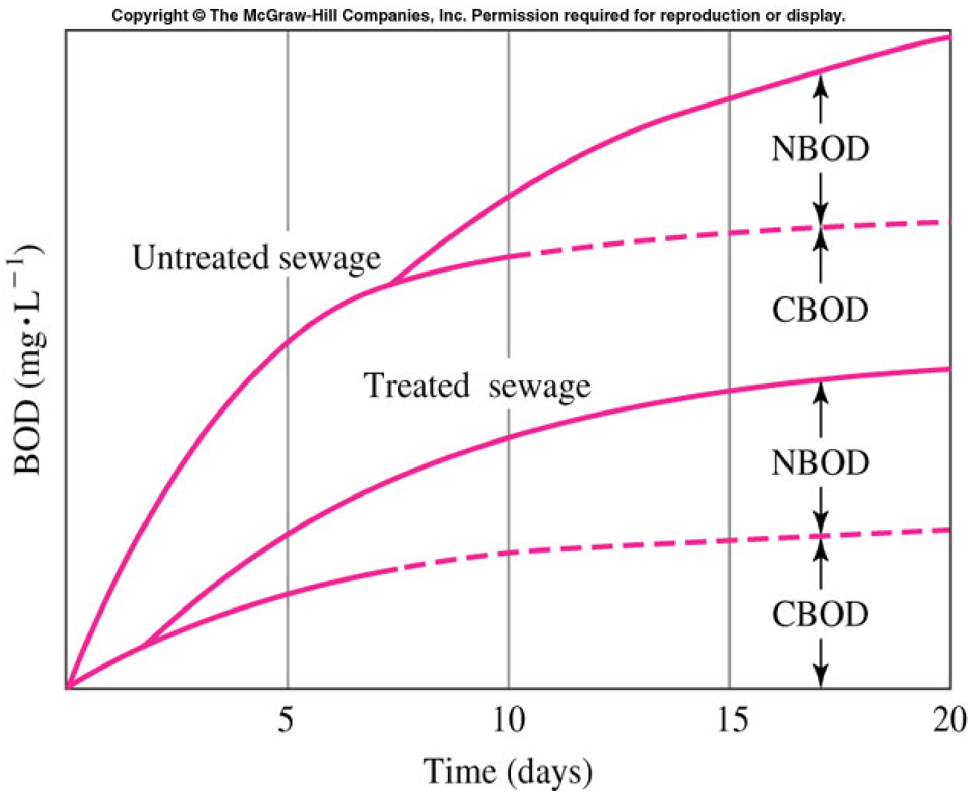
Nitrogenous BOD

- So far, our assumption was that the oxygen demand is due to carbon oxidation only
- Organic compounds also contain reduced nitrogen
- The reduced nitrogen is released to form ammonium ion (NH_4^+)
- This may contribute significantly to overall oxygen demand by:

$$NH_4^+ + 2O_2 \longrightarrow NO_3^- + H_2O + 2H^+$$

Nitrogenous BOD

The BOD curve when NBOD is significant



- Lag time exists because carbon-utilizing bacteria carbon is more prevalent at the beginning
- As CBOD goes down, the population of ammonia-utilizing bacteria increases, leading to NBOD consumption
- For treated sewage, the lag time is shorter, because there's not much food for carbon-utilizing bacteria

