Water treatment I

Today's lecture

- Goal of water treatment

- Water treatment system overview

- Rapid mix, coagulation, flocculation

- Softening and hardness

Water treatment

- Goal of municipal water treatment: to provide water that is both potable and palatable
    - potable: safe to drink; palatable: pleasant to drink

- Factors determining drinking water quality
    - Physical: color and turbidity, temperature, taste and odor
    - Chemical: toxic chemicals and chemicals that make water non-palatable
    - Microbiological: pathogens
    - Radiological: ex) uranium

Indicator for pathogens

- Indicator is needed for pathogens because it is not practical to analyze all different species
- Total coliforms
  - Most frequently used indicator for pathogens
  - Reasons for using total coliforms as an indicator:
    - Inhabit the intestinal tracks of humans and other mammals
    - Exist in large numbers in individuals
    - Survive in natural waters for relatively long without growth
    - Relatively easy to analyze

Sources of drinking water

- Surface water
  - Variable composition
  - Low mineral content
  - Low hardness
  - High turbidity
  - Colored
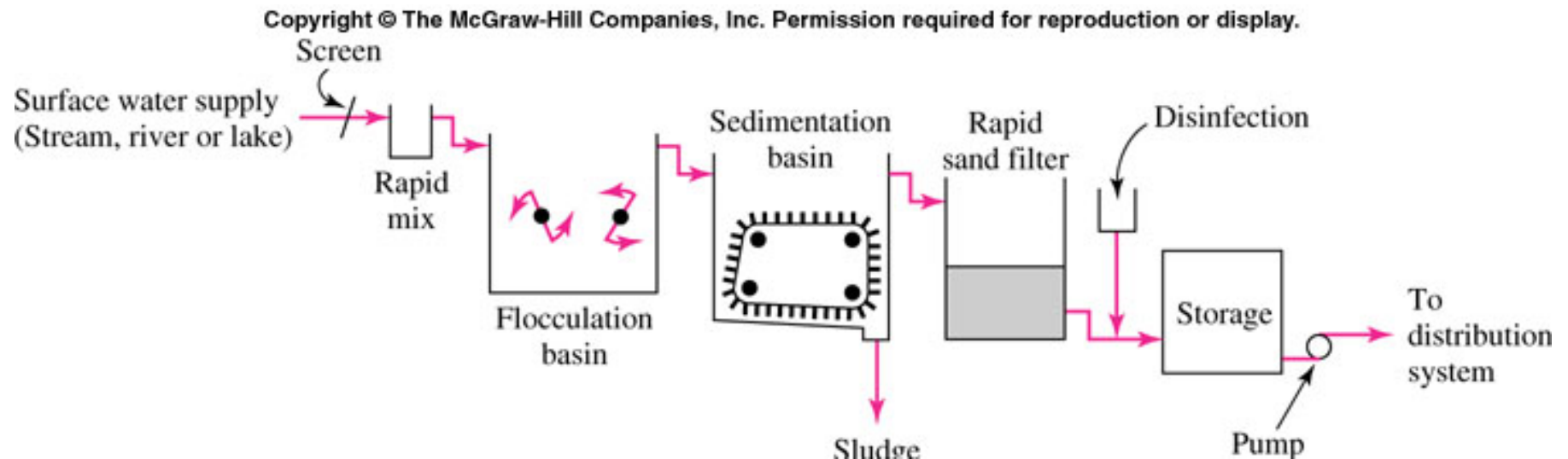 - DO present

