Experiment ID: 3b

ION EXCHANGE

Gazi University

Department of Chemical Engineering

2019-2020 Spring Semester (Online Education Term)

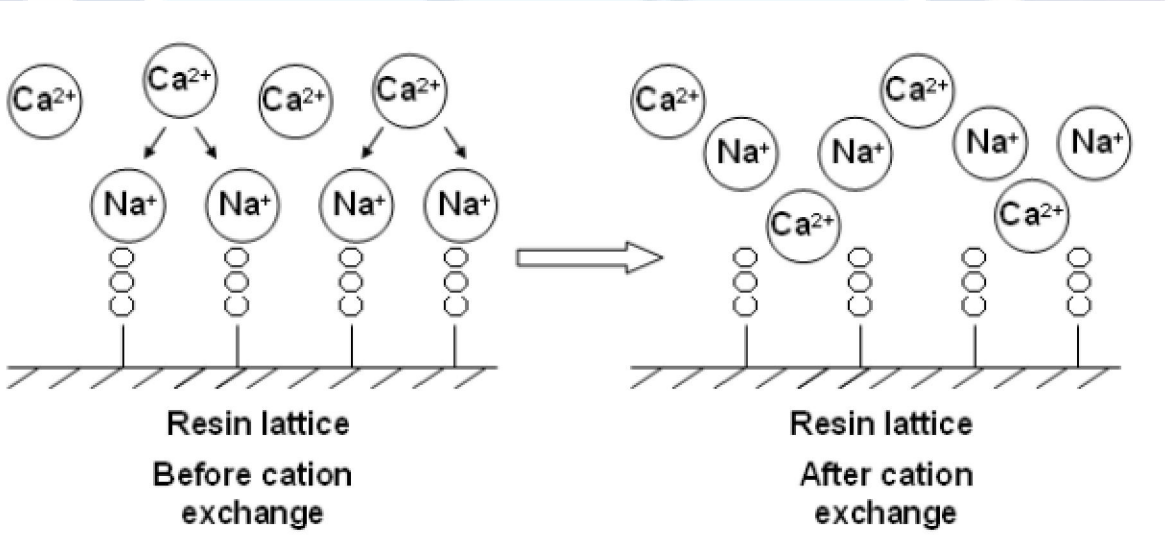
CHE482 Chemical Engineering Laboratory III

Objective;

- To investigate the behavior of the ion exchange column during loading and/or recovery process.
- To examine the properties of the ion exchanger.

- Ion exchange is reversible chemical reactions in which an ion in solution is exchanged with an ion bound to the solid substance.

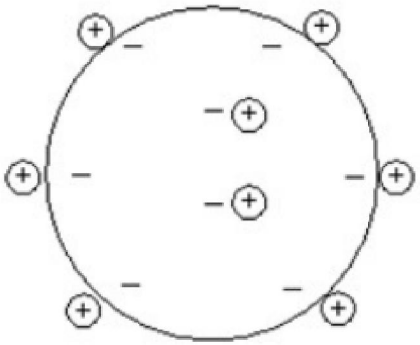
- While the ions on the solid surface pass to the solution, the ions in the solution are connected to the surface of the solid by electrostatic forces. This exchange process continues until the concentrations of the two types of ions on the surface and in the solution reach equilibrium.



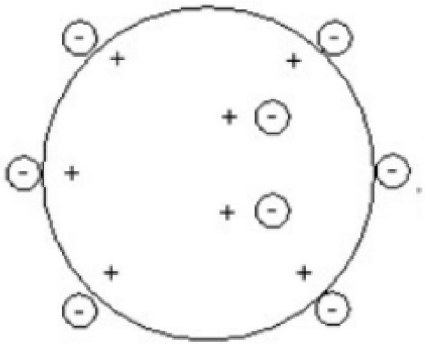
Zhang, L., Dzombak, D., 2010, Challenges and strategies for the use of saline water as cooling water in power plant cooling systems, Carnegie Mellon University National Energy Technology Laboratory

- Ion exchangers are insoluble solid substances containing exchangeable cations and anions.
- The materials used for ion exchange are generally divided into two.

