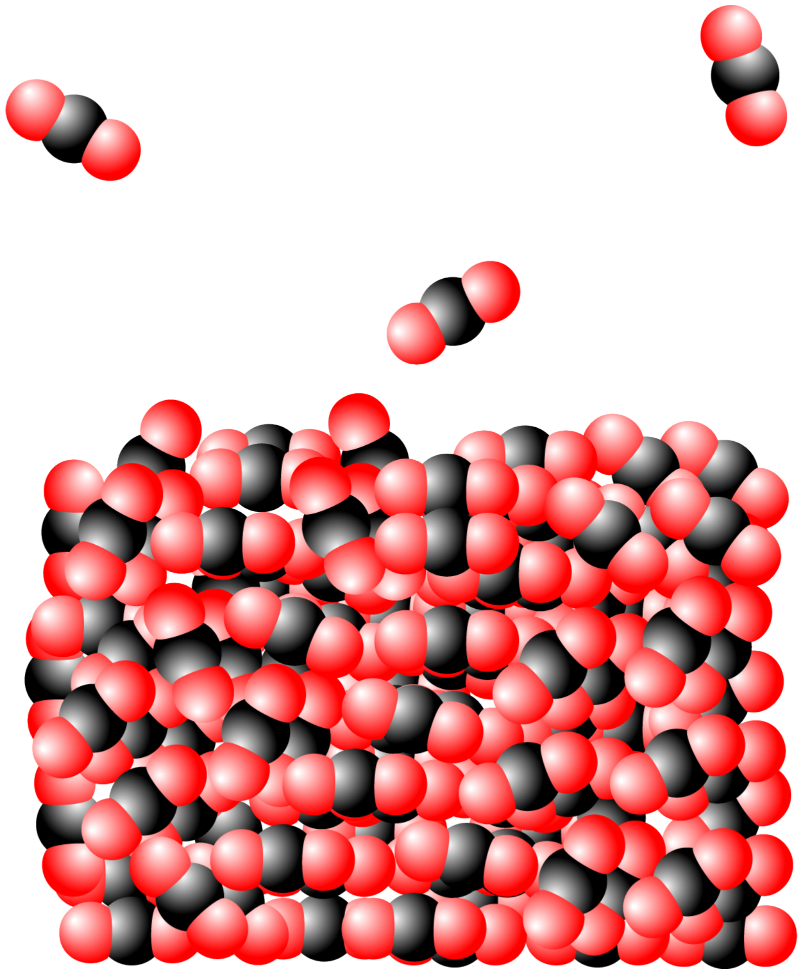
Why Changes Happen

- Consider a system that can switch back and forth between two states, A and B, such as between solid carbon dioxide and gaseous carbon dioxide.

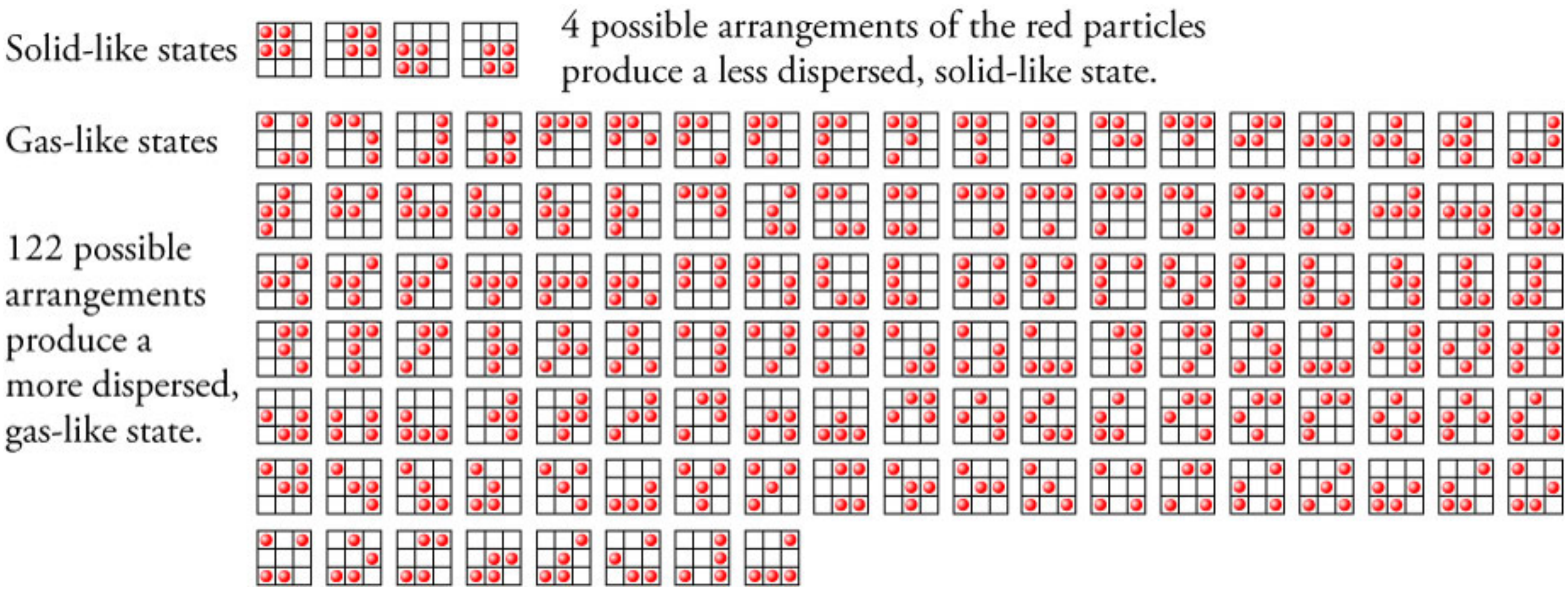


Why Changes Happen

- 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.

