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UNIT

1 Water Technology

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Previous Year Question
(2024 Pattern)

2.3 Numerical on Hardness

- Q. 25 ml hard water sample required 11.2 ml 0.01 M EDTA; after boiling 7.9 ml. Calculate total, temporary & permanent hardness. (April 2025)

- Q. Hardness of 50,000 L water removed by zeolite softener; 250 L NaCl (100 g/L) used Calculate hardness. (Nov 2024)

3. Determination of Hardness & Alkalinity

3.1 EDTA Method for Hardness Determination

- Q. What is hardness of water? Explain EDTA method with procedure, reactions & formula. (Nov 2024)

3.2 Alkalinity of Water

- Q. 100 ml sample: 7.6 ml to phenolphthalein endpoint, 15.2 ml total. Identify type & amount of alkalinity. (Nov 2024)

- Q. 25 ml sample: 3.7 ml to phenolphthalein endpoint, 7.4 ml to methyl orange endpoint Calculate types & amount of alkalinity. (April 2025)

4. Effects of Hard Water in Boilers

4.1 Priming and Foaming

- Q. State the causes of foaming in boiler and give remedial measures. (April 2025)

4.2 Scale and Sludge Formation

- Q. What are scales & sludges? Explain causes of scale formation in boilers. (Nov 2024)

- Q. Explain the causes of scales in boiler, give 2 disadvantages & 2 prevention methods. (April 2025)

5. Water Treatment Methods

5.1 Zeolite Method (with numerical)

- Q. Explain Zeolite process with figure, working, ion exchange, regeneration & advantages. (April 2025)

5.2 Demineralization Method

- Q. Give cation & anion exchange reactions for deionisation of water containing $MgCl_2$. (Nov 2024)

6. Purification of Water

6.1 Reverse Osmosis

- Q. Explain reverse osmosis with figure. (Nov 2024)

- Q. Define reverse osmosis. Give two advantages and two limitations. (April 2025)

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◂ Impurities in Water ▸

- Impurities in water are harmful or unwanted substances (like dirt, chemicals, or germs) that make the water unclean. These impurities can make the water look muddy, taste bad, or even make people sick if they drink it.

- They also cause problems in industries by damaging machines or affecting product quality. Clean water should be clear, safe, and free from such harmful substances.

◆ Types of impurities in water ◆

Impurities in water are classified into the following types:

1. Suspended Impurities

- These are tiny solid particles that cannot mix or dissolve in water.
- Instead of becoming part of the water, they stay separate and can be seen floating or settling down at the bottom.
- They remain floating or settle down slowly.

Example: sand, clay, mud, dust, clay particles floating in river water.

2. Dissolved Impurities

- These impurities mix completely with water, disappearing like sugar in tea. You can't see them anymore because they break down into tiny particles that spread evenly throughout the water.
- They cannot be removed by simple filtration.

Examples:

- Dissolved salts (chlorides, sulphates, carbonates of calcium and magnesium)
- Dissolved gases (carbon dioxide, oxygen, nitrogen)

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3. Colloidal Impurities

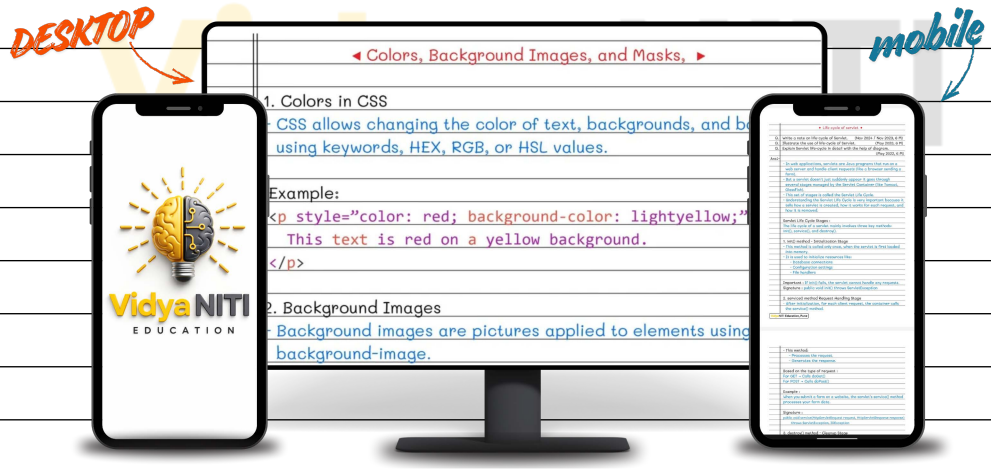
- Some impurities are made of very tiny particles. These particles are not fully dissolved in water, but they are so small that they do not settle down easily. They keep floating in the water for a long time, making the water look cloudy.
- They pass through filter paper but can be removed by special methods like coagulation.