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

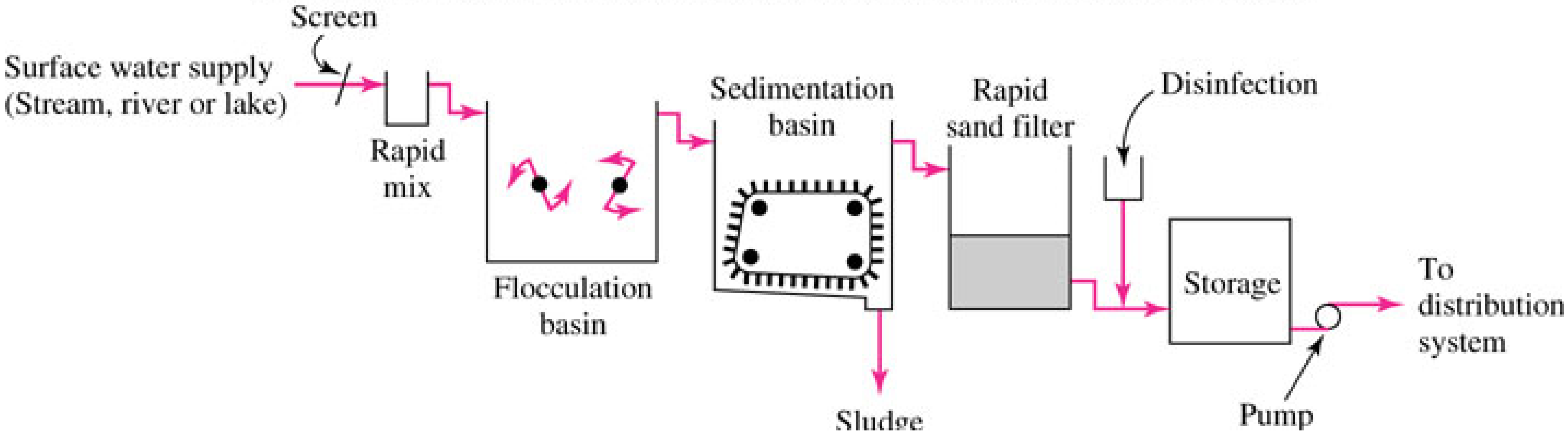
- Factors determining drinking water quality
  - Physical: color and turbidity, temperature, taste and odor
  - Chemical: toxic chemicals and chemicals that make water non-palatable
  - Microbiological: pathogens
  - Radiological: ex) uranium