State A		**State B**
$CO_2(s)$	$\rightleftharpoons$ $\rightleftharpoons$	$CO_2(g)$
Less dispersed (spread out)		More dispersed (spread out)
Fewer ways to arrange particles and energy		More ways to arrange particles and energy
Less probable		More probable

9-Point Universe



Probability of Gas

- In a 9-point universe, 96% of the arrangements of 4 particles are gas-like.
- In a 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 shift to a 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.

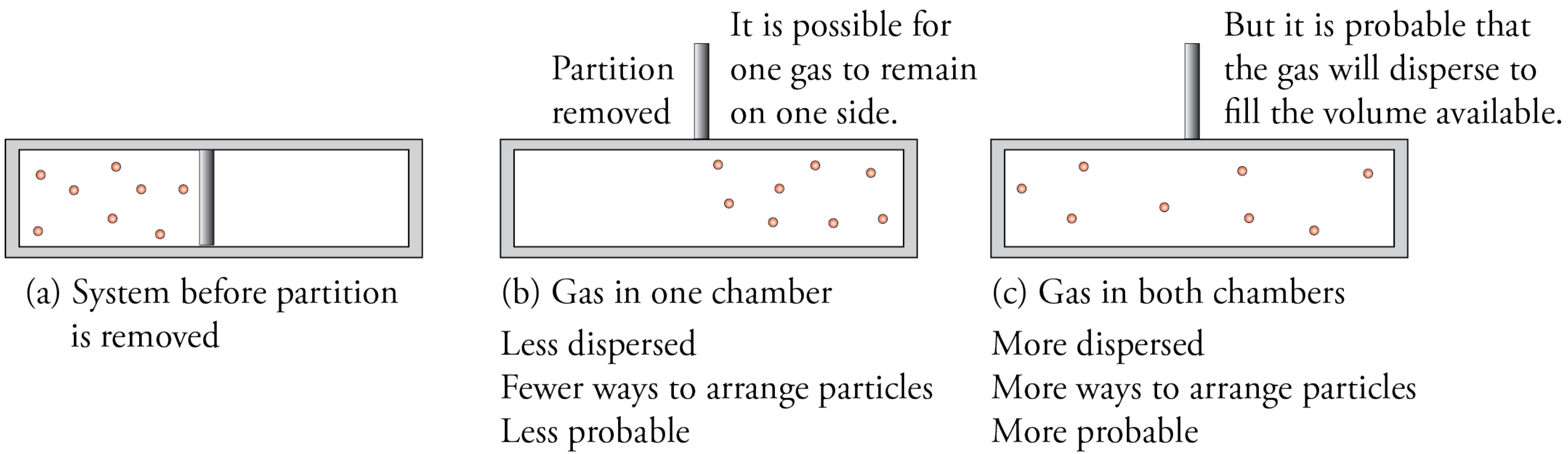
- Why does dry ice, $CO_2(s)$, spontaneously shift to $CO_2(g)$?
  - Internal kinetic energy is associated with the random movement of particles in a system.
  - Internal kinetic energy makes it possible for CO_2 molecules to move back and forth between solid and gas.
  - If the particles can move freely 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

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

$CO_2(s)$	$CO_2(g)$
Less dispersed	More dispersed
Fewer ways to arrange particles	More ways to arrange particles
Less probable	More probable