Examples: organic waste, bacteria, microscopic particles of clay.

4. Microbial Impurities

- These impurities are tiny living organisms that are present in water. They cannot be seen with the naked eye but can cause diseases if the water is not cleaned or boiled.
- They can cause diseases.

Examples: bacteria, viruses, protozoa.



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◆ Numerical on Hardness ◆

Q. A water sample contains 120 mg/L of Ca^{2+} and 48 mg/L of Mg^{2+}. Calculate the total hardness of the water in ppm (as $CaCO_3$ equivalent).

Ans:-

- We need to find the total hardness of a water sample caused by calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions. The hardness is measured in ppm (parts per million) as $CaCO_3$ equivalent, which is a standard way to express water hardness.

Step 1: Understand the Given Data

- The water contains:

120 mg/L of Ca^{2+}

48 mg/L of Mg^{2+}

- Atomic masses:

Ca = 40, Mg = 24, C = 12, O = 16.

Step 2: Calculate the Molar Mass of "CaCO" _3

- $CaCO_3$ (calcium carbonate) is used as the reference for hardness.
- Its molar mass is:

$$40(Ca) + 12(C) + 3 \times 16(O) = 100 \text{ g/mol}$$

Step 3: Convert Ca^{2+} to $CaCO_3$ Equivalent

- To find how much $CaCO_3$ would give the same hardness as Ca^{2+}:

$$\text{Equivalent} = \left(\frac{\text{Molar mass of } CaCo_3}{\text{Atomic mass of Ca}}\right) \times \text{Concentration of } Ca^{2+}$$

$$= \frac{100}{40} \times 120 = 300 mg/L$$

Step 4: Convert Mg^{2+} to $CaCO_3$ Equivalent

- Similarly, for Mg^{2+} :

$$\text{Equivalent} = \left(\frac{\text{Molar mass of } CaCo_3}{\text{Atomic mass of Ca}}\right) \times \text{Concentration of } Ca^{2+}$$

$$= \frac{100}{24} \times 48 = 200 \text{ mg/L}$$

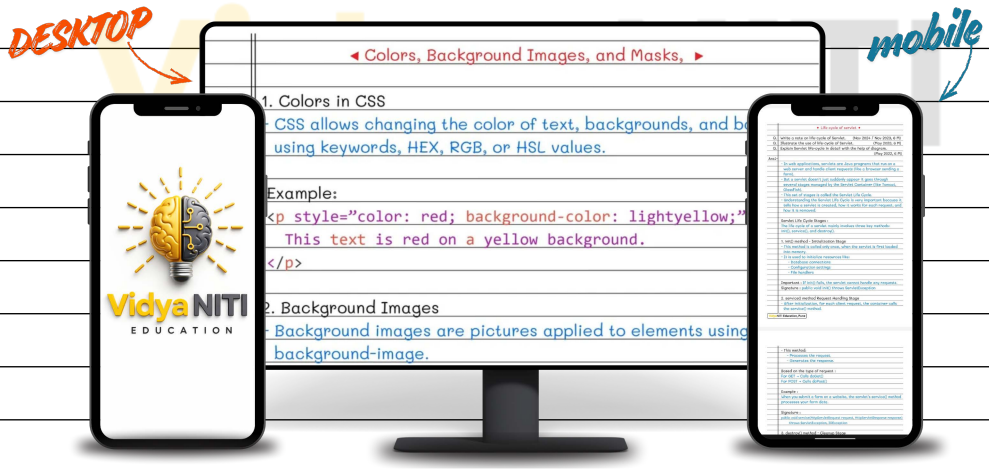
Step 5: Calculate Total Hardness

- Add the equivalents of Ca^{2+} and Mg^{2+} :

Total Hardness = 300 mg/L + 200 mg/L = 500 ppm (as $CaCO_3$)

Final Answer:

- The total hardness of the water sample is 500 ppm (as$CaCO_3$ equivalent).