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

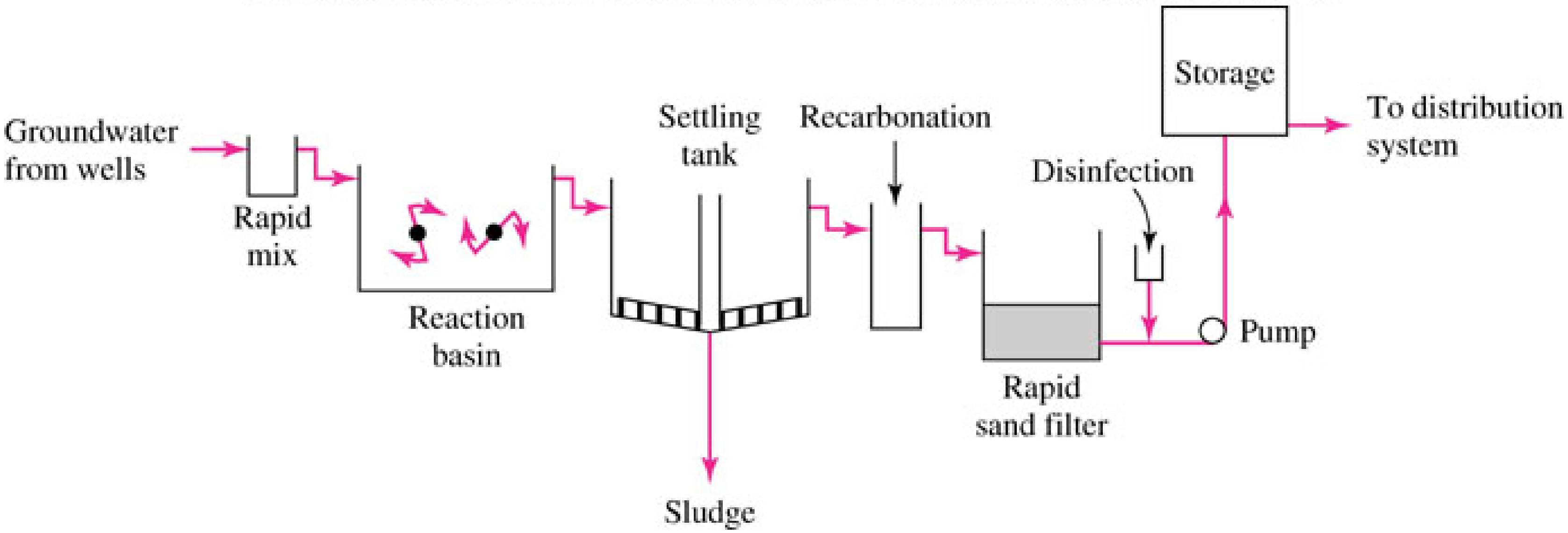
Water treatment systems

- Coagulation plant: conventional surface water treatment



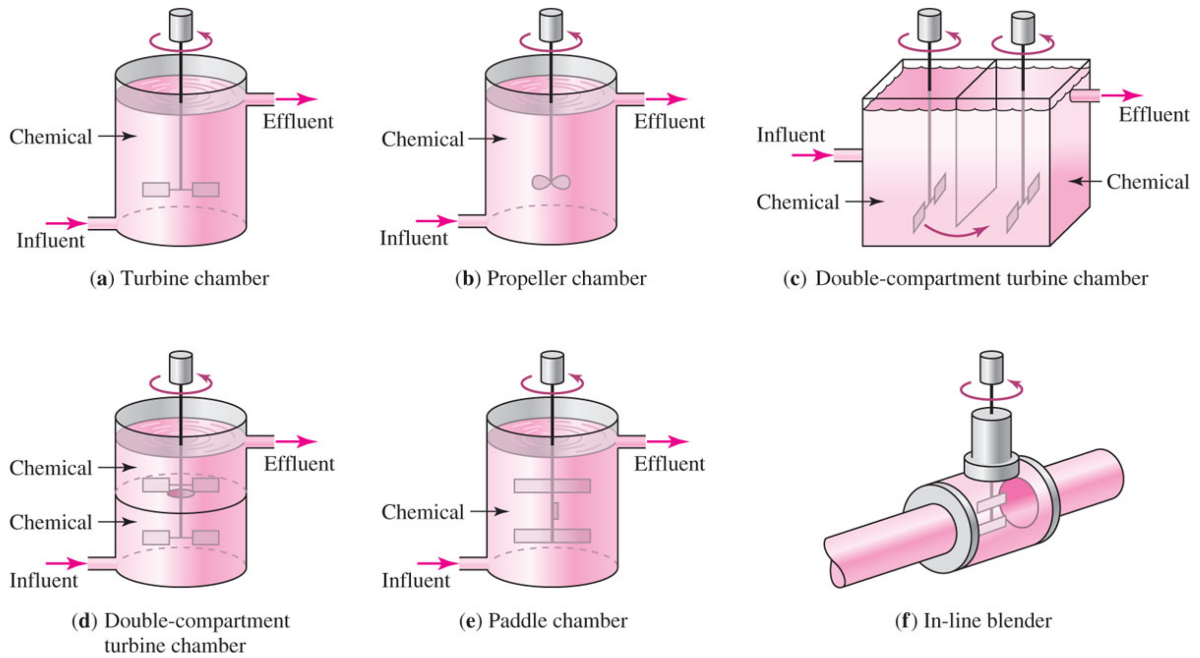
Water treatment systems

- Water softening plant: for groundwater with high hardness



Rapid mix

- To blend chemicals (ex: coagulants, softening agents) with water
- Short retention time (10-30 s)