- Groundwater
  - Constant composition
  - High mineral content
  - High hardness
  - High Fe, Mn
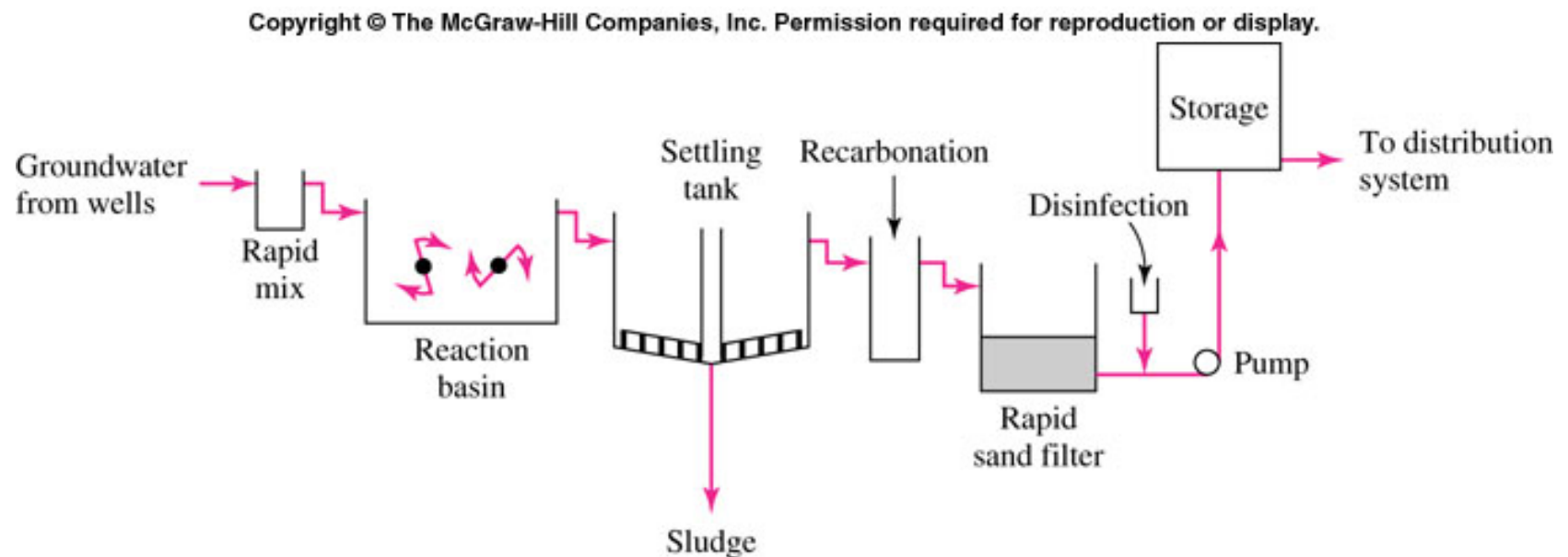 - Low turbidity
  - Low color
  - Low DO

Water treatment systems

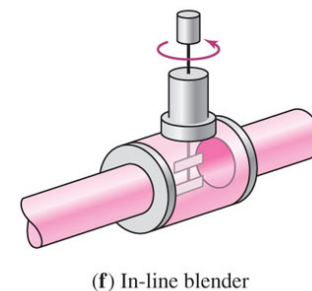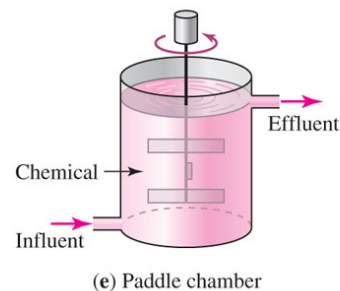- Coagulation plant: conventional surface water treatment

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Water treatment systems

- Water softening plant: for groundwater with high hardness

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Rapid mix

- To blend chemicals (ex: coagulants, softening agents) with water

- Short retention time (10-30 s)

Chemical → | Effluent
Influent →
(a) Turbine chamber

Chemical → | Effluent
Influent →
(b) Propeller chamber

Influent →
Chemical →
Effluent
Chemical
(c) Double-compartment turbine chamber

Chemical → | Effluent
Chemical →
Influent →
(d) Double-compartment turbine chamber