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Q. 50 mL of a water sample required 15 mL of 0.01 M EDTA solution for titration. Calculate the total hardness of the water in ppm (as $CaCO_3$ equivalent).

Ans:-

- We need to calculate the total hardness of a water sample using the results from an EDTA titration. Hardness is measured in ppm (parts per million) as $CaCO_3$ equivalent, which tells us how much calcium and magnesium are in the water.

Step 1: Given Data

- Volume of water sample tested: 50 mL
- Volume of EDTA solution used: 15 mL
- Molarity (strength) of EDTA solution: 0.01 M (Molarity means moles per liter)

Step 2: Use the Hardness Formula

The formula to calculate hardness from an EDTA titration is:

$$\text{Hardness (ppm)} = \frac{\text{Volume of EDTA (mL)} \times \text{Molarity of EDTA} \times 1000}{\text{Volume of Water Sample (mL)}}$$

Here's what each part means:

- Volume of EDTA × Molarity of EDTA → Gives the amount of EDTA used (in millimoles).
- Multiply by 1000 → Converts grams to milligrams (since 1 ppm = 1 mg/L).
- Divide by Water Sample Volume → Adjusts for the amount of water tested.

Step 3: Plug in the Numbers

Substitute the given values into the formula:

$$\text{Hardness} = \frac{15\ \text{mL} \times 0.01\ \text{M} \times 1000}{50\ \text{mL}}$$

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$$= \frac{15 \times 10}{50} = \frac{150}{50} = 3 \text{ ppm (as } CaCO_3)$$

Final Answer:

- The total hardness of the water sample is 3 ppm (as "CaCO"_3 equivalent).

In Simple Words:

- The water is very soft because it takes only a tiny amount of EDTA (a chemical that binds to calcium and magnesium) to neutralize the hardness. A hardness of 3 ppm means there's very little calcium or magnesium in the water.

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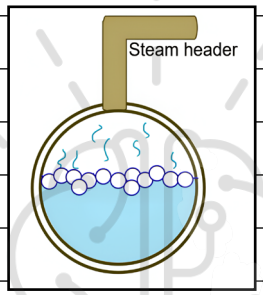
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- This can result in increased maintenance costs and energy losses.

2. Foaming

- Foaming is the formation of a stable layer of foam or bubbles on the surface of boiler water. These bubbles do not break easily and can carry water droplets along with steam.



Causes of Foaming:

High concentration of dissolved solids:

- Salts and other impurities reduce surface tension and form stable foam.

Oils and Grease:

- Oils can create a sticky layer on the water surface, encouraging foam formation.

Organic Impurities:

- Presence of organic materials also leads to foaming.

Effect of Foaming:

- Causes water carryover with steam.
- Lowers the quality of steam.
- Leads to poor efficiency of turbines and steam engines.
- Can block steam pipelines and cause damage to boiler parts.
- Reduces overall boiler efficiency and increases maintenance work.

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◆ Scale and Sludge formation ◆

Q. What are scales & sludges? Explain causes of scale formation in boilers. (Nov 2024)

Q. Explain the causes of scales in boiler, give 2 disadvantages & 2 prevention methods. (April 2025)

Ans:

1. Sludge:

- Sludge is a soft, loose, muddy deposit that settles at the bottom or in low-temperature areas of the boiler.
- It consists of impurities like clay, sand, silt, and organic matter.
- Sludge is not hard and can be removed easily by blowdown.
- Sludge reduces boiler efficiency and can block pipelines if not removed.