1. Cation exchangers (Sodium ion exchangers and hydrogen ion exchangers)
2. Anion exchangers (Strong basic anion exchangers and weak basic anion exchangers)



Cation exchanger



Anion exchanger

- ❖ There are negatively charged ions around the cation exchangers to attract cations.
- ❖ There are positively charged ions around the anion exchangers to attract cations.

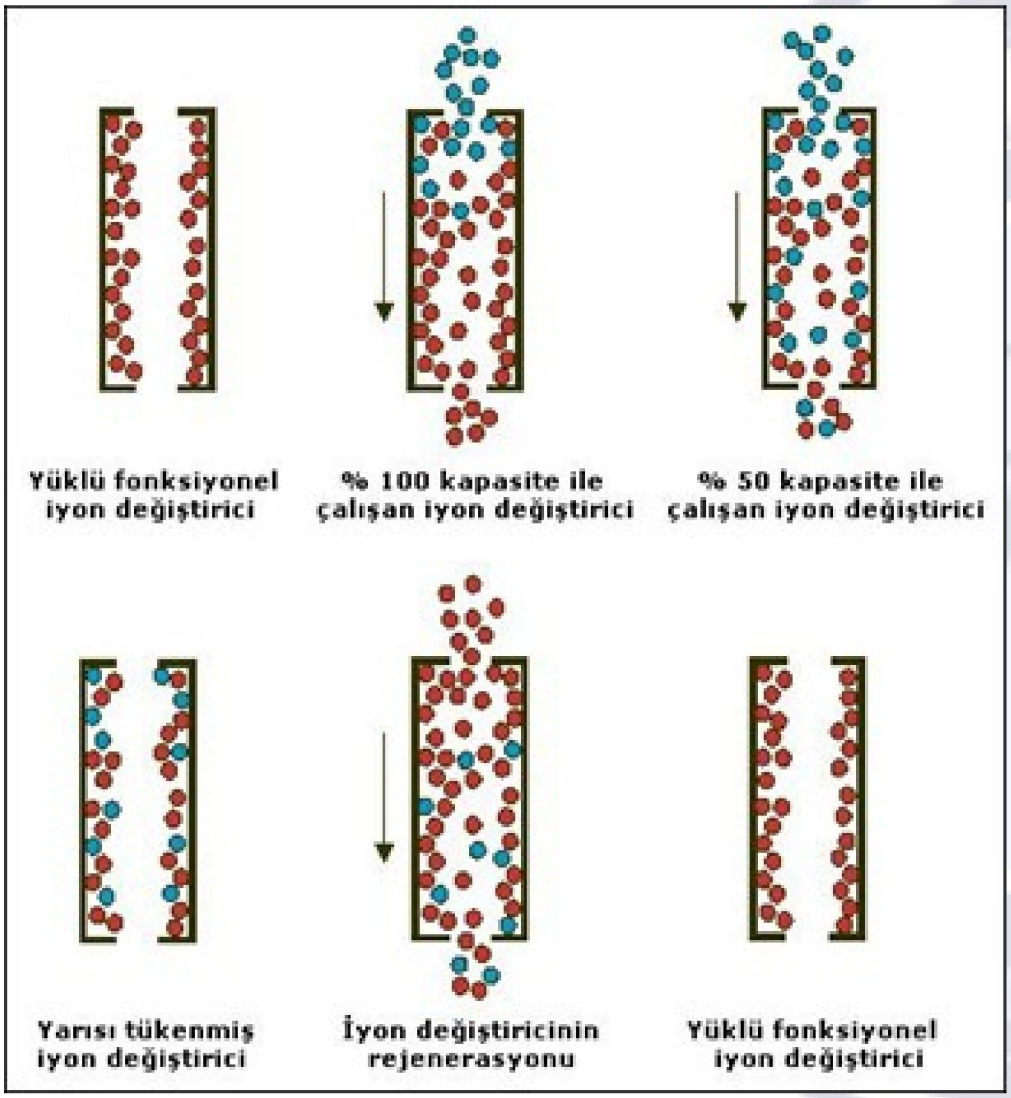
- As the ion exchanger, the most commonly used materials are resins.
- The most used ion exchange natural material is zeolite.
- Apart from this, many materials such as cellulose, clay, wool, active carbon coal, lignin, metal oxides have ion exchange properties.
- Some typical ions that can be used in ion exchangers are:
  - H+ (proton) and OH− (hydroxide)
  - Single charged ions (Na^+, K^+, or Cl^-)
  - Double charged ions (Ca^{2+} or Mg^{2+})
  - Polyatomic inorganic ions (e.g. SO_4^{2-} or PO_4^{3-})
  - Organic bases, molecules often containing amino functional groups (e.g. -NR2H +)
  - Organic acids, mostly –COO– (carboxylic acid) functional groups
  - Ionizable biomolecules: amino acids, peptides, proteins etc.
- Ion exchange is a reversible process. The material used as the ion exchanger can be regenerated or this material can be loaded with those ions by passing a certain ion group.