Chemical → | Effluent
Influent →
(e) Paddle chamber

(f) In-line blender
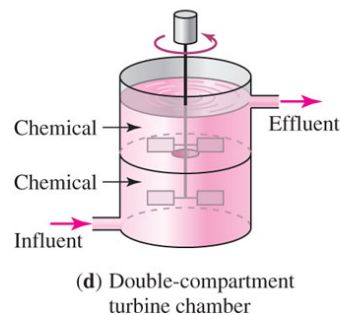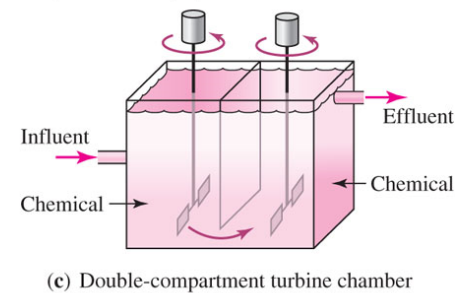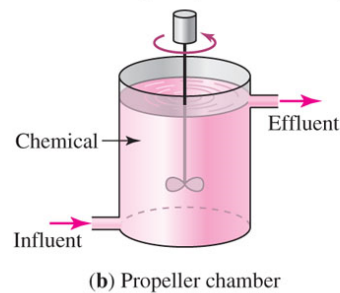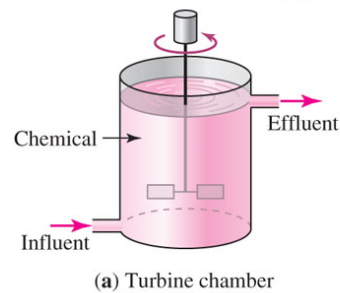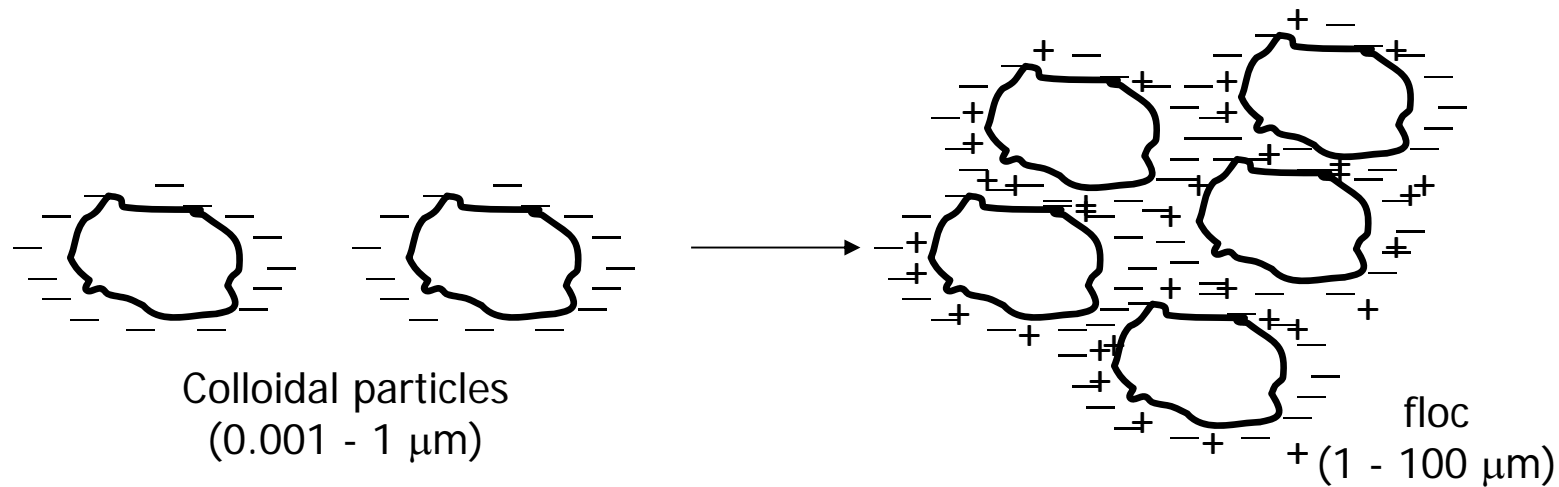
Coagulation-flocculation

- Coagulation-flocculation process is used to remove colloidal particles from water
  - Coagulation: in the rapid mix; intensive mixing; short retention time
  - Flocculation: in the flocculation basin; gentle mixing; longer retention time

Colloids

- Small particles (0.001 to 1 μm)

- Usually negatively charged

- Stability of colloidal suspension

  - "Stable" colloidal suspension: particles are like-charged →
    → particles repel each other → particles do not stick
    together or settle down easily

  - Destabilization of colloidal suspension: neutralizing the
    particle charge so that the particles can stick together and
   settle down

Coagulation

- Goal: To alter the surface charge of the particles that contribute to color and turbidity so that the particles adhere to one another and are capable of settling by gravity

- Formation of a "floc" (larger, settleable particle)

Colloidal particles
(0.001 - 1 μm)

floc
(1 - 100 μm)

Coagulants

- Coagulants: chemicals added to water for coagulation
- Metal salts or polymeric materials are used as coagulants

