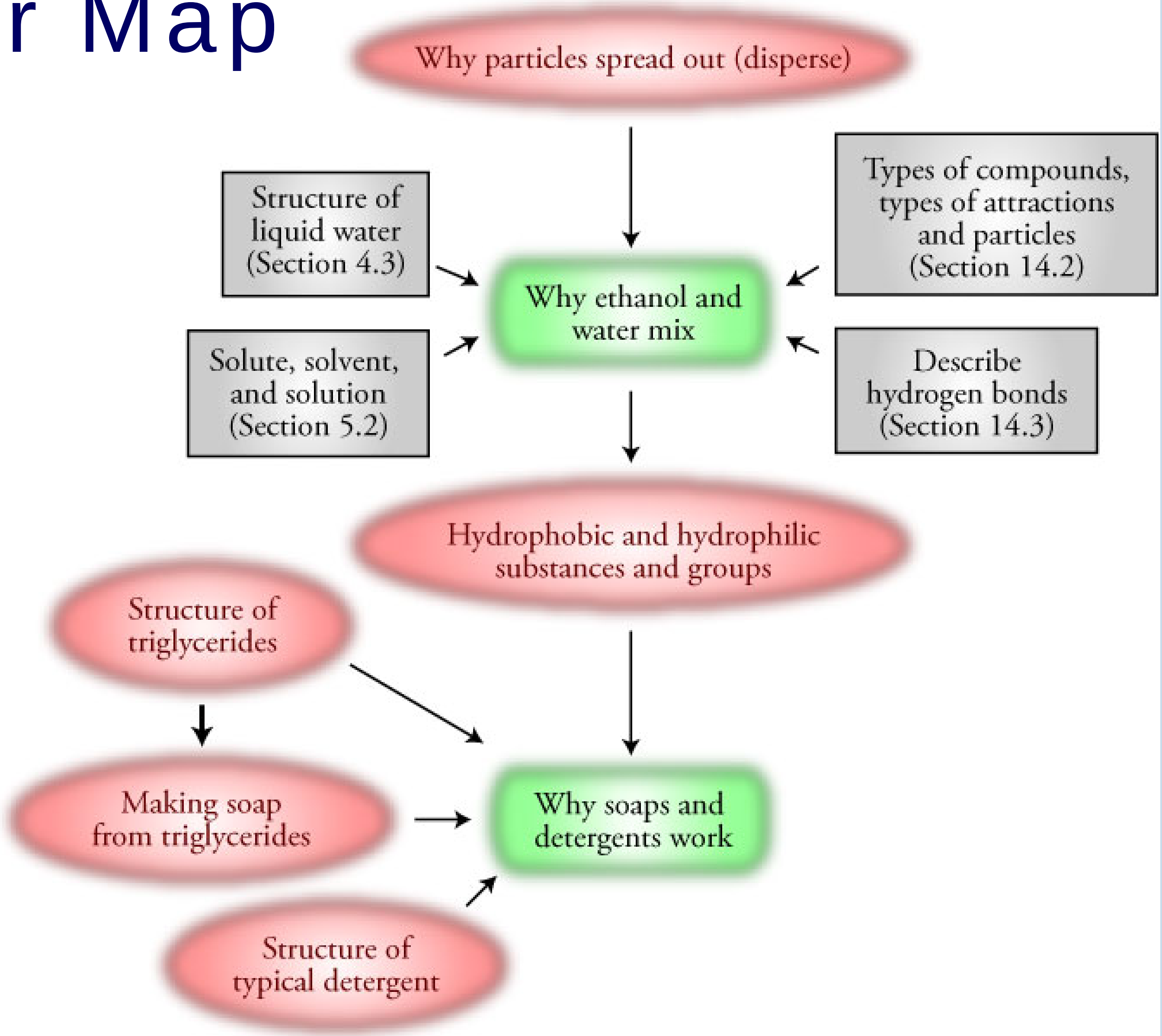
Chapter 15

Solution Dynamics

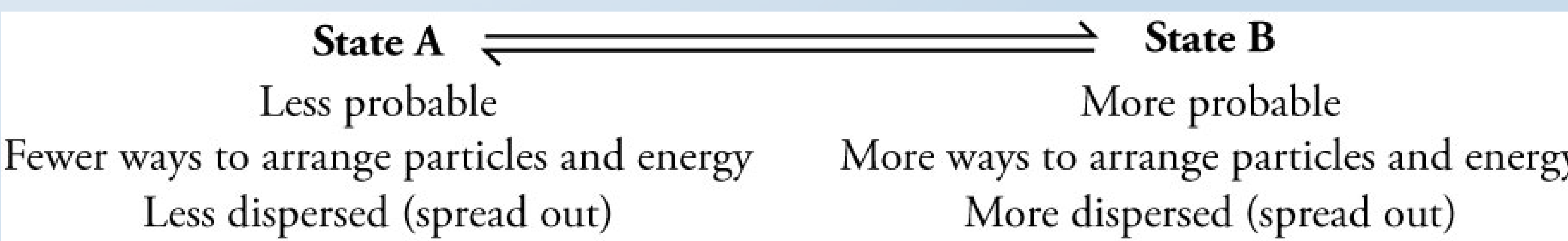
Chapter Map



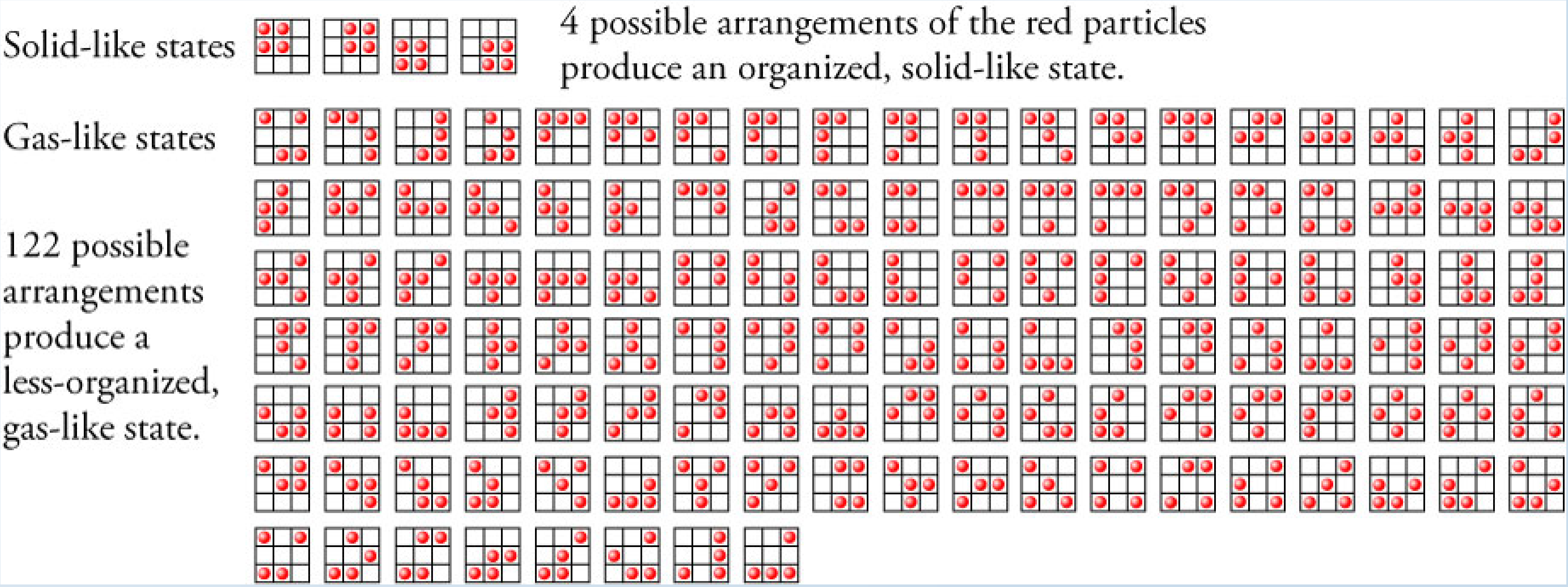
Why particles spread out (disperse)
Structure of liquid water (Section 4.3)
Types of compounds, types of attractions and particles (Section 14.2)
Why ethanol and water mix
Solute, solvent, and solution (Section 5.2)
Describe hydrogen bonds (Section 14.3)
Hydrophobic and hydrophilic substances and groups
Structure of triglycerides
Making soap from triglycerides
Why soaps and detergents work
Structure of typical detergent

Why Changes Happen

- Consider a system that can switch freely between two states, A and B.
- Probability helps us to predict that the system will shift to state B if state B has its particles and energy more dispersed, leading to more ways to arrange the particles and energy in the system.



9-Point Universe



Probability of Gas

- In 9-point universe, 96% of the arrangements of 4 particles are gas-like.
- In 16-point universe, 99.5% of the arrangements of 4 particles are gas-like.
- Therefore, an increase in the number of possible positions leads to an increase in the probability that the system will be in the more dispersed, gas-like state.
- In real systems, there are huge numbers of particles in huge numbers of positions, so there is an extremely high probability that the systems will be in the more dispersed, gas-like state.

General Statement

- Changes tend to take place to shift from less probable, less dispersed arrangements that have fewer ways to arrange the particles to more probable, more dispersed states that have more ways to arrange the particles.

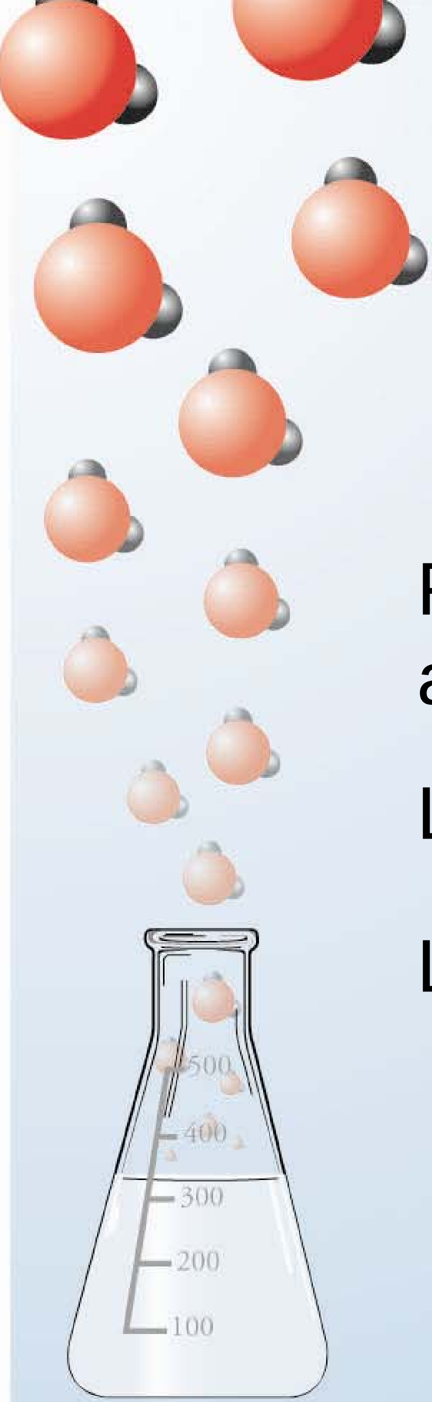
Solids shift spontaneously to gases.

- Why does dry ice, $CO_2(s)$, sublime? Why does the change favor the gas?
  - Internal kinetic energy is associated with the random movement of particles in a system.
  - Internal kinetic energy makes it possible for CO_2 molecules to move back and forth between solid and gas.
  - If the particles can move freely back and forth between solid and gas, they are more likely to be found in the more dispersed gas state, which has more equivalent ways to arrange the particles.