2. Scale:

- Scale is a hard, solid layer of salts (such as calcium and magnesium salts) that sticks to the inner surfaces of the boiler.
- It forms mainly on heating surfaces where evaporation and temperature are high.
- Scales are difficult to remove and lead to serious problems like overheating and damage to the boiler.

Causes of Sludge Formation in Boilers:

1. Presence of Impurities:

- Impurities like clay, sand, and organic matter remain suspended in water and settle down as sludge.

2. Low Temperature:

- In cooler areas of the boiler, these impurities tend to settle easily.

3. Poor Water Treatment:

- If water is not treated properly, impurities remain in the water and lead to sludge formation.

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4. Chemical Reactions:
- Sometimes, chemicals added for water treatment react and form sludge.

Causes of Scale Formation in Boilers:

1. Presence of Hard Water:
- Hard water contains calcium and magnesium salts.
- On heating, these salts become solid and stick to the boiler surface as scales.

2. High Temperature:
- High temperature forces dissolved salts to become insoluble and form scales.

3. High pH (Alkaline Conditions):
- When the water is highly alkaline, it promotes scale formation.

4. Evaporation:
- Continuous evaporation increases salt concentration, resulting in scales.

Causes of Deposit Formation in Boilers:

1. Hard Water:
- Calcium and magnesium salts precipitate and settle as deposits.

2. Suspended Impurities:
- Clay, silt, and organic matter settle and form deposits.

3. High Temperature:
- High temperature causes salts to precipitate and deposit on boiler surfaces.

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4. Poor Water Treatment:

- Lack of chemical treatment allows impurities to remain in water and form deposits.

Disadvantages of Scales in Boilers:

1. Reduced Heat Transfer:

- Scales act as insulators and reduce heat transfer, lowering boiler efficiency.

2. Overheating:

- Scales cause uneven heating, which may lead to damage or bursting of boiler parts.

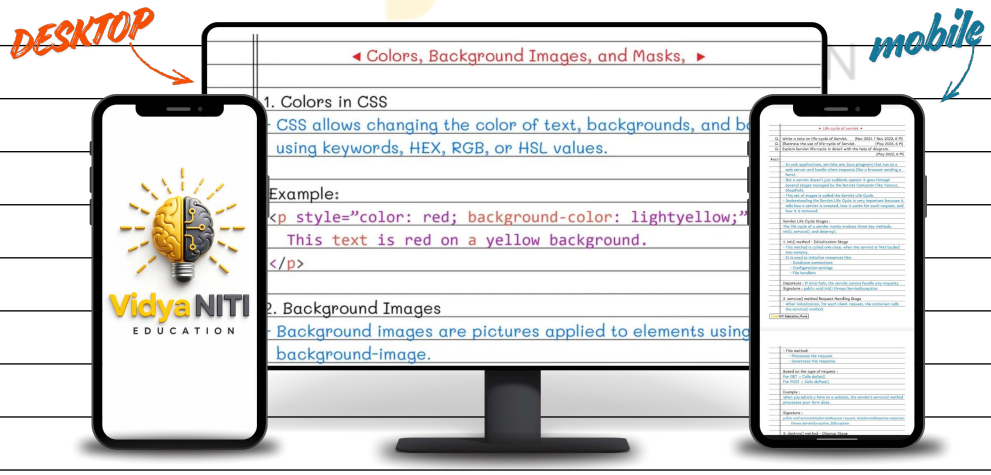
3. Increased Fuel Consumption:

- More fuel is needed because heat transfer is blocked, leading to higher operating costs.

4. Corrosion:

- Scales trap impurities that can cause corrosion and weaken boiler parts.