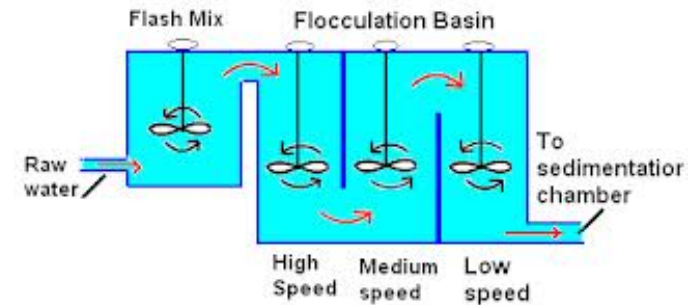Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.
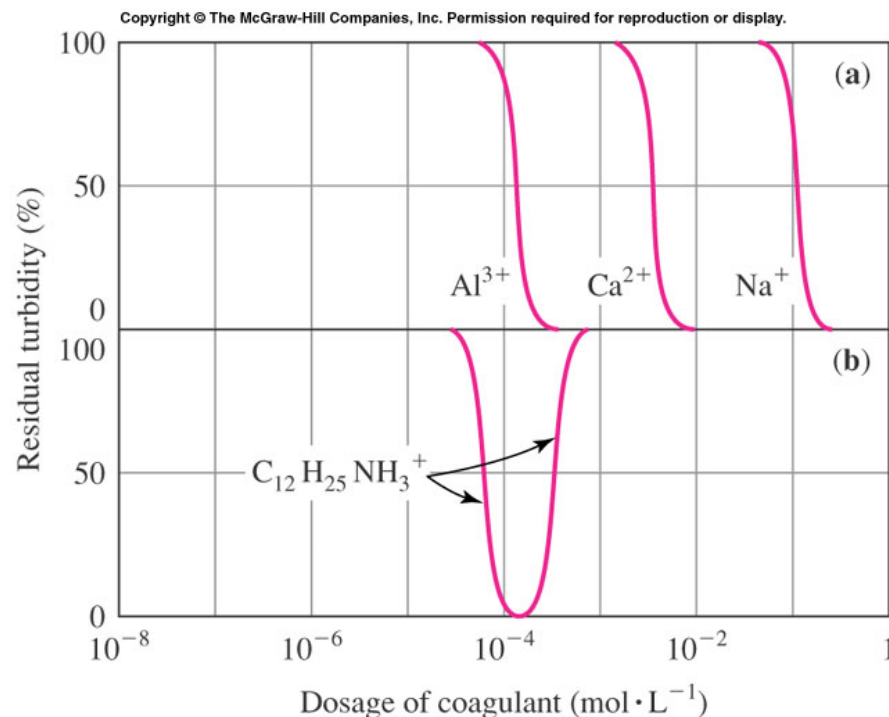
- Metal salts: compression of electrical double layer + charge neutralization + enmeshment

  (trivalent ions are most effective!)

- Cationic polymers: charge neutralization + bridging

  (charge reversal if overdosed)

Coagulants

- Key properties
  - Trivalent cation
  - Nontoxic
  - Insoluble in neutral pH

- Commonly used coagulants
  - Al^{3+} or Fe^{3+} salts
  - Alum ($Al_2(SO_4)_3 \cdot 14H_2O$): most common
    - Alum dissolution: $Al_2(SO_4)_3 \cdot 14H_2O \leftrightarrow 2Al^{3+} + 3SO_4^{2-} + 14H_2O$
  - Ferric (Fe^{3+}) cations: $Fe_2(SO_4)_3 \cdot 7H_2O$, $FeCl_3 \cdot 7H_2O$