Coagulation-flocculation

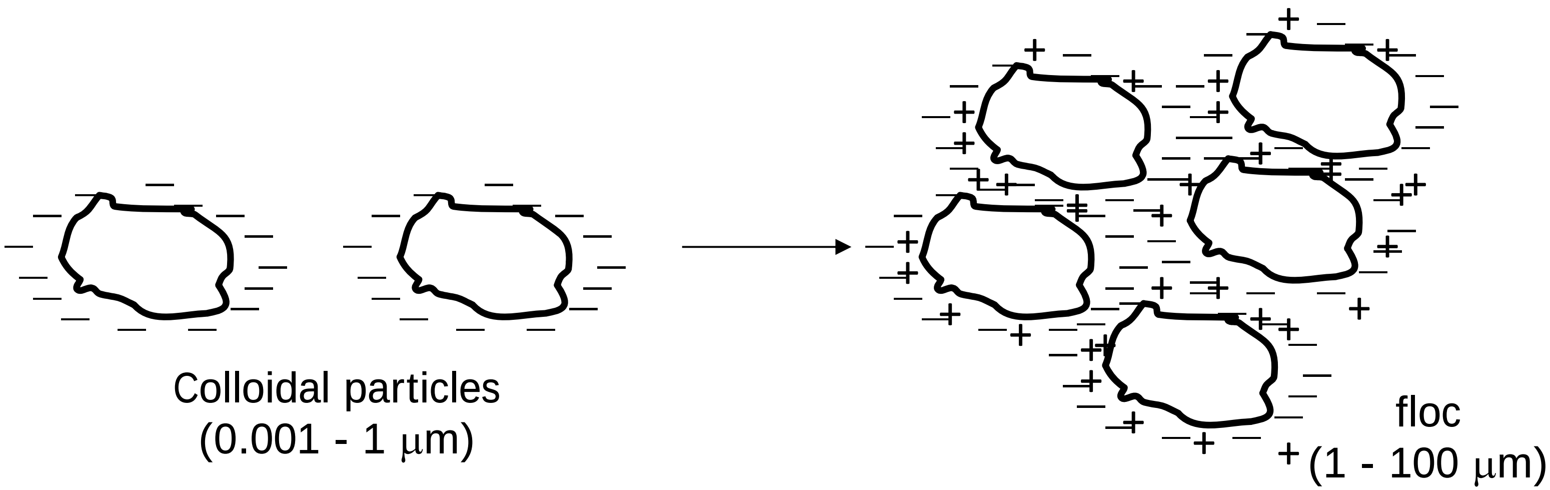
- Coagulation-flocculation process is used to remove colloidal particles from water
  - Coagulation: in the rapid mix; intensive mixing; short retention time
  - Flocculation: in the flocculation basin; gentle mixing; longer retention time

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

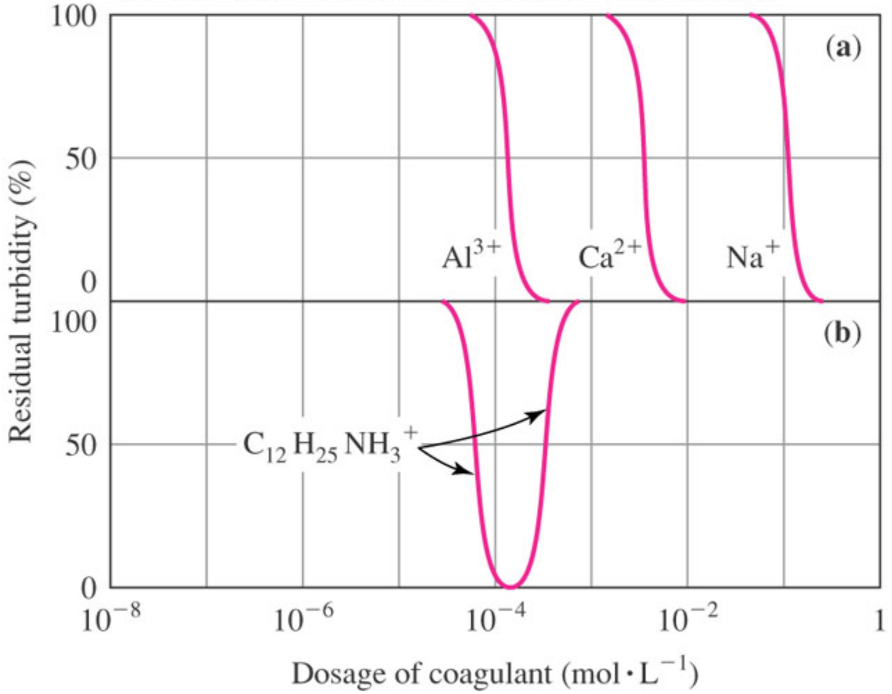
Coagulation

- 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)



Coagulants

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



- Metal salts: compression of electrical double layer + charge neutralization + enmeshment

  (trivalent ions are most effective!)