The important properties of ion exchangers are;

- Chemical, physical and thermal stability,
- Controlled and effective exchange capacity,
- Homogeneity,
- Hydrophilic structure,
- Fast ion exchange and regeneration opportunity

Ion exchanger usage areas are;

- Water treatment and preparation
- Agriculture and livestock
- Pollution control
- Energy
- Mining
- Metallurgy



When ion exchanger that contains sodium (defined as X) as an exchangable cation contact with the solution containing calcium and magnesium ions,

the sodium ion will be exchanged by calcium and magnesium ions as follows.

$$2\ NaX + Ca^{+2} \longrightarrow CaX_2 + 2\ Na^{+}$$
$$2\ NaX + Mg^{+2} \longrightarrow MgX_2 + 2\ Na^{+}$$

Parameters affecting ion exchange;

- Flow Rate;

If the flow rate is low, sufficient surface contact cannot be achieved and the channeling at flow occurs. If the flow rate is high, enough ion transfer is not performed because of the low contact time.

- Contact time and surface area

When the contact time is low, mass transfer does not take place efficiently.

- Solution Concentration

When the concentration of the solution is low, the driving force for mass transfer is also low.

- Measurement Method of Ca ++ Ion in the Sample

The color change of the indicator used in titration occurs above a certain pH value.

- Regenerant type, Concentration and Time

Regeneration may not be achieved at the desired speed.

- Type of Ion Exchanger

The ion exchange may not be achieved at the desired speed and the current capacity of the ion exchanger may not be fully used.

Experimental procedure

- Before starting the experiment, the zeolite in the column must be regenerated. For this purpose, 1 liter of 0.01 N NaCl solution is passed through the system for regeneration. Meanwhile, the average flow rate is measured.
- After regeneration, 1 liter of 0.01 N $CaCl_2$ solution is prepared for ion exchange and this solution passed through the column where the zeolite is located.
- Samples are taken periodically during the passage of $CaCl_2$ from the column. 1 ml buffer solution and 2-3 drops of eriochrome black-T are added to the samples. Then, titration is performed with EDTA solution to determine the Ca++ concentration in these samples. The amount of spent EDTA as a result of titration is recorded.