Flocculation

- Goal: allow particles to grow by gentle mixing so that they can easily settle

- Usually configured as a three step process

- Too little mixing → not enough energy for particles to stick together

- Too much mixing → particles break down

http://chemistry.tutorvista.com

http://www.tech-faq.com
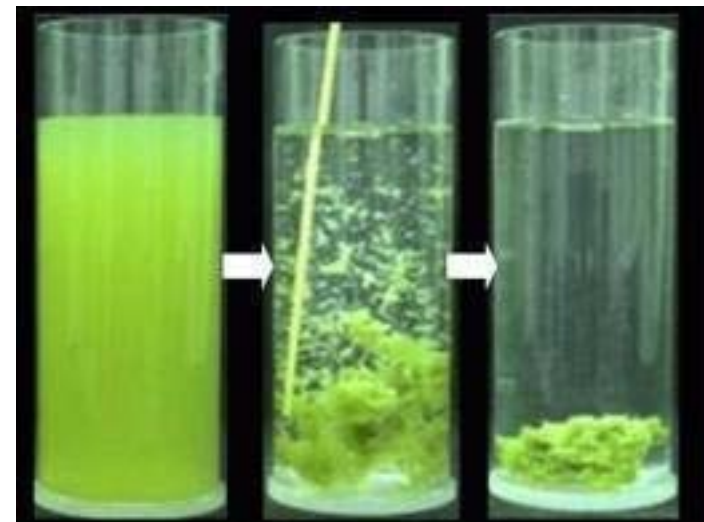
Softening

- Goal: to reduce hardness of water

- Hardness

  - The term used to characterize a water that does not lather well, causes a scum, and leaves scales
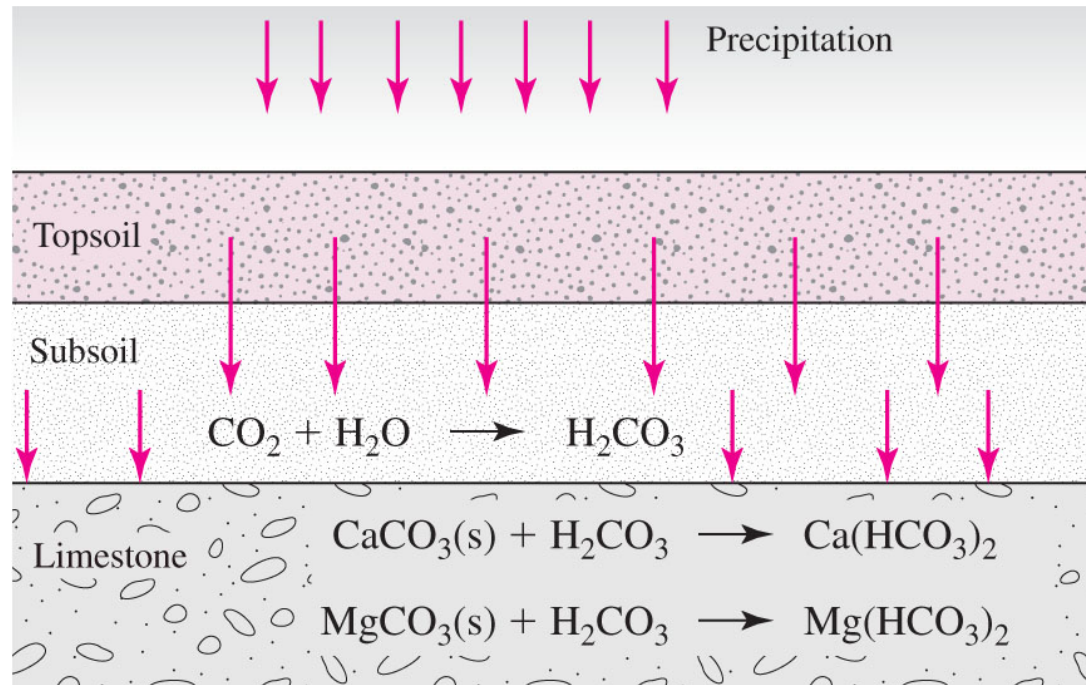
  - Caused by polyvalent cations (+2, +3, …)

http://www.watersoftenerbest.
blogspot.com

http://www.proenv.com

Formation of hardness

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Precipitation

Topsoil

Subsoil

$CO_2 + H_2O \longrightarrow H_2CO_3$

Limestone

$CaCO_3(s) + H_2CO_3 \longrightarrow Ca(HCO_3)_2$

$MgCO_3(s) + H_2CO_3 \longrightarrow Mg(HCO_3)_2$

- As rainwater infiltrates, the water gets CO_2 by the respiration of microorganisms
- Recall $CO_2 + H_2O \rightarrow H_2CO_3$
- Carbonic acid (H_2CO_3) dissolves limestone ($CaCO_3$, $MgCO_3$)
- Hardness is of concern in limestone areas