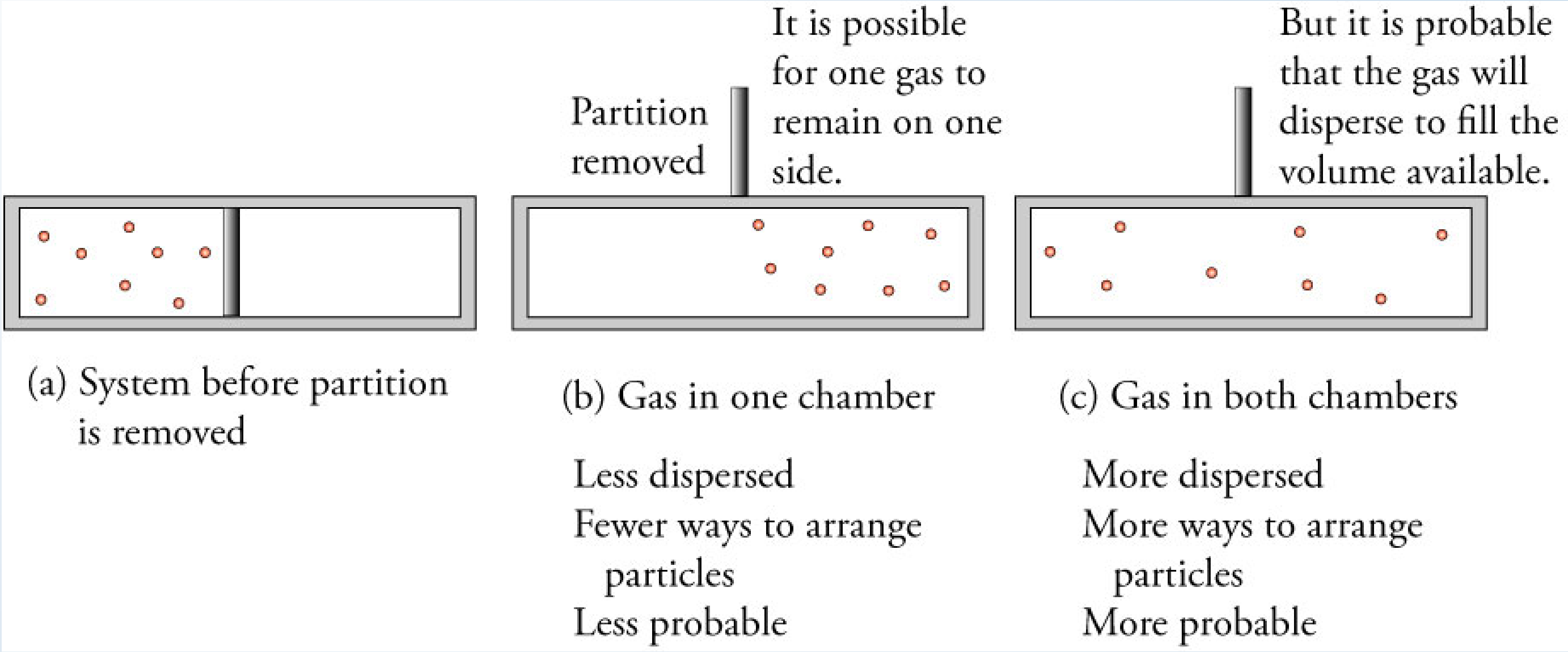
Solid to Gases

$CO_2(s) \longrightarrow CO_2(g)$

Fewer ways to arrange particles	More ways to arrange particles
Less probable	More probable
Less dispersed	More dispersed



Gases Expand

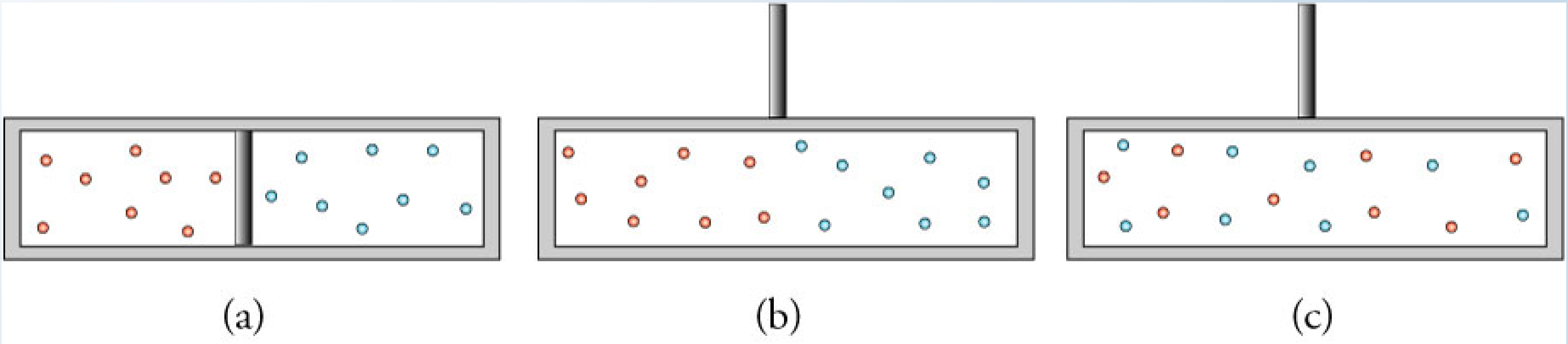


When the barrier between the two chambers in the container shown in (a) is raised, it is possible that the gas will end up in one chamber, like in (b), but it is much more likely that it will expand to fill the total volume available to it, like in (c).

Matter gets dispersed (spread out).

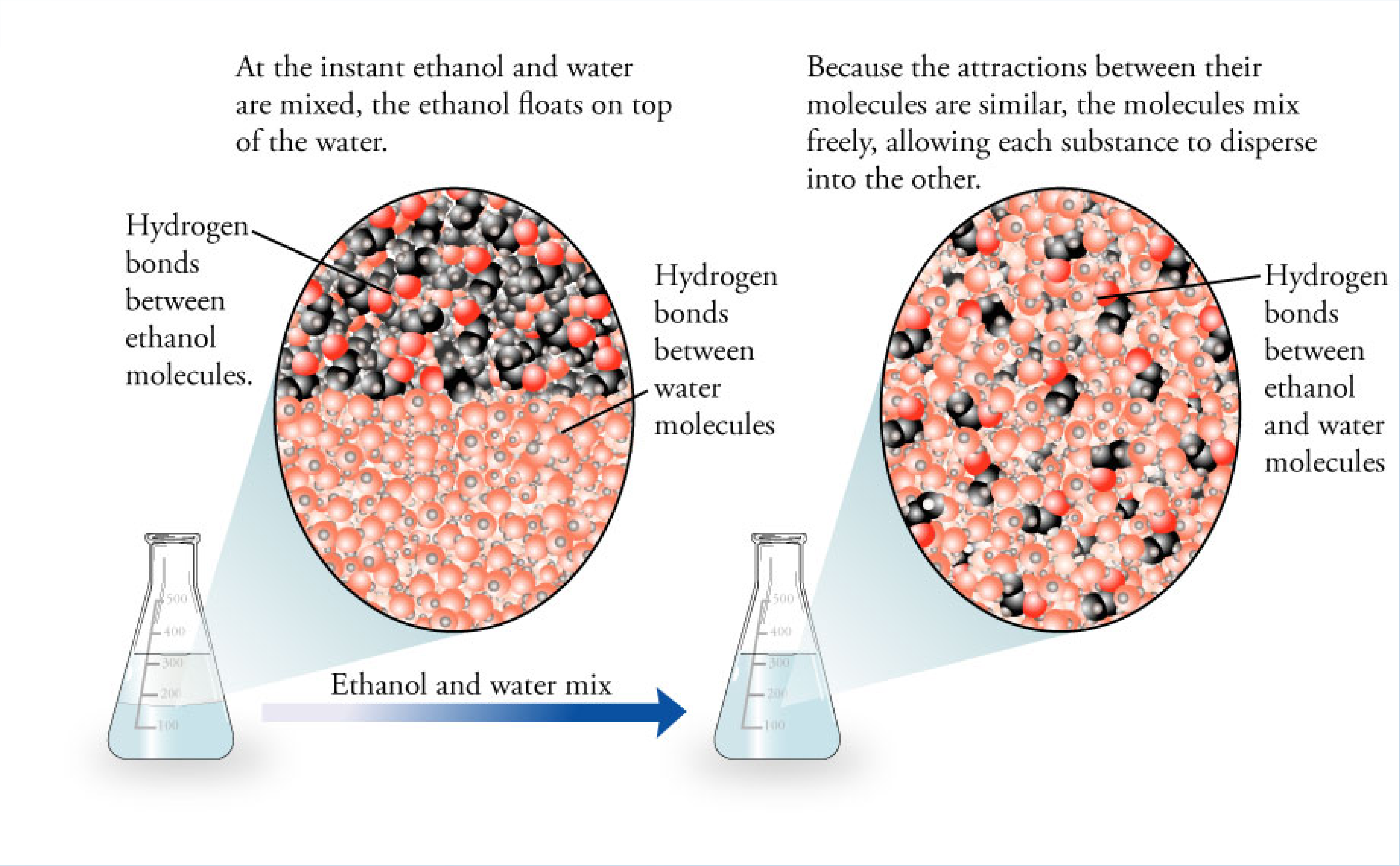
Gas in one chamber →	Gas in both chambers
Fewer ways to arrange particles	More ways to arrange particles
Less probable	More probable
Less dispersed	More dispersed

Substances tend to mix.

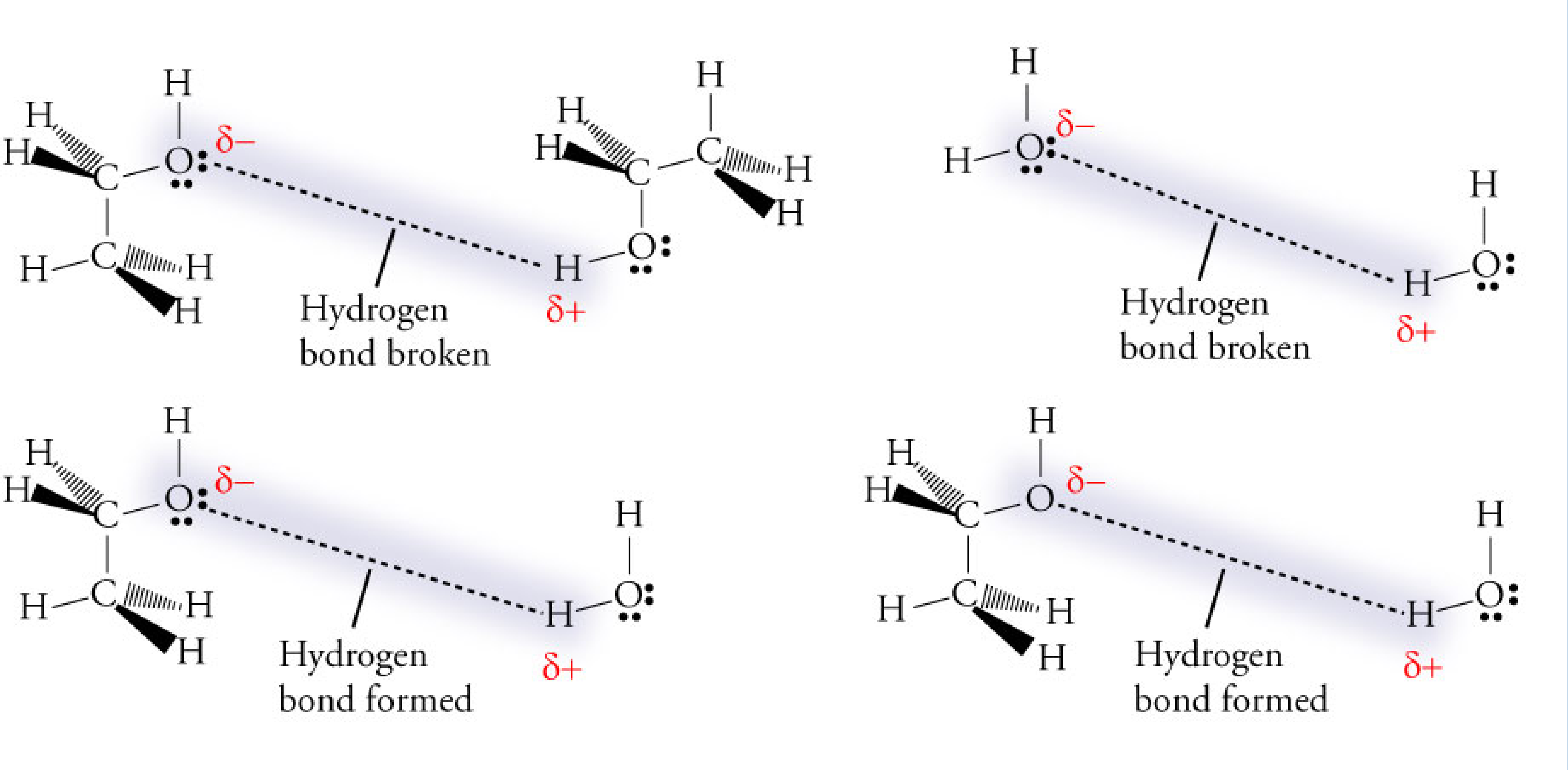


When the barrier between the two gases in the container shown in (a) is raised, it is possible that the gases will stay separated, like in (b), but it is much more likely that they will mix, like in (c).