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◆ Demineralization / Deionisation Method ◆

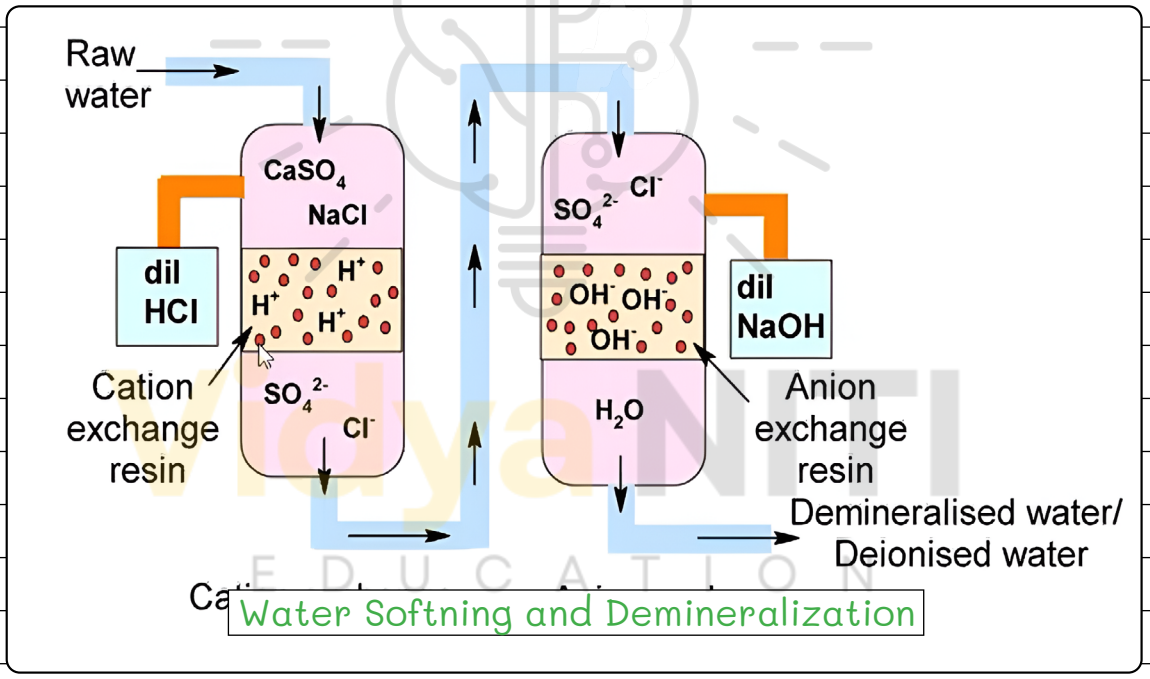
Q. Draw neat and labelled diagram of demineralization method give ion exchange and regeneration reaction of water containing $CaCl_2$.

(Oct. 23, 6M)

Q. Give cation & anion exchange reactions for deionisation of water containing $MgCl_2$. (Nov 2024)

Ans:-

- The demineralization method is a powerful process to remove all dissolved ions (both cations and anions) from water, producing pure, deionized water.



- Demineralization uses ion-exchange resins to remove cations (like Ca^{2+}, Mg^{2+}, Na^{+}) and anions (like Cl^{-}, SO_4^{2-}) from water.
- It produces pure water free from minerals, suitable for industrial and laboratory use.

Working:

1. Raw Water Enters:

- Raw water containing dissolved ions (Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, SO_4^{2-}) flows into the system (as shown in the image under "Raw water").

2. Cation Exchange:

- Water passes through a cation-exchange resin ($R\text{-}H^+$).
- Cations like Ca^{2+}, Mg^{2+}, and Na^+ are exchanged with H^+ ions.

$$R\text{-}H^+ + Ca^{2+} \rightarrow R\text{-}Ca^{2+} + 2H^+$$
$$R\text{-}H^+ + Na^+ \rightarrow R\text{-}Na^+ + H^+$$

3. Anion Exchange:

- Water then passes through an anion-exchange resin ($R\text{-}OH^-$).
- Anions like Cl^- and SO_4^{2-} are exchanged with OH^- ions.

$$R\text{-}OH^- + Cl^- \rightarrow R\text{-}Cl^- + OH^-$$
$$R\text{-}OH^- + SO_4^{2-} \rightarrow R\text{-}SO_4^{2-} + 2OH^-$$

4. Formation of Pure Water:

- The H^+ and OH^- ions combine to form pure water.

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

- The result is deionized water (as shown in the image under "Deionised water").

