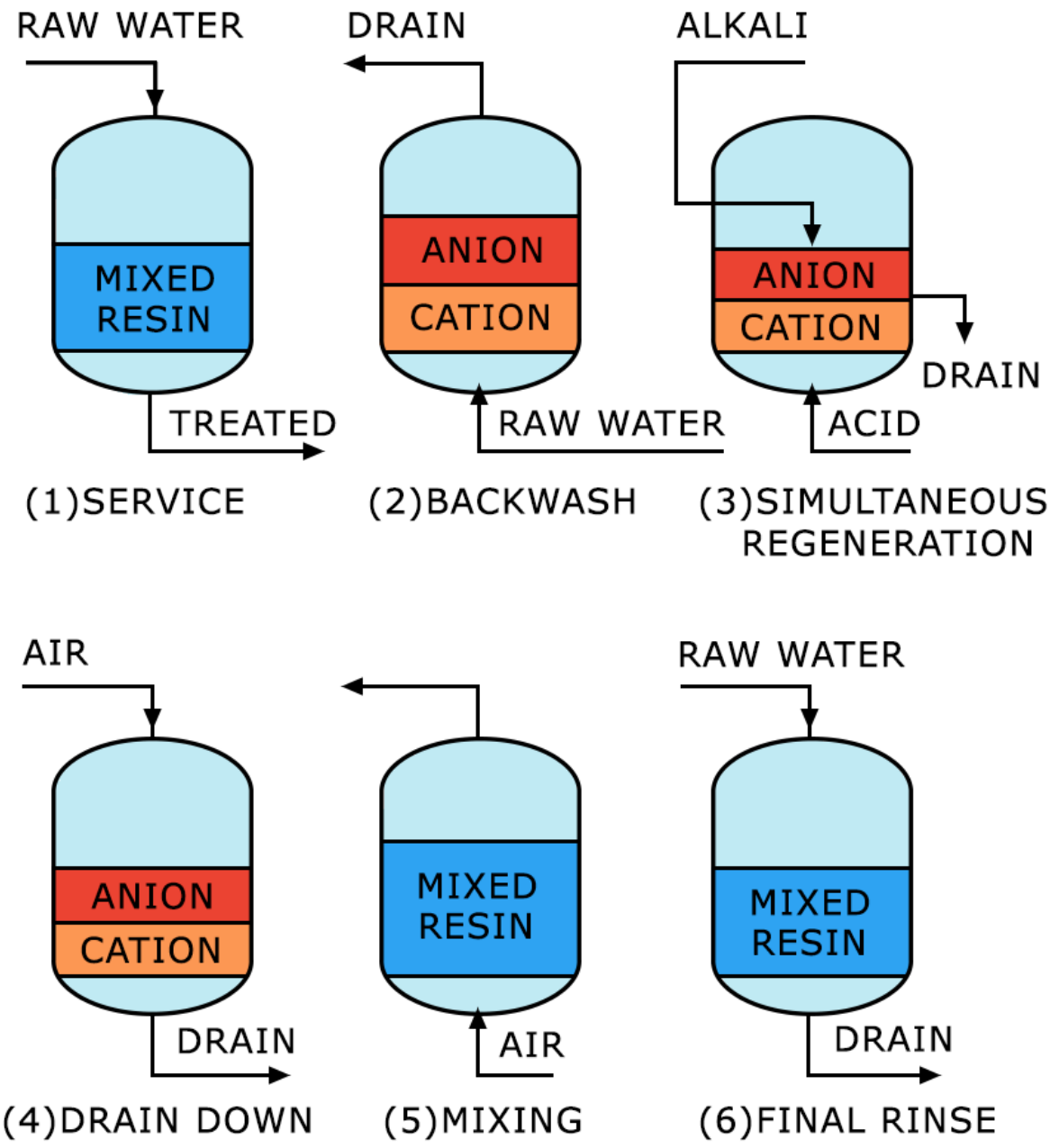
$$R\overset{+}{N}H_3OH^{-} + Cl^{-} \rightleftharpoons R\overset{+}{N}H_3Cl^{-} + OH^{-}$$