Ethanol and Water Mixing

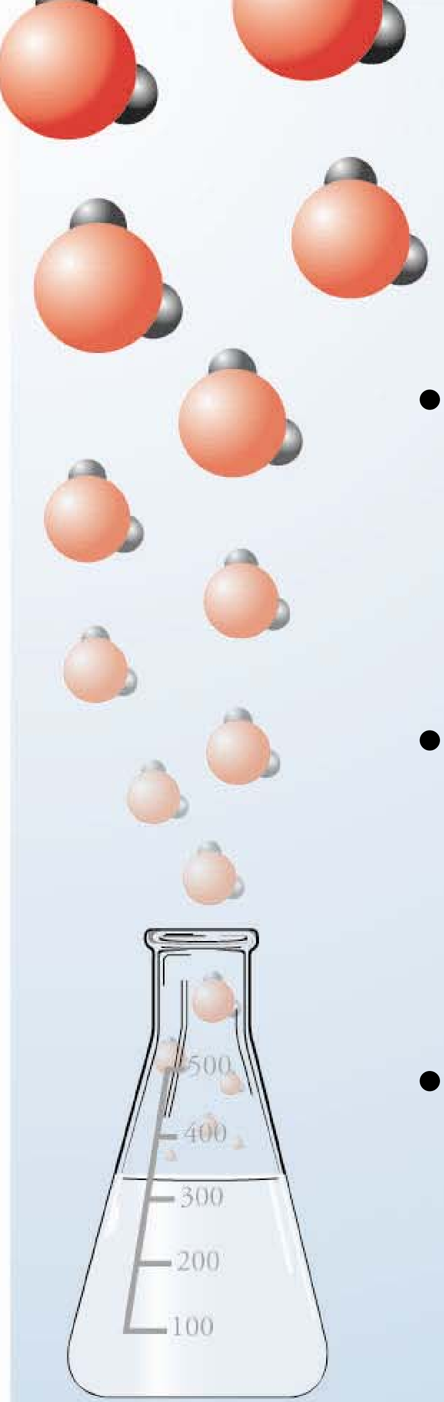


Attractions Broken and Made



Solubility

- If less than one gram of the substance will dissolve in 100 grams (or 100 mL) of solvent, the substance is considered ***insoluble***.
- If more than ten grams of substance will dissolve in 100 grams (or 100 mL) of solvent, the substance is considered ***soluble***.
- If between one and ten grams of a substance will dissolve in 100 grams (or 100 mL) of solvent, the substance is considered ***moderately soluble***.

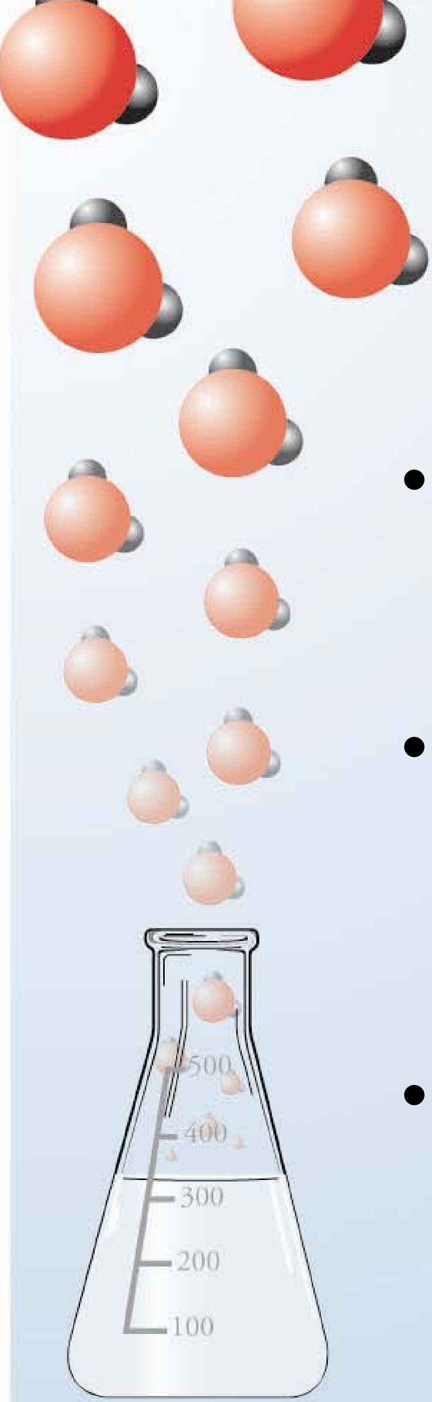


“Like Dissolves Like”

- Polar substances are expected to dissolve in polar solvents.
  - For example, ionic compounds, which are very polar, are often soluble in the polar solvent water.
- Nonpolar substances are expected to dissolve in nonpolar solvents.
  - For example, nonpolar molecular substances are expected to dissolve in hexane, a common nonpolar solvent.

"Like Does Not Dissolve Unlike"

- Nonpolar substances are not expected to dissolve to a significant degree in polar solvents.
  - For example, nonpolar molecular substances are expected to be insoluble in water.
- Polar substances are not expected to dissolve to a significant degree in polar solvents.
  - For example, ionic compounds are insoluble in hexane.



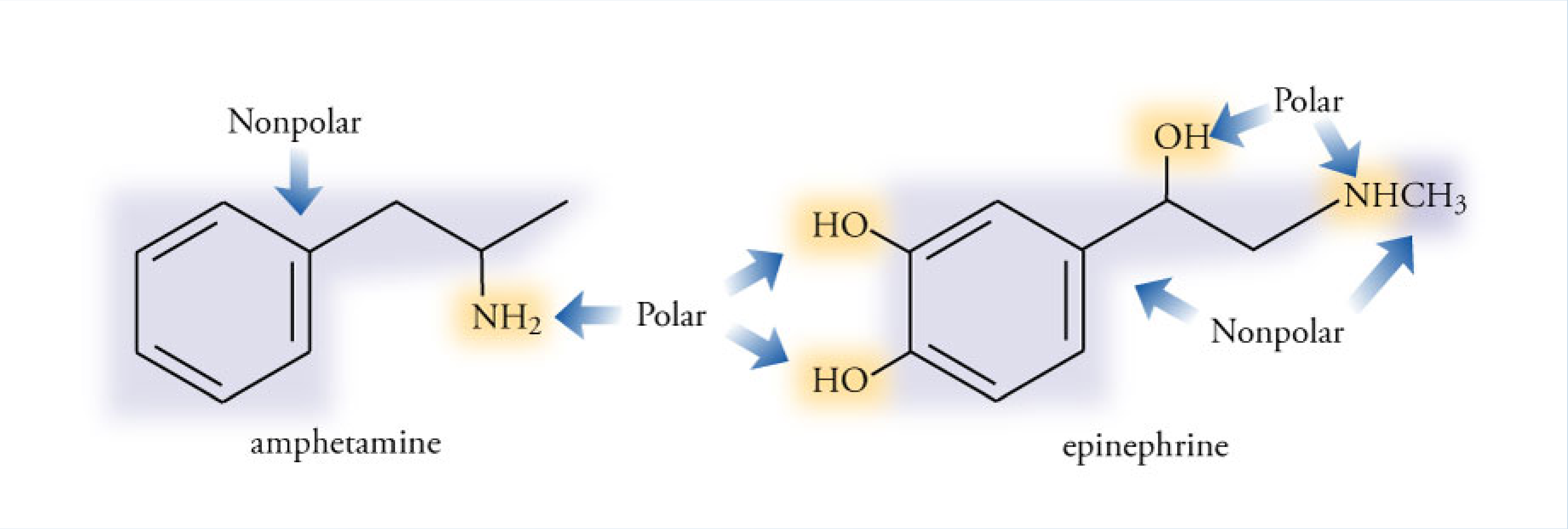
Summary of Solubility Guidelines

- Ionic Compounds
  - Often soluble in water
  - Insoluble in hexane
- Molecular compounds with nonpolar molecules
  - Insoluble in water
  - Soluble in hexane
- Molecular Compounds with small polar molecules
  - Usually soluble in water
  - Often soluble in hexane

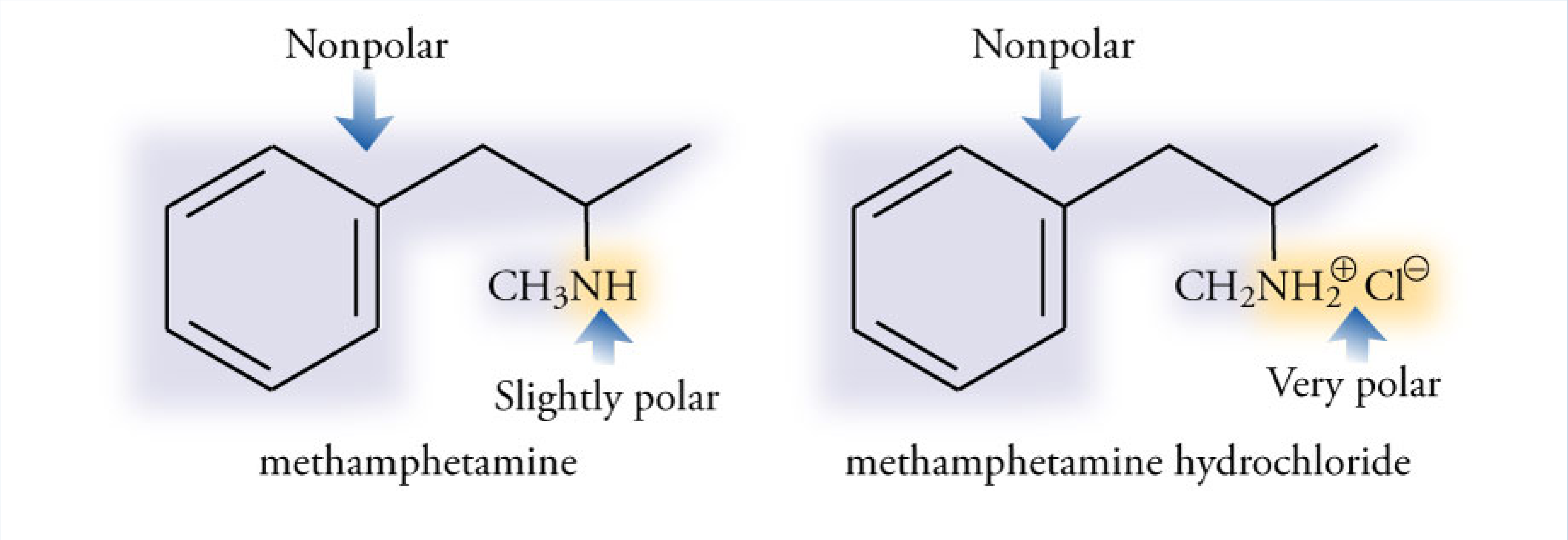
Water Solubility

- If we are comparing the water solubility of two similar molecules, the one with the higher percentage of the molecule that is polar (***hydrophilic***) is expected to have higher water solubility.
- We predict that the molecule with the higher percentage of its structure that is nonpolar (***hydrophobic***) to be less soluble in water.