- Cationic polymers: charge neutralization + bridging

  (charge reversal if overdosed)

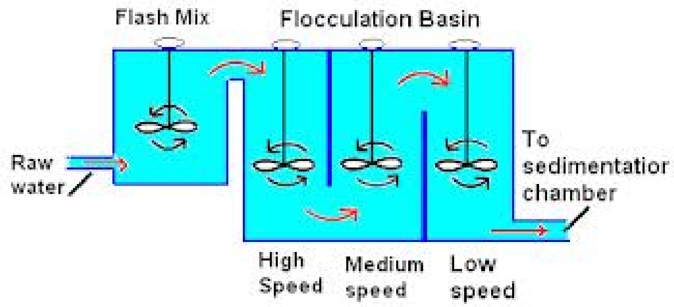
Coagulants

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

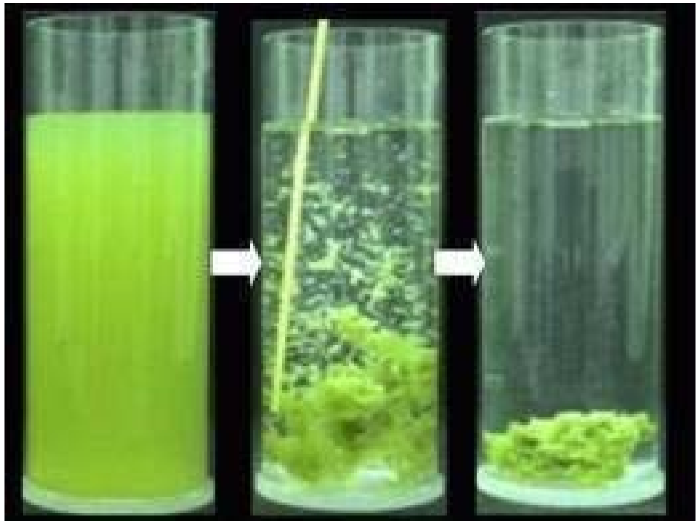
- Commonly used coagulants
  - Al^{3+} or Fe^{3+} salts
  - Alum ($Al_2(SO_4)_3 \cdot 14H_2O$): most common
    - Alum dissolution: $Al_2(SO_4)_3 \cdot 14H_2O \leftrightarrow 2Al^{3+} + 3SO_4^{2-} + 14H_2O$
  - Ferric (Fe^{3+}) cations: $Fe_2(SO_4)_3 \cdot 7H_2O$, $FeCl_3 \cdot 7H_2O$