Regeneration of Resins:

- Over time, the resins become exhausted (fully converted to $R\text{-}Ca^{2+}$, $R\text{-}Na^+$, $R\text{-}Cl^-$, etc.).

To reuse them, the resins are regenerated:

Cation Resin: Regenerated using acid (HCl).

$$R\text{-}Ca^{2+} + 2HCl \rightarrow R\text{-}H^+ + CaCl_2$$

Anion Resin: Regenerated using alkali (NaOH).

$$R\text{-}Cl^- + NaOH \rightarrow R\text{-}OH^- + NaCl$$

This step is shown in the image under "Acid for regeneration" and "Alkali for regeneration".

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Advantages:

- Produces high-purity water free from all ions.
- Suitable for industrial, laboratory, and pharmaceutical applications.
- Resins can be regenerated and reused.

Disadvantages:

- Requires chemicals (acid and alkali) for regeneration.
- High operational cost for large-scale use.

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Q. Give the ion-exchange and regeneration reactions involved in the deionisation of water containing $MgCl_2$. (March 24, 4M)

Ans:

Deionization of Water Containing $MgCl_2$

1. Raw Water Enters:

- Raw water containing dissolved ions (Mg^{2+}, Cl^-, along with other ions like Ca^{2+}, Na^+, SO_4^{2-}) flows into the system.
- Magnesium chloride ($MgCl_2$) dissociates in water as:

$$MgCl_2 \rightarrow Mg^{2+} + 2Cl^-$$

2. Cation Exchange:

- Water passes through a cation-exchange resin ($R\text{-}H^+$).
- Mg^{2+} (and other cations like Ca^{2+}, Na^+) are exchanged with H^+ ions.

Reactions:

$$R\text{-}H^+ + Mg^{2+} \rightarrow R\text{-}Mg^{2+} + 2H^+$$

$$R\text{-}H^+ + Na^+ \rightarrow R\text{-}Na^+ + H^+$$

3. Anion Exchange:

- Water then passes through an anion-exchange resin ($R\text{-}OH^-$).
- Cl^- (and other anions like SO_4^{2-}) are exchanged with OH^- ions.

Reactions:

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

$$2R\text{-}OH^- + SO_4^{2-} \rightarrow R_2\text{-}SO_4^{2-} + 2OH^-$$

4. Formation of Pure Water:

- The H^+ (from cation exchange) and OH^- (from anion exchange) combine to form pure water (H_2O).

Reaction:

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

- The result is deionized water, free from Mg^{2+}, Cl^-, and other ions.

Regeneration of Exhausted Resins:

- Over time, the resins become saturated with Mg^{2+}, Cl^-, etc., and must be regenerated.

Cation Resin Regeneration (Using HCl Acid):

- The $R\text{-}Mg^{2+}$ resin is treated with hydrochloric acid (HCl) to restore $R\text{-}H^{+}$ form.

Reaction:

$$R\text{-}Mg^{2+} + 2HCl \rightarrow R\text{-}H^{+} + MgCl_2 \text{ (washed out)}$$

Anion Resin Regeneration (Using NaOH Alkali):

- The $R\text{-}Cl^{-}$ resin is treated with sodium hydroxide (NaOH) to restore $R\text{-}OH^{-}$ form.

Reaction:

$$R\text{-}Cl^{-} + NaOH \rightarrow R\text{-}OH^{-} + NaCl \text{ (washed out)}$$

Advantages:

- Produces high-purity water free from Mg^{2+}, Cl^{-}, and other ions.
- Suitable for laboratories, pharmaceuticals, and industrial processes.
- Resins are reusable after regeneration, making the process sustainable.

Disadvantages:

- Requires harsh chemicals (HCl & NaOH) for regeneration.
- High operational cost for large-scale applications.
- Wastewater generation ($MgCl_2$, NaCl solutions) during regeneration.

Conclusion:

- The deionization process effectively removes Mg^{2+} and Cl^{-} (from $MgCl_2$) by exchanging them with H^{+} and OH^{-}, producing pure water.

- The resins are regenerated using acid (HCl) and alkali (NaOH), allowing repeated use. This method is widely used where ultra-pure water is essential.

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