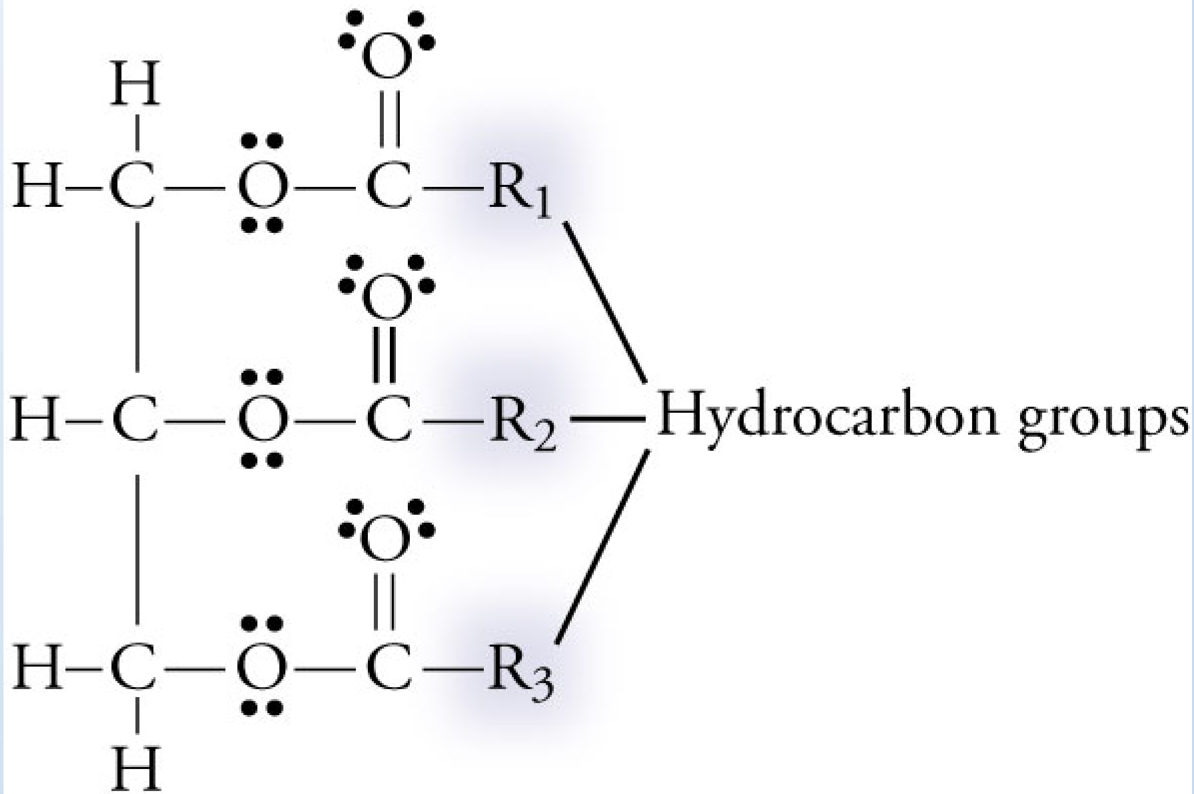
Hydrophobic and Hydrophilic



Methamphetamine

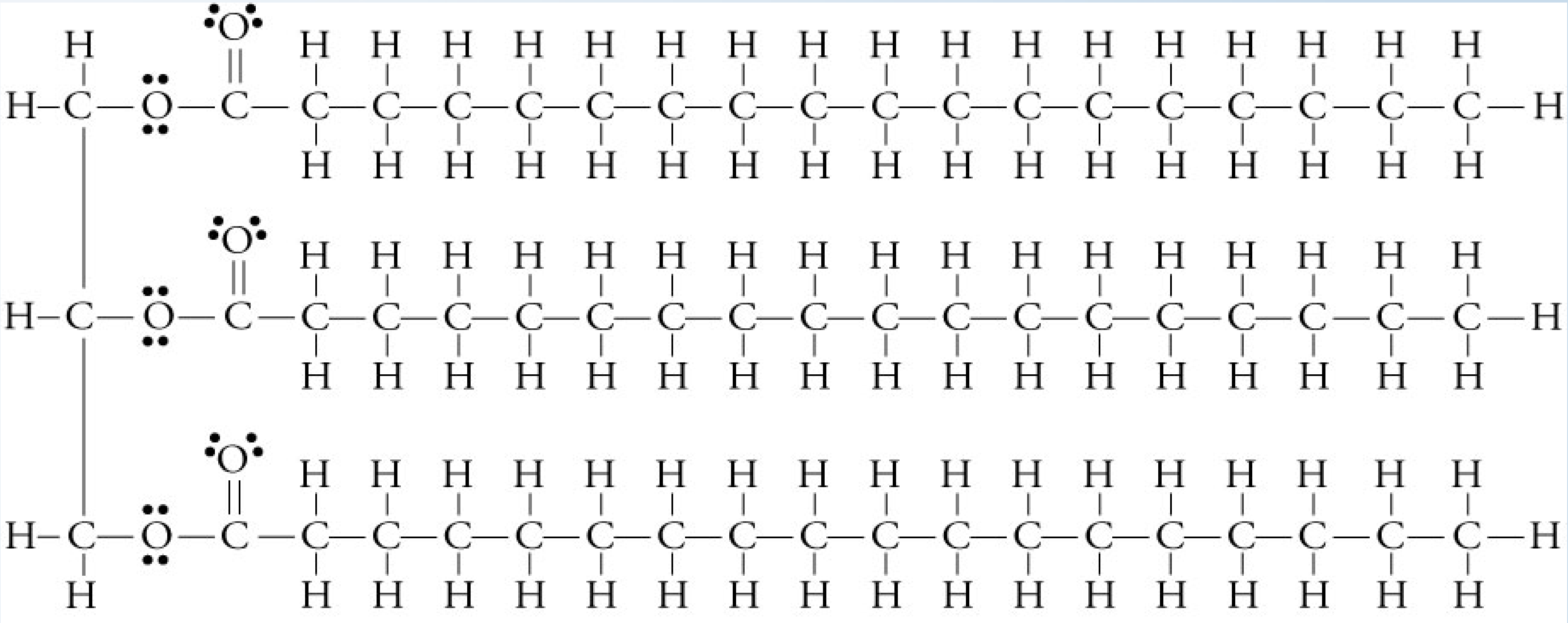


Triglycerides (Fats and Oils)