Mixed Bed Deionizer

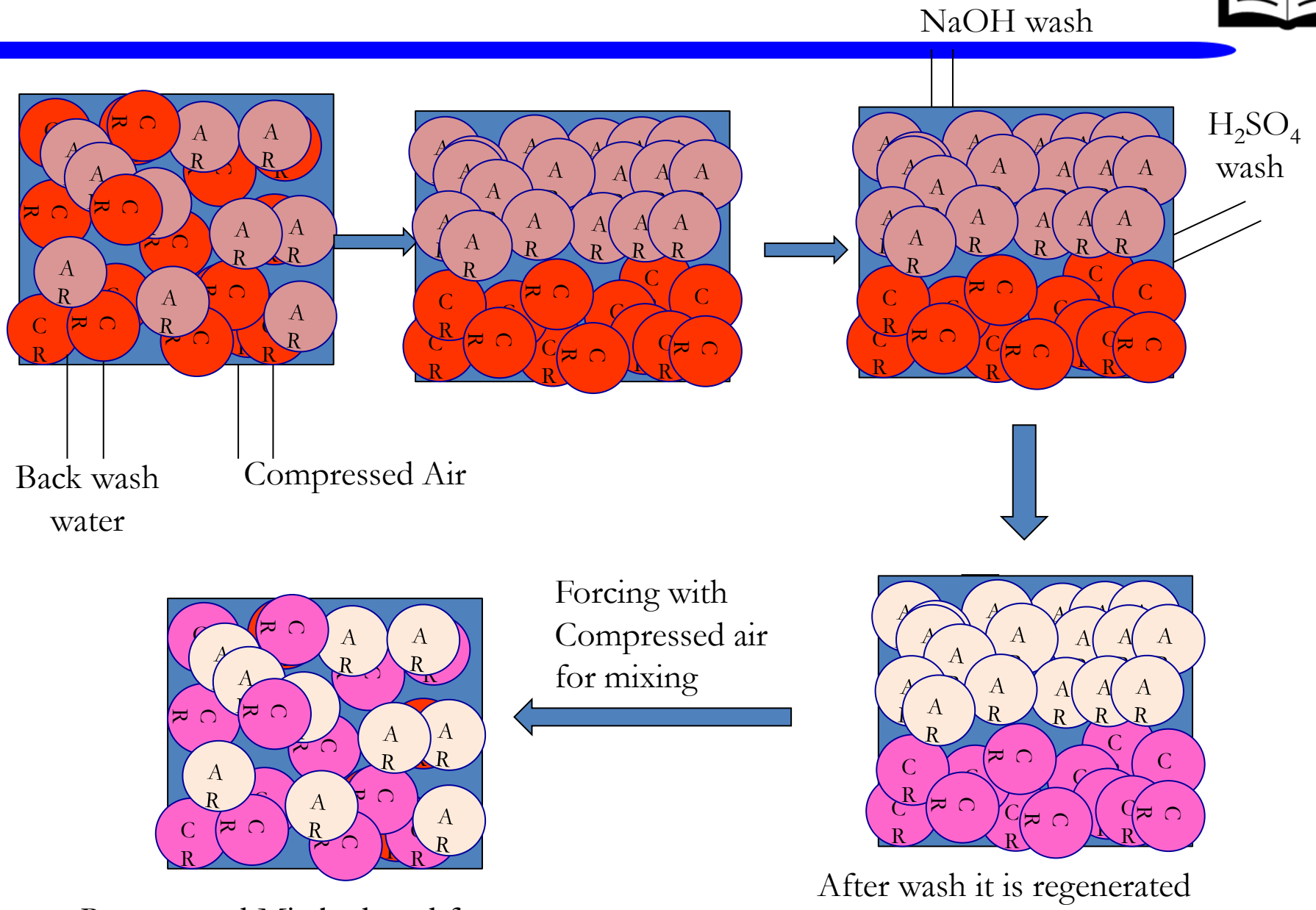


Containing an intimate mixture of hydrogen exchanger and strongly basic anion exchanger

The outgoing water from the mixed-bed contains even less than 1 ppm of dissolved salts


RAW WATER
MIXED RESIN
TREATED
(1)SERVICE
DRAIN
ANION
CATION
RAW WATER
(2)BACKWASH
ALKALI
ANION
CATION
DRAIN
ACID
(3)SIMULTANEOUS REGENERATION
AIR
ANION
CATION
DRAIN
(4)DRAIN DOWN
MIXED RESIN
AIR
(5)MIXING
RAW WATER
MIXED RESIN
DRAIN
(6)FINAL RINSE

Mix bed to be regeneration process



Ion-Exchange Resin Process

- **The mixed bed deionizer consist of cation and anion exchange resins mixed together in a single pressure vessel.**
- **When water is passed through mixed bed it comes in contact, a number of times, with the two kinds of exchanges alternatively. As a result the net effect of mixed bed exchanger is equivalent to passing water through a series of several cation and anion exchangers.**
- **The quality of water obtained from mixed bed is appreciably higher than the water produced from two bed plants.**
- **Mixed bed exchange produce water with hardness less than 1 ppm**

Regeneration:

- The mixed bed is back washed by forcing water in the upward direction. This separate the cation and anion exchanges from the mixed bed. Being lighter the anion resin occupies upper part and the denser cation at the bottom.
- Now these layers can be washed with NaOH and H_2SO4 respectively to regenerate anion and cation exchange resins. After regeneration again they are mixed by forcing compressed air.

Generally soften water (e.g. RO, etc) will be further purified by this method

Advantages & Disadvantages of ion-exchange resin process

- **Advantages:**
  - Can be used for highly acidic and highly alkaline water
  - Residual hardness of water is as low as 1 ppm.
  - Very good for treating water for high pressure boilers

- **Disadvantages:**
  - Expensive equipment and chemicals
  - Turbidity of water should be < 10 ppm. Otherwise output will be reduced; turbidity needs to be coagulated before treatment.
  - Needs skilled labour