Gases Expand to Fill Container

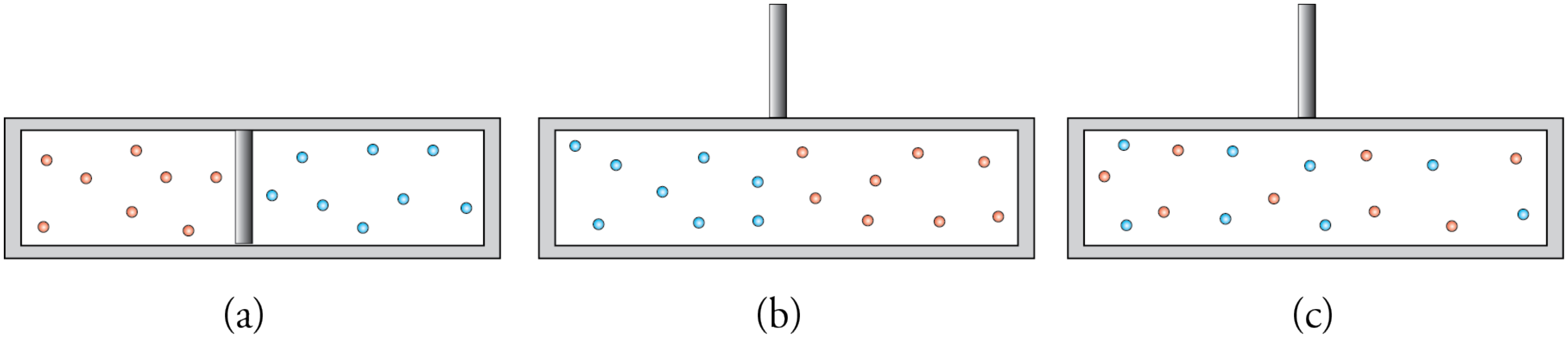


When the barrier between the two chambers in the container shown in (a) is raised, it is possible that the gas will end up in one chamber, like in (b), but it is much more likely that it will expand to fill the total volume available to it, like in (c).

Particles tend to disperse (spread out).

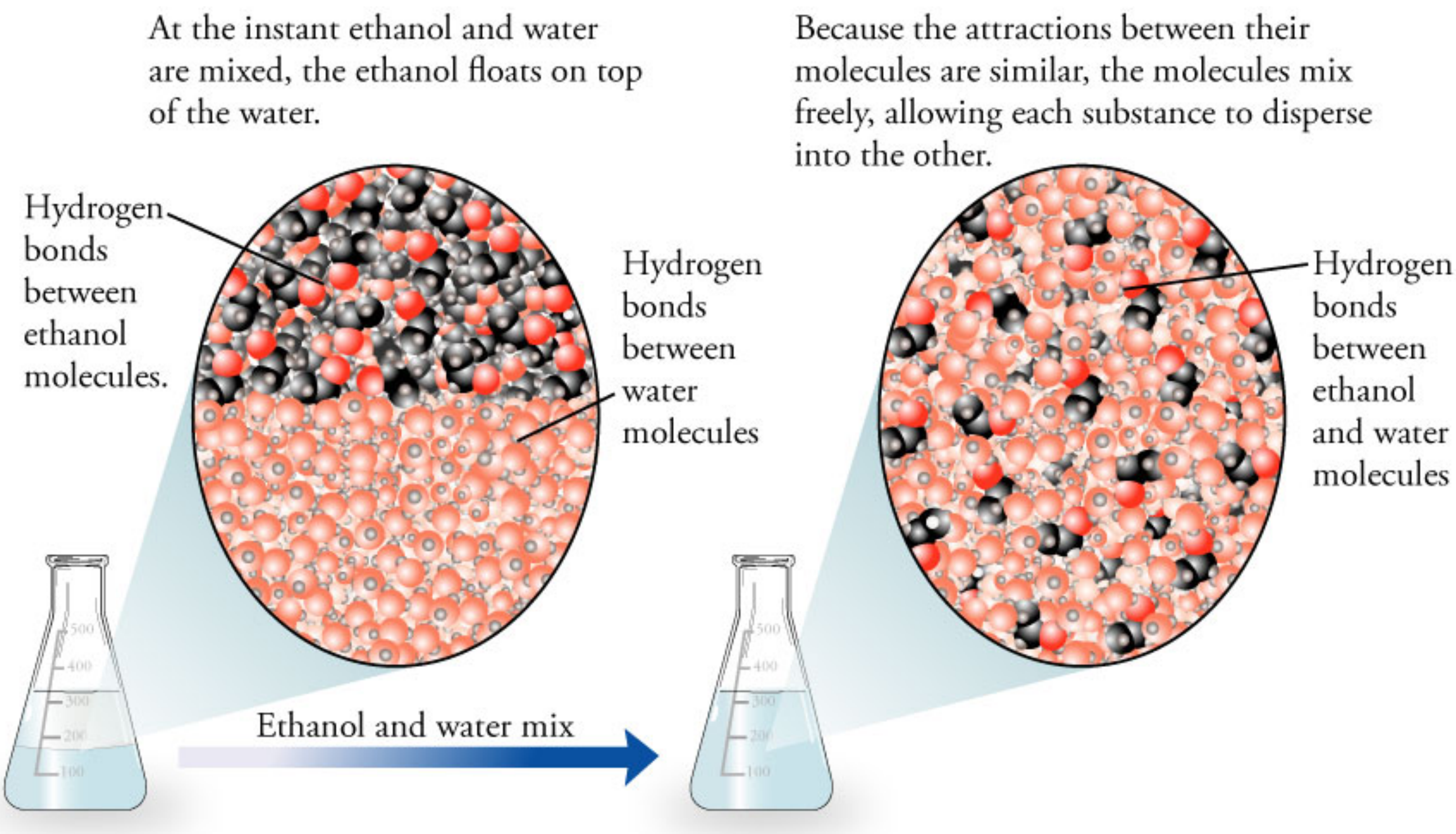
Gas in one chamber	→	Gas in both chambers
Fewer ways to arrange particles		More ways to arrange particles
Less probable		More probable
Less dispersed		More dispersed

Substances tend to mix.