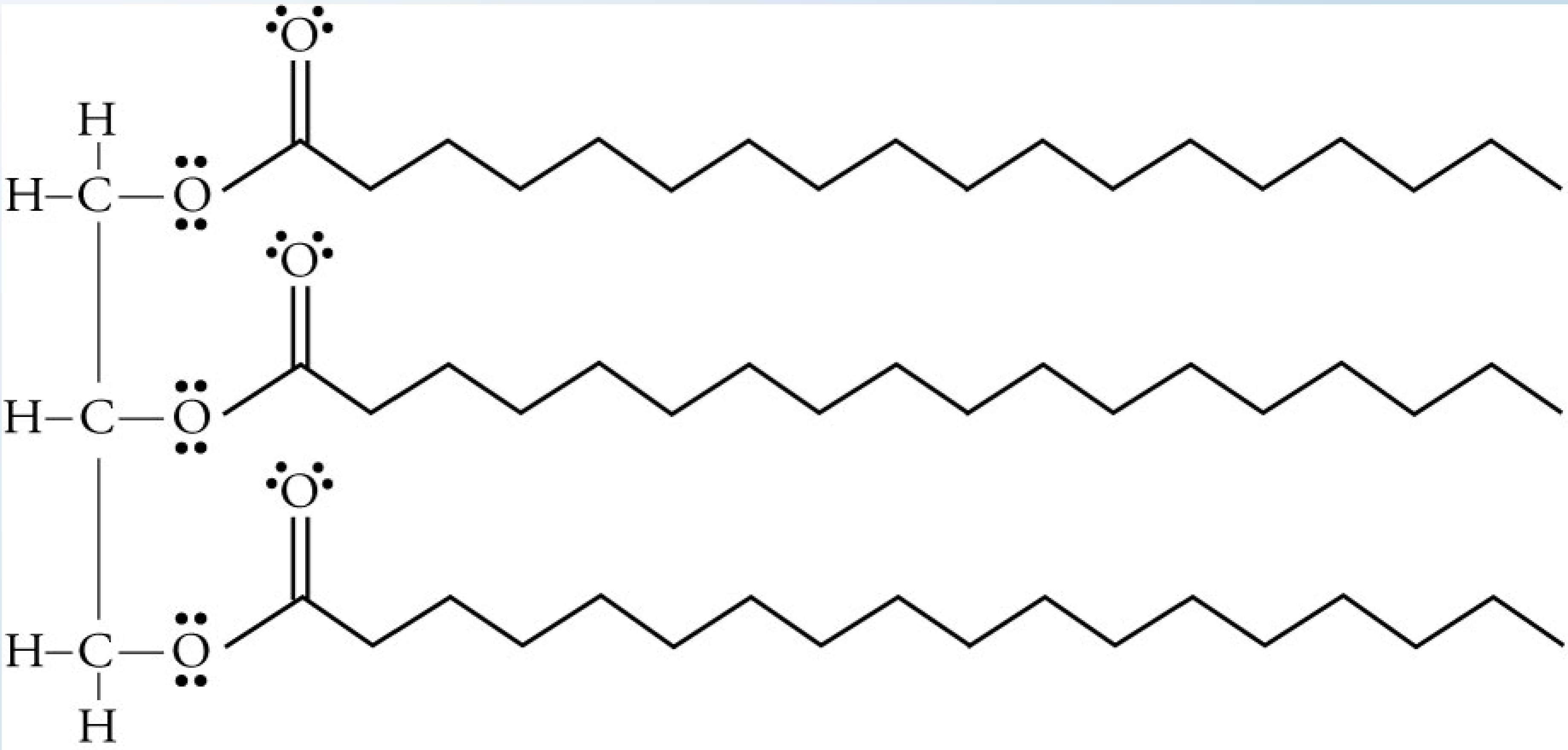


triglyceride

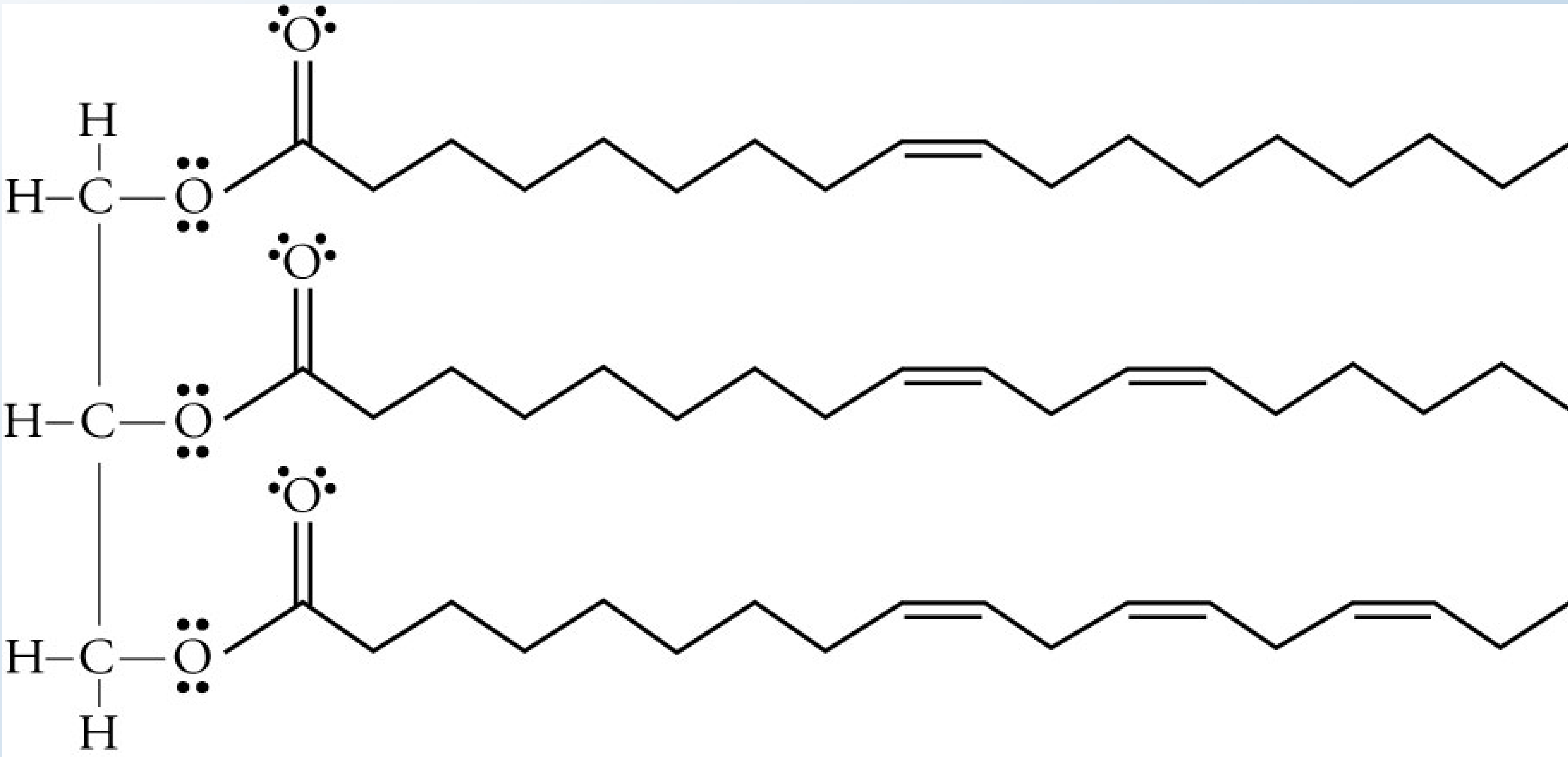
Tristearin



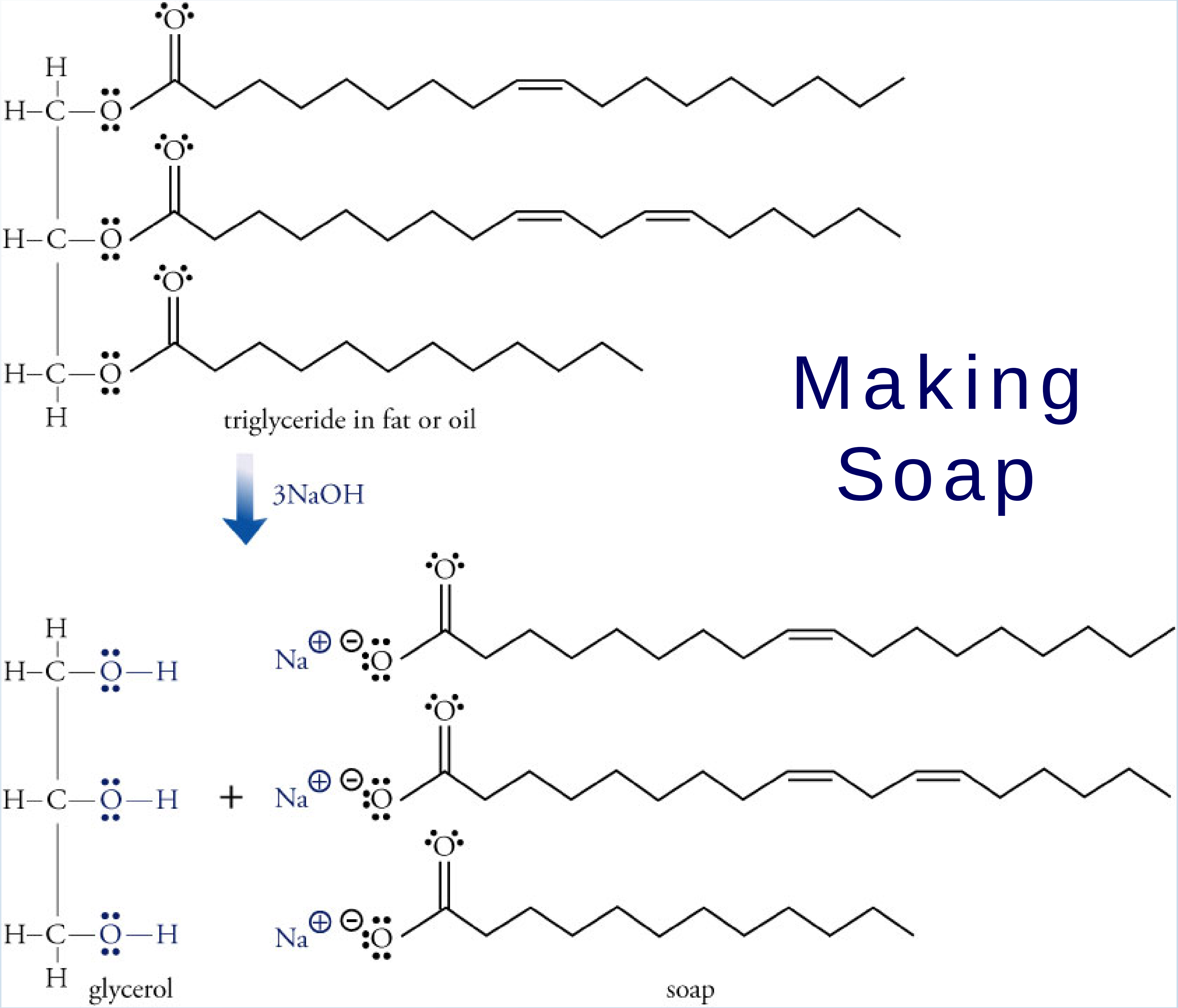
Tristearin – Line Drawing



Typical Liquid Triglyceride