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

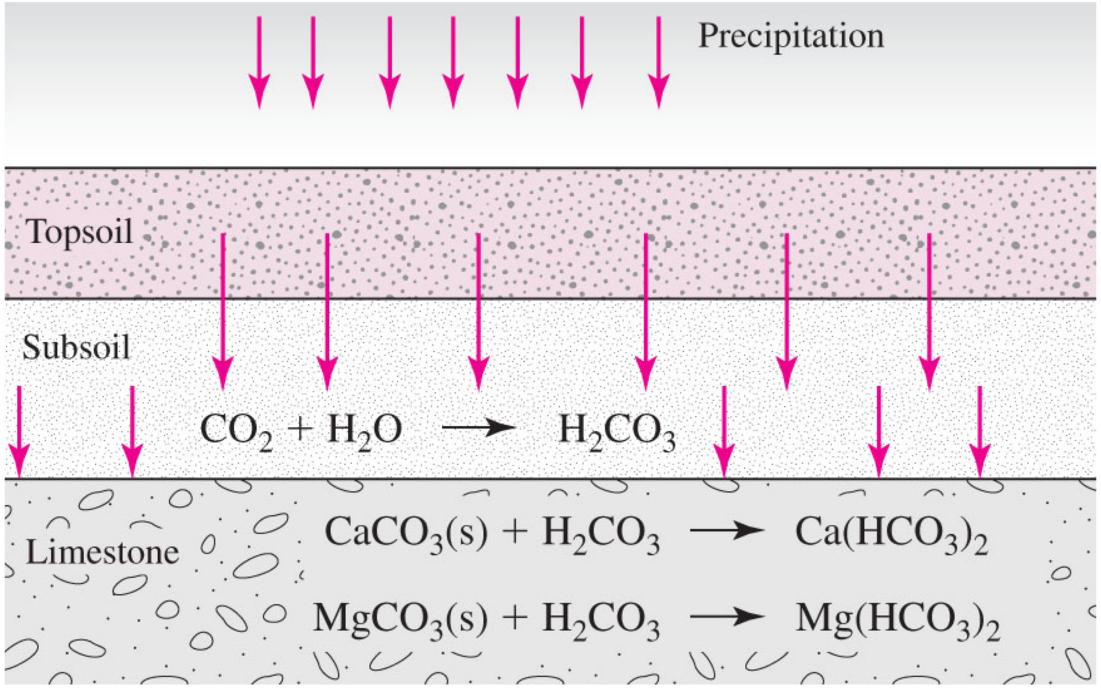
Softening

- 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

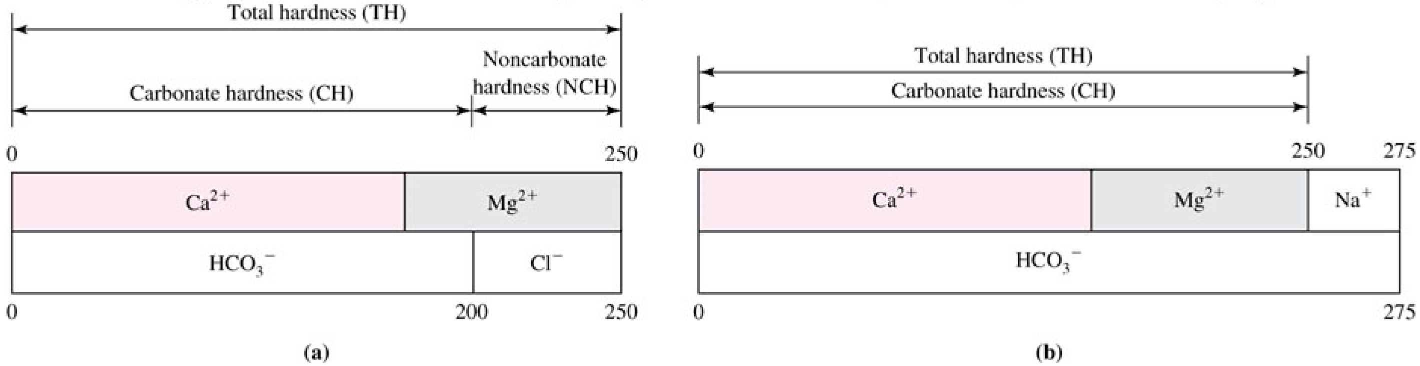
Formation of hardness



- 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)



Hardness

- Units
  - eq/L or meq/L
  - mg/L as $CaCO_3$ (recall our alkalinity homework)
  - 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:

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

$$Mg^{2+} + \ 2OH^{-} \ \rightleftharpoons \ Mg(OH)_2(s)$$

- 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

Lime-soda softening

Let's think about the treatment of the water sample.

The water sample in the previous question has a TH of 100 mg/L as $CaCO_3$ and can be classified as moderately hard water. What is the pH required to reduce the Ca^{2+}-hardness to 0.01 mM (1 mg/L as $CaCO_3$)? What is the pH required to reduce the Mg^{2+}-hardness to 0.01 mM (1 mg/L as $CaCO_3$)? The pK_s of $CaCO_3$ and $Mg(OH)_2$ are 8.34 and 11.25, respectively. The initial pH of the water sample is 7.2. Neglect the effect of ionic strength.

Ion	**Concentration**		
	In mg/L	In meq/L	In M
Ca^{2+}	40	2.00	1.00×10^{-3}
Mg^{2+}	10	0.823	4.11×10^{-4}
HCO_3^-	110	1.83	1.83×10^{-3}

Reading assignment

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