ION EXCHANGE APPARATUS
amfield
SIEMENS


MASTERFLEX®
SOLID STATE SPEED CONTROL
FWD • OFF • REV
POWER
SPEED
Cole Parmer Instrument Co. Chicago, Illinois 60648


Platon


easy-load®
MasterFlex®
model 7518-00
TANK C
TANK D
TEST WATER
DISTILLED WATER


EXCHANGE
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CATION
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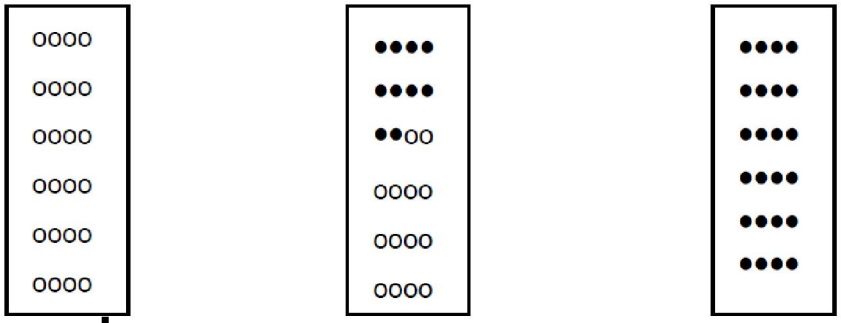
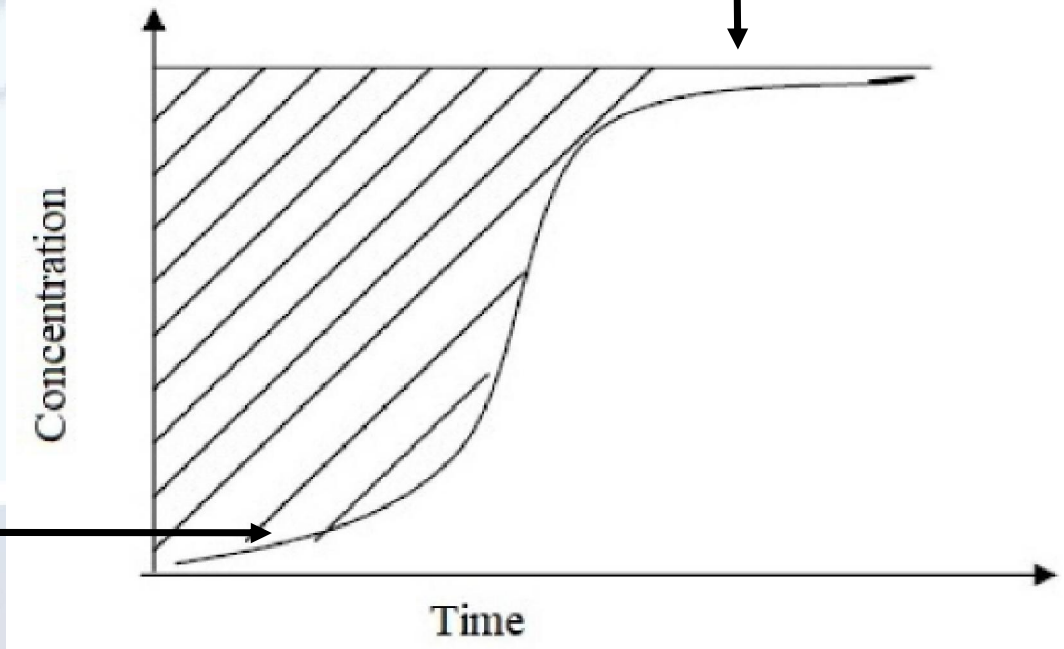
ANION



Steps of ion exchange in a packed column



Typical concentration-time curve in a packed column

Calculations and evaluation of results

- Plot the concentration-time curve separately for the exchangable cations.
- Plot again the same graphs as number of bed volumes versus normalized concentration (C/C_0).
- Calculate the theoretical ion exchange capacity of the column.
- Calculate the amount of cations exchanged during the experiment in grams of equivalent grams. Using this value, calculate the percent ion change by taking into account the ion exchange capacity of the ion exchanger in the column and the total amount of ion in the solution.
- Calculate the pressure drop in the column. Accordingly, discuss the suitability of the selected flow rate.
- How are the values calculated above affected by increasing or decreasing the flow rate? Discuss.