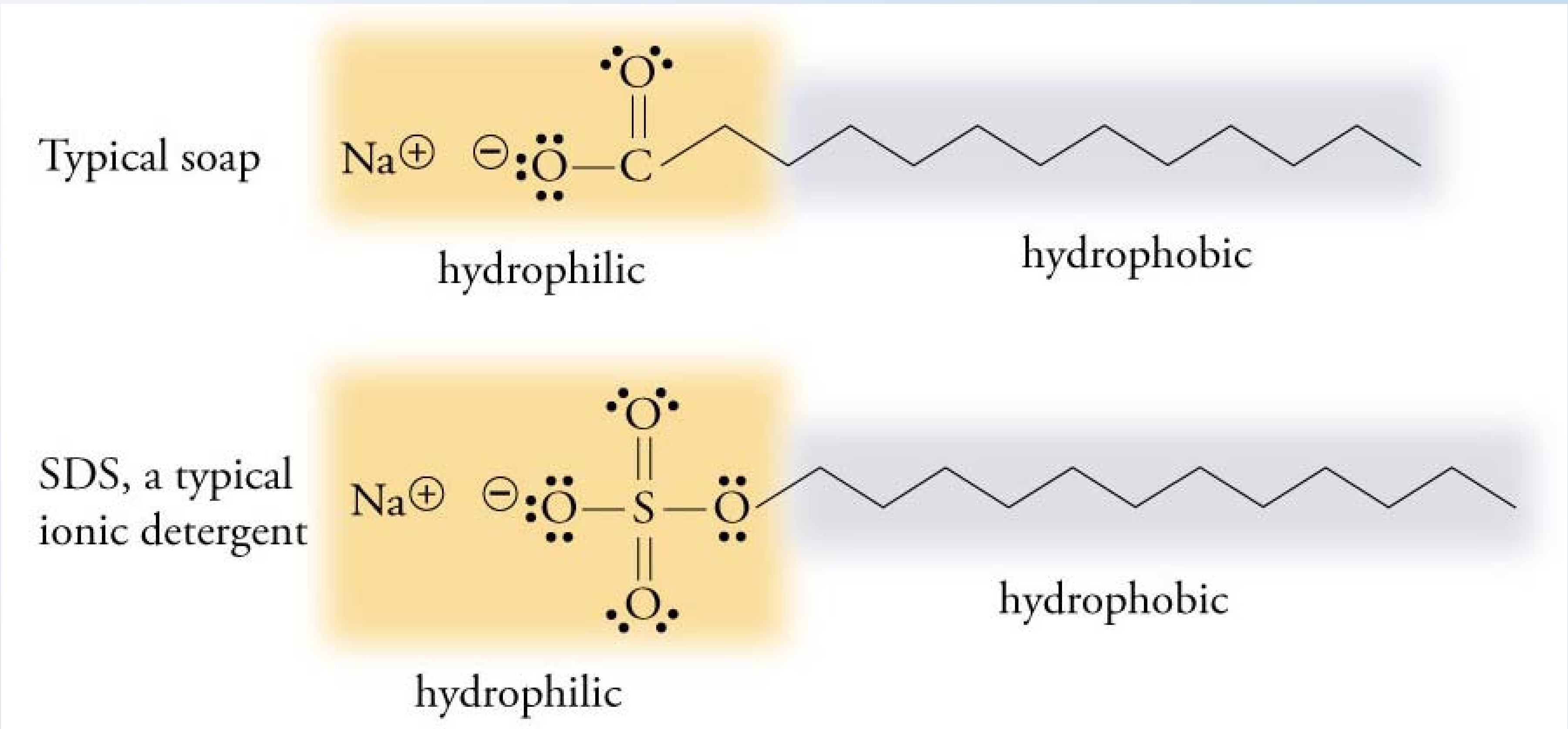


Making Soap

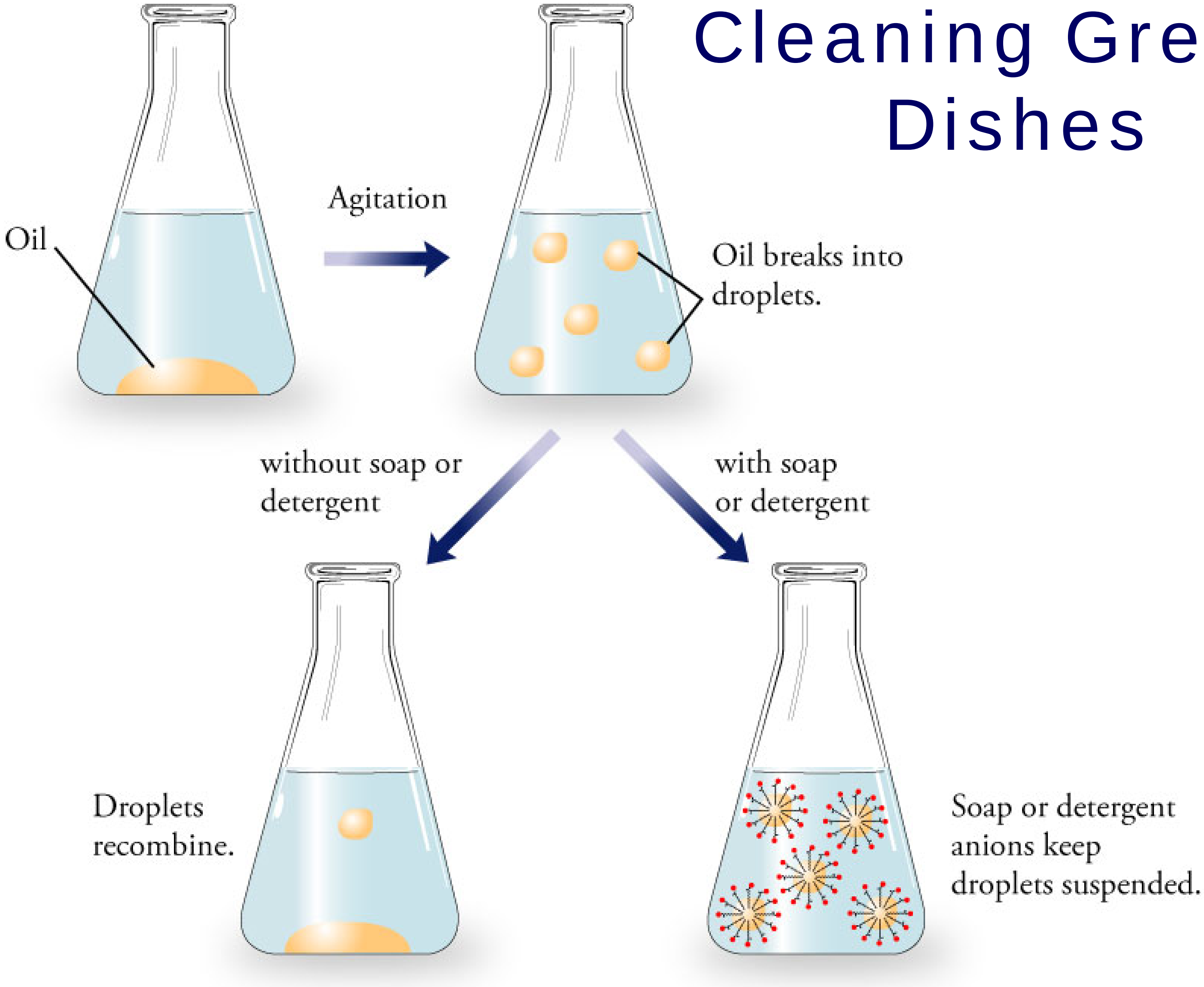


H
H–C–O
H–C–O
H–C–O
H
triglyceride in fat or oil
3NaOH
H
H–C–O–H
H–C–O–H
H–C–O–H
H
glycerol
+
Na
Na
Na
O
soap

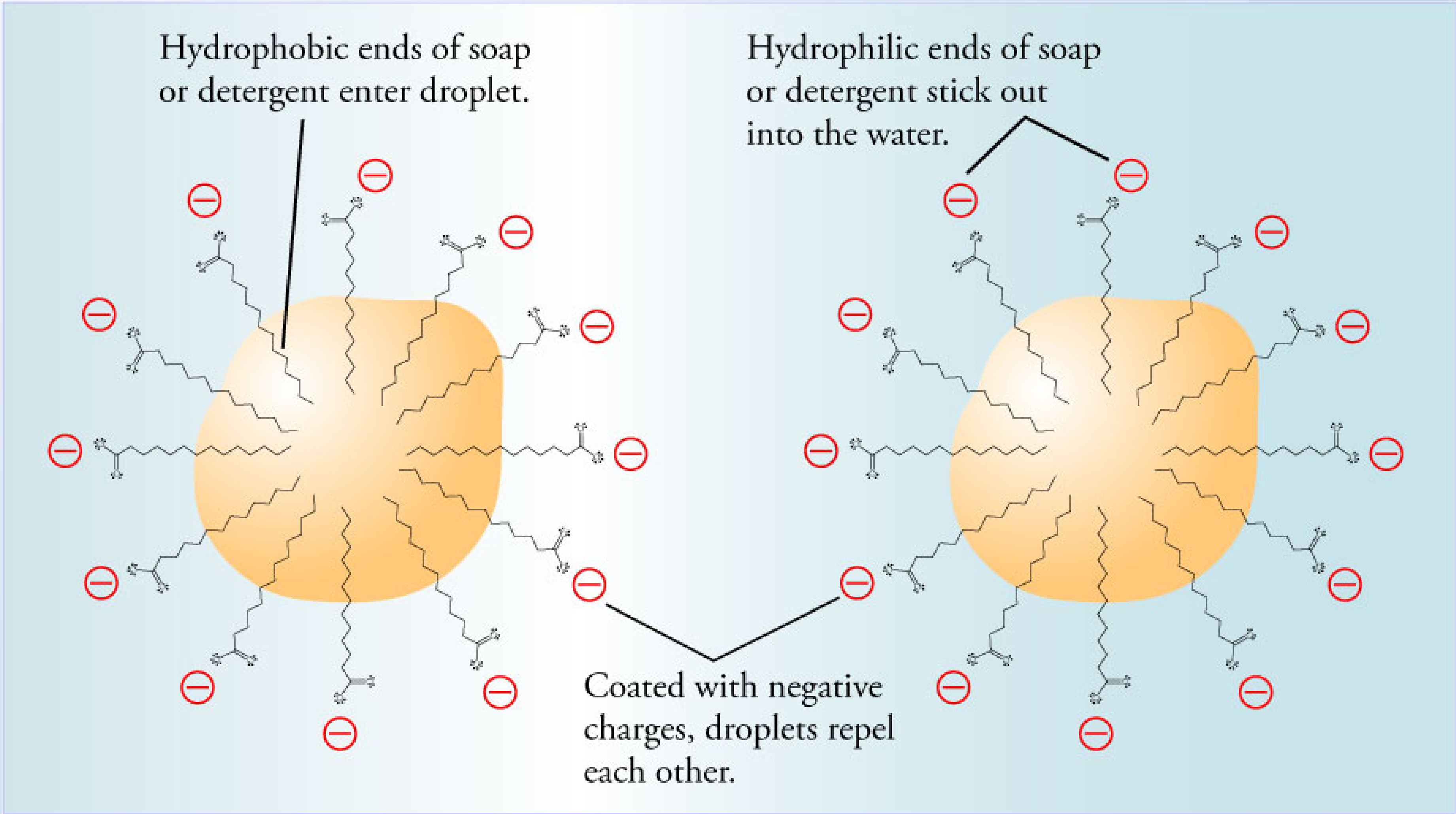
Soap and Detergent

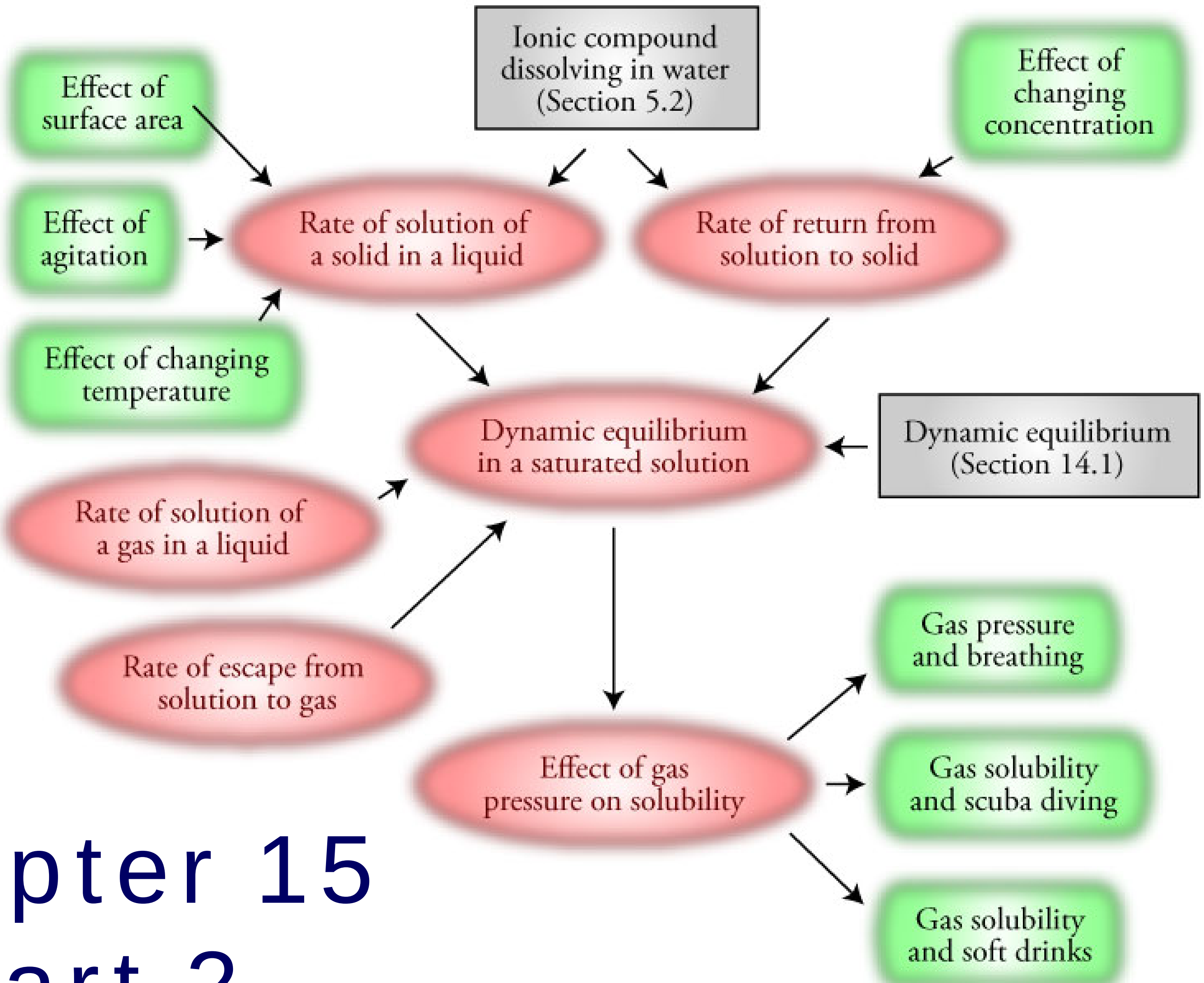


Cleaning Greasy Dishes



Oil Droplets and Soap or Detergent





Chapter 15 part 2

Solute Concentration and Rate of Return to Solid Form

Higher concentration of solute particles in solution

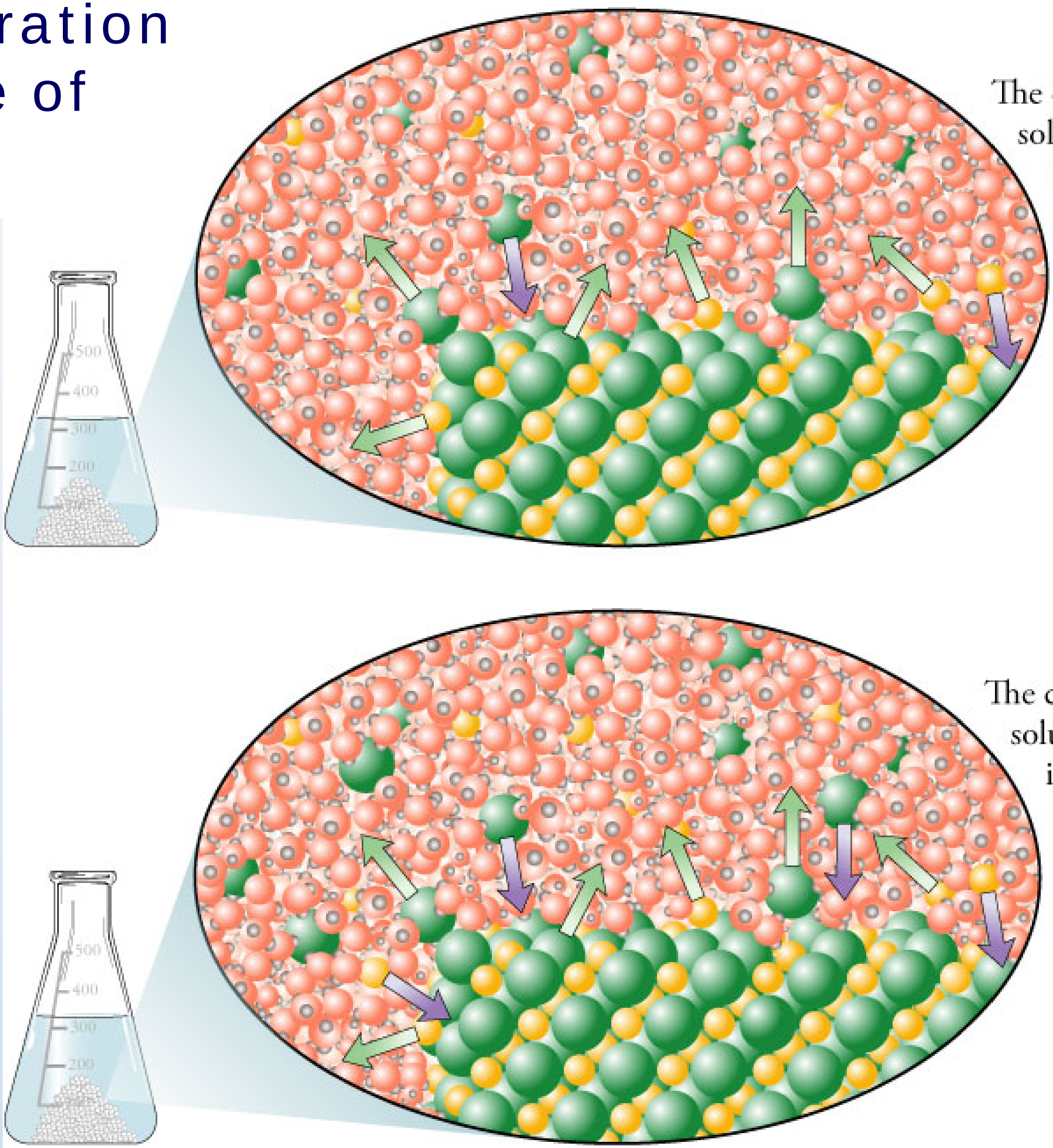
↓

More collisions per second between solute and solid

↓

Increased rate of return to the solid

Concentration and Rate of Return

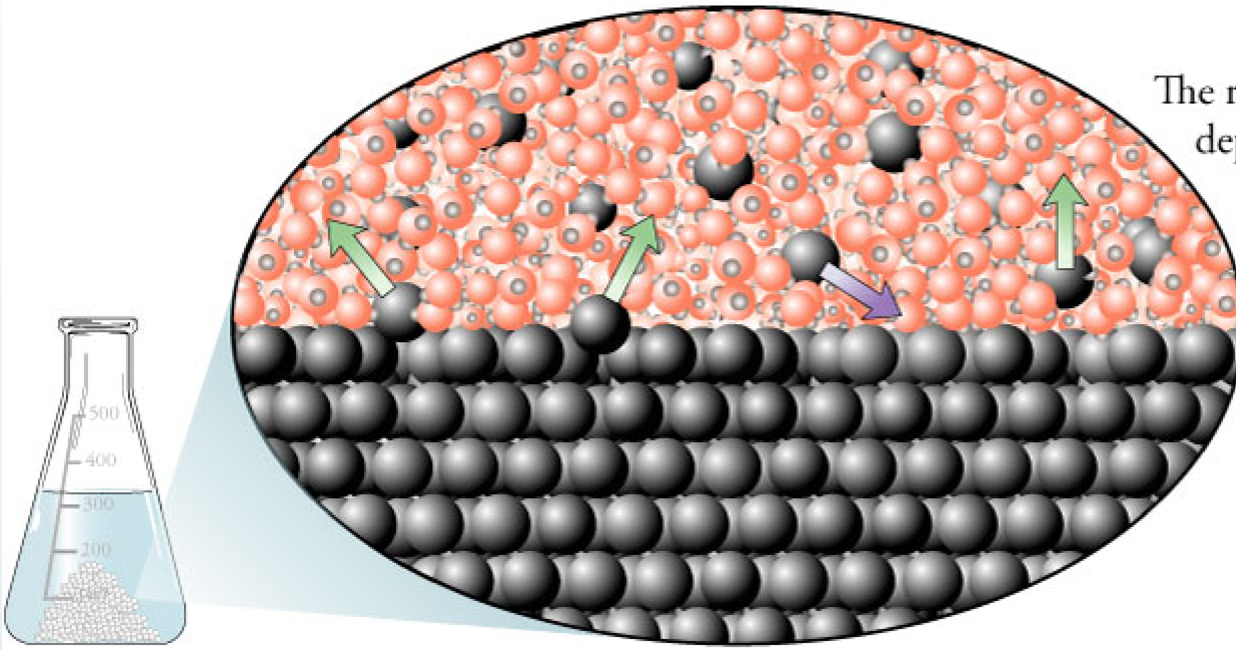


The concentration of solute in the solution is low, so the rate of return is low.

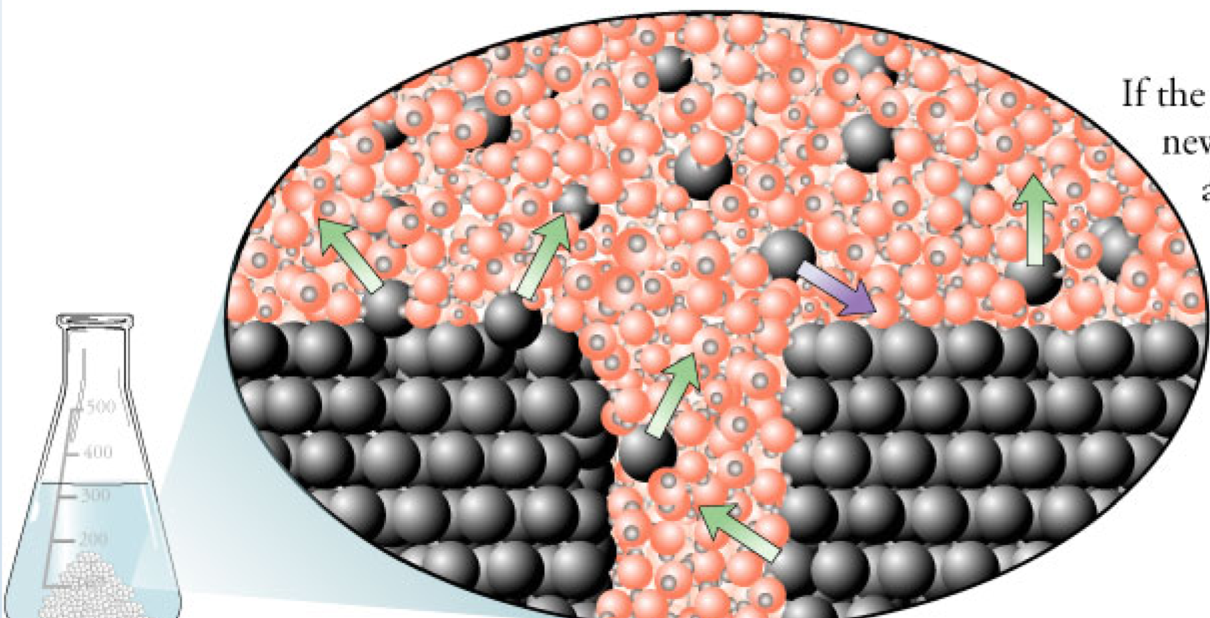
The concentration of solute in the solution is higher, so the rate of return is higher.

Rate of Solution Dependent on:

- Surface area of the solute
- Degree of agitation or stirring
- Temperature



The rate of solution depends on the number of particles at the solid's surface.



If the solid is fragmented, new surfaces are exposed, allowing more particles to escape into solution.

Agitation and Rate of Solution

Increased agitation

↓

Decreased concentration of dissolved solute particles near the solid

↓

Decreased rate of return to the solid

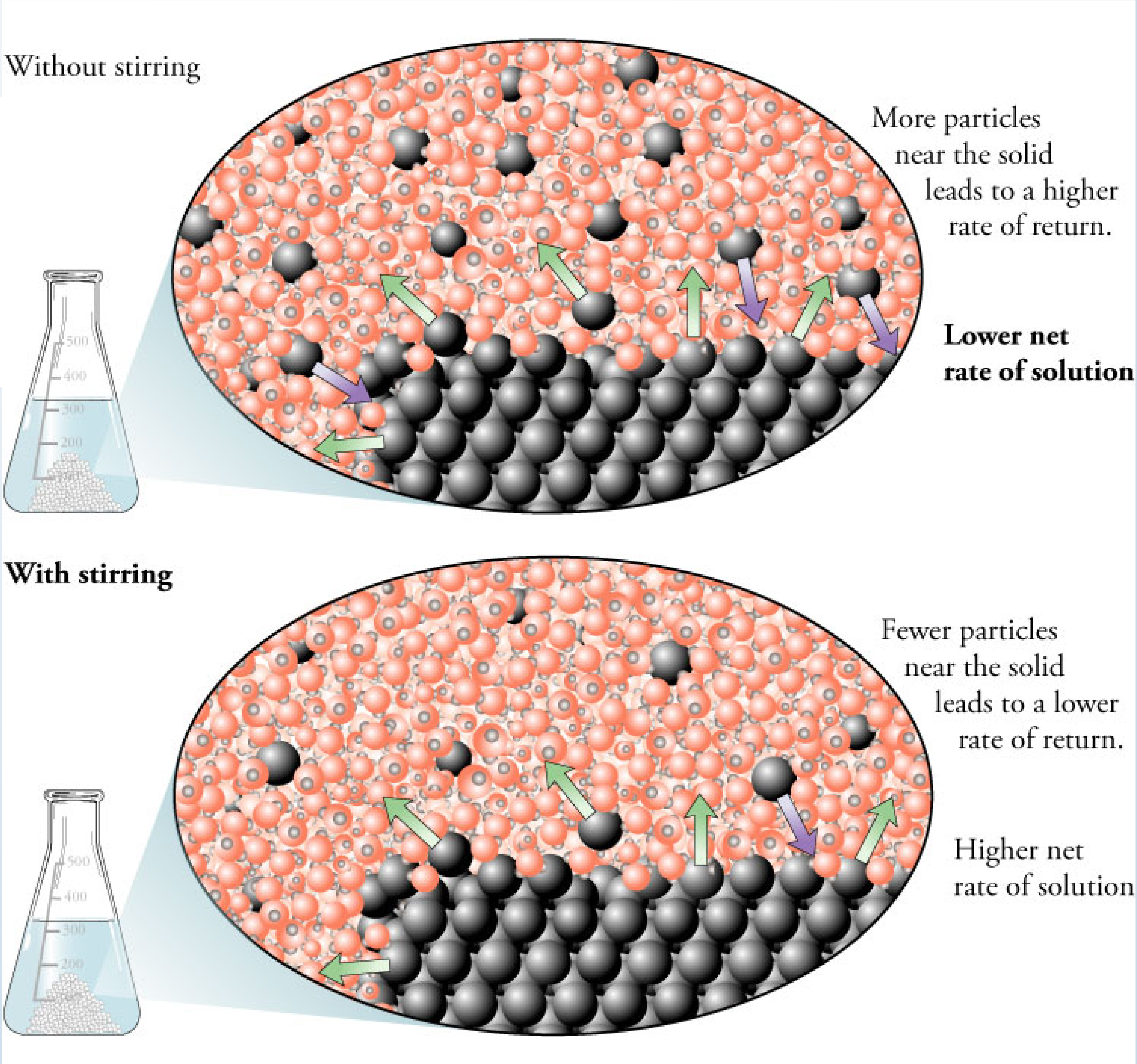
↓

Increased difference between the rate of solution and the rate of return

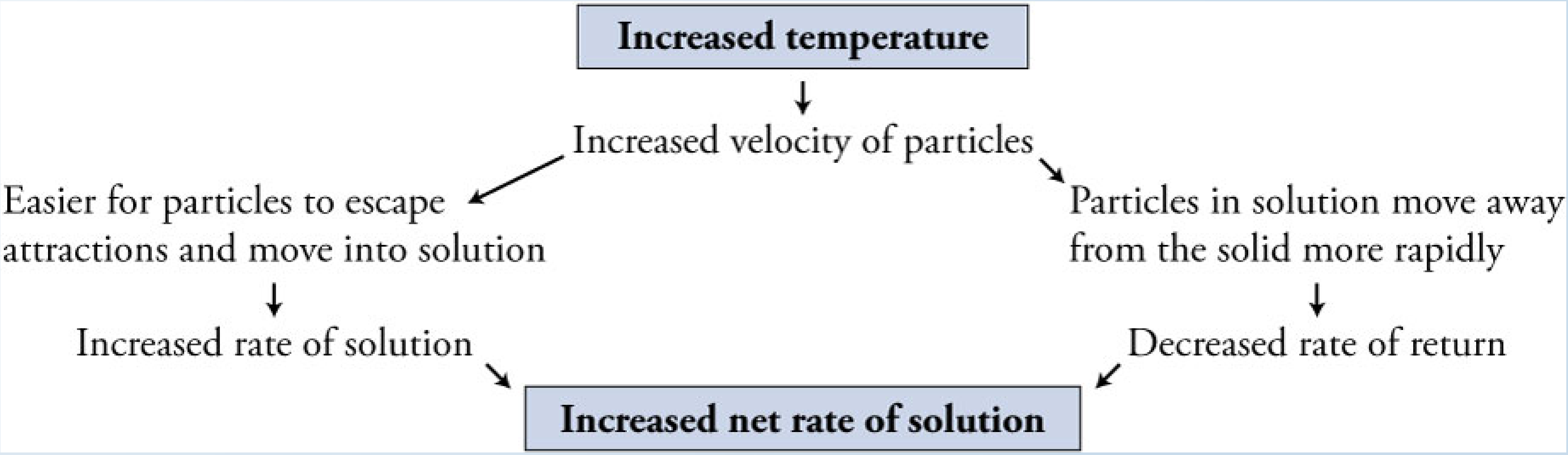
↓

Increased net rate of solution

Agitation and Rate of Solution



Temperature and Rate of Solution



Dynamic Equilibrium and Saturated Solutions

Addition of a large amount of solid to a liquid

↓

Initially, rate of solution is greater than the rate of return

↓

Net increase in number and concentration of particles in solution

↓

Increased rate of collision between dissolved particles and solid

↓

Increased rate of return...

↓

...Until rate of return equals rate of solution

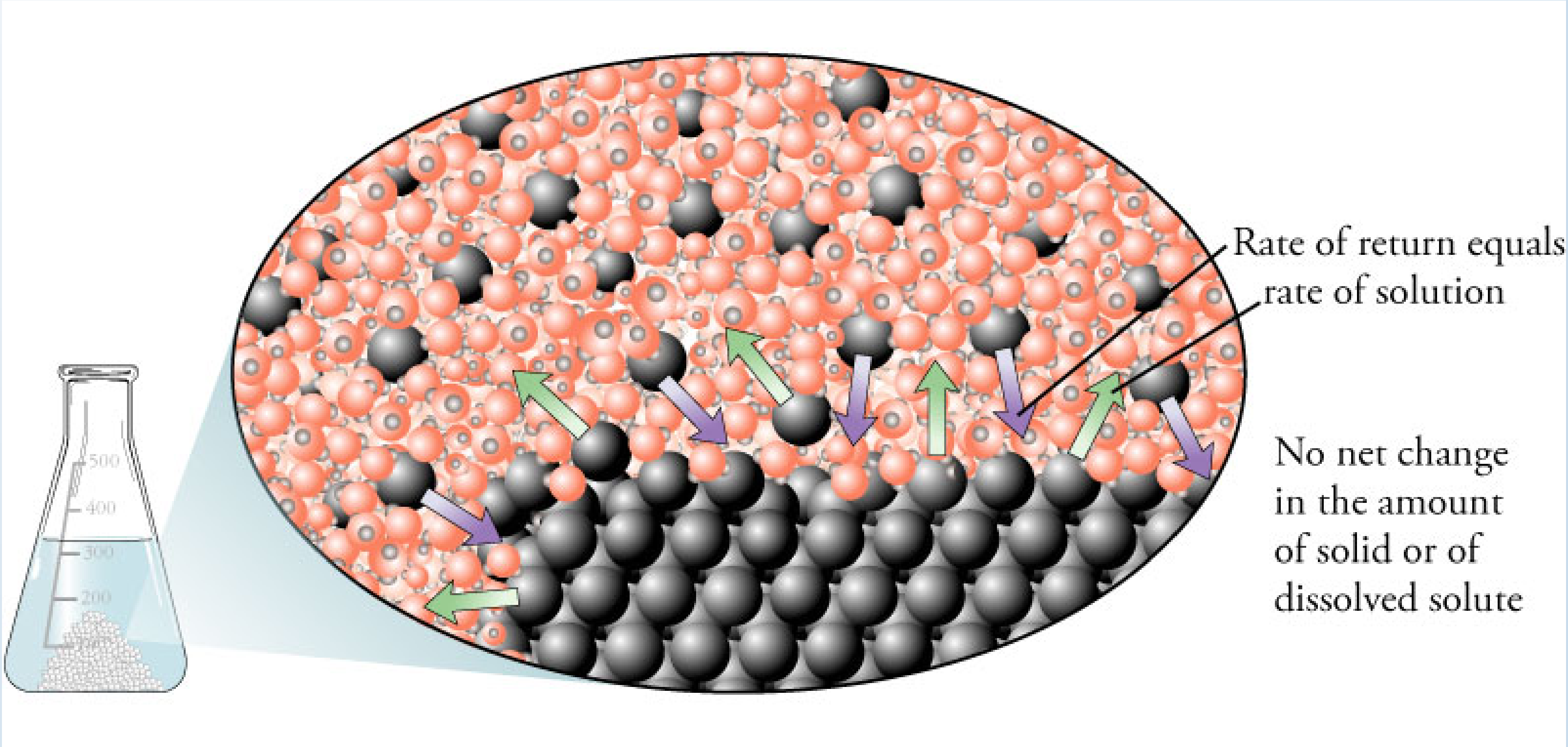
↓

Constant changes from solid to dissolved solute and back, but no net change in amounts of solid and dissolved solute

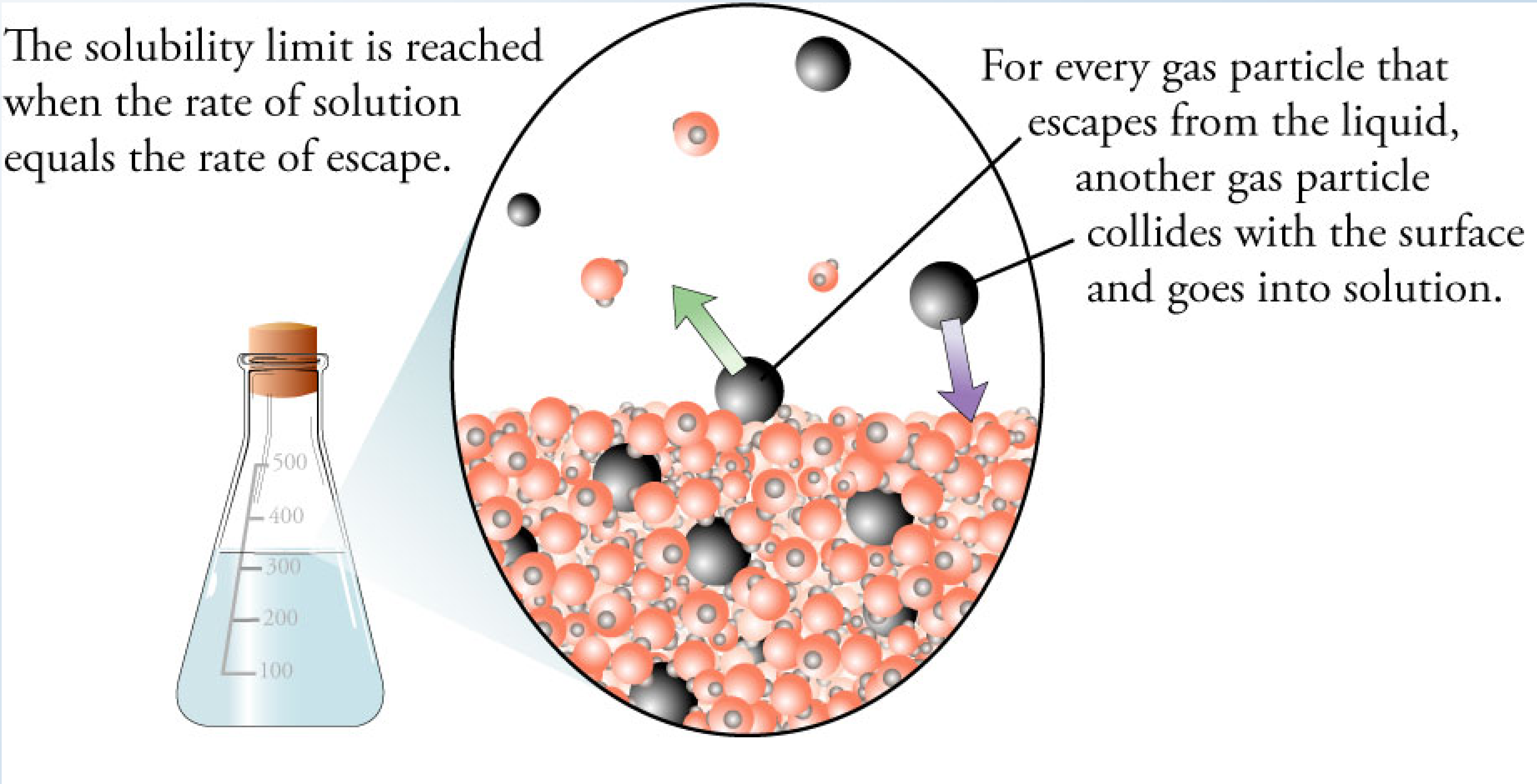
↓

Saturated solution due to dynamic equilibrium

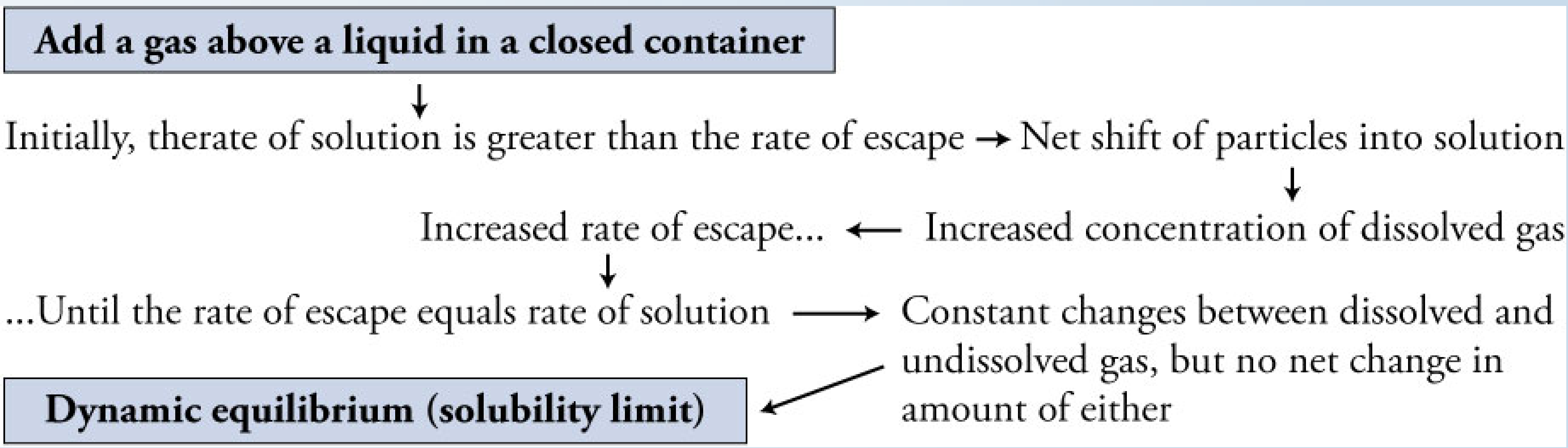
Dynamic Equilibrium in a Saturated Solution



Dynamic Equilibrium for Gas Dissolved in Liquid



Gas Solubility



Partial Pressure and Gas Solubility