Hardness

- Total hardness
  - Technically: the sum of all polyvalent cations
  - Practically: the sum of Ca^{2+} and Mg^{2+}
  - Total hardness (TH) is divided into carbonate (CH) and noncarbonate (NCH) hardness (TH = CH + NCH)

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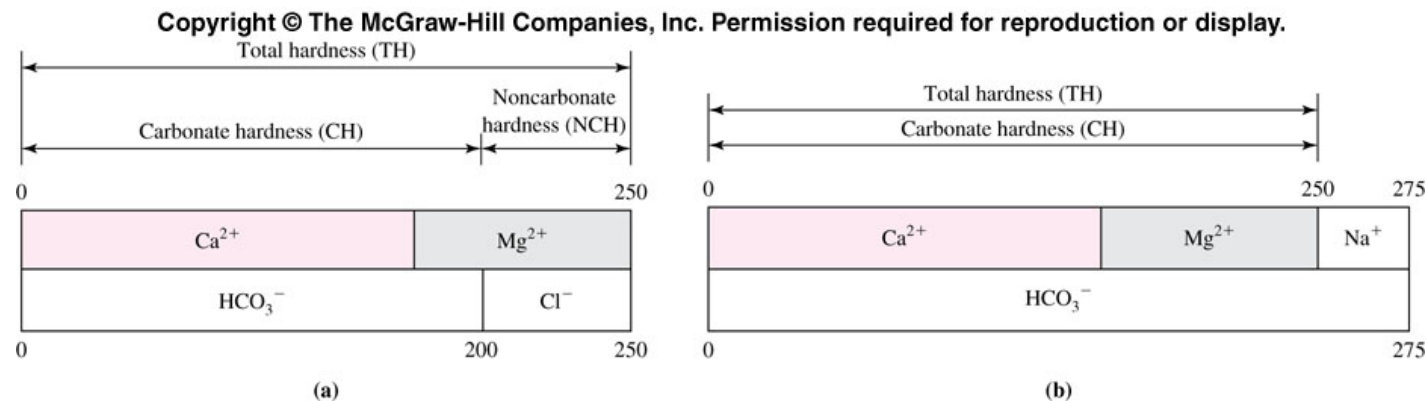
Hardness

- Units
  - eq/L or meq/L
  - mg/L as $CaCO_3$ (recall alkalinity unit)
  - Unit conversion: (mg/L as $CaCO_3$) = 50 x (meq/L)

    (as $CaCO_3$ is 50 mg/meq)

| Term	Concentration range (mg/L as $CaCO_3$)
Soft	<17.1
Slightly hard	17.1-60
Moderately hard	60-120
Hard	120-180
Very hard	>180

Hardness

Q: A sample of water has the following concentration of ions. Calculate the total hardness and the carbonate hardness of the water sample.

Ion	Concentration (mg/L)	Ion	Concentration (mg/L)
Ca^{2+}	40	HCO_3^-	110
Mg^{2+}	10	SO_4^{2-}	67.2
Na^+	11.8	Cl^-	11
K^+	7.0		

Lime-soda softening

- Addition of lime ($Ca(OH)_2$) and soda ash (Na_2CO_3)

- Precipitates Ca^{2+} and Mg^{2+} using following reactions:

$$Ca^{2+} + CO_3^{2-} \rightleftharpoons CaCO_3\ (s)$$

$$Mg^{2+} + 2OH^- \rightleftharpoons Mg(OH)_2(s)$$
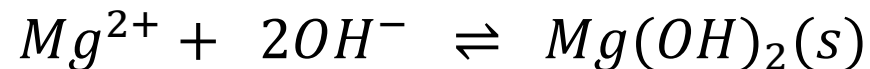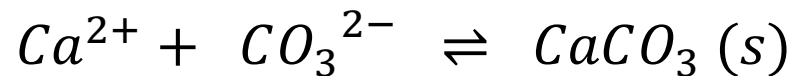
- Target on Ca^{2+} and carbonate hardness first, leaving as much Mg^{2+} and noncarbonate hardness as possible
  - pH of water should be ~10.3 for Ca^{2+} precipitation and ~11 for Mg^{2+} precipitation
  - Have to provide CO_3^{2-} for noncarbonate hardness

Reading assignment

Textbook Ch 10 p. 453-457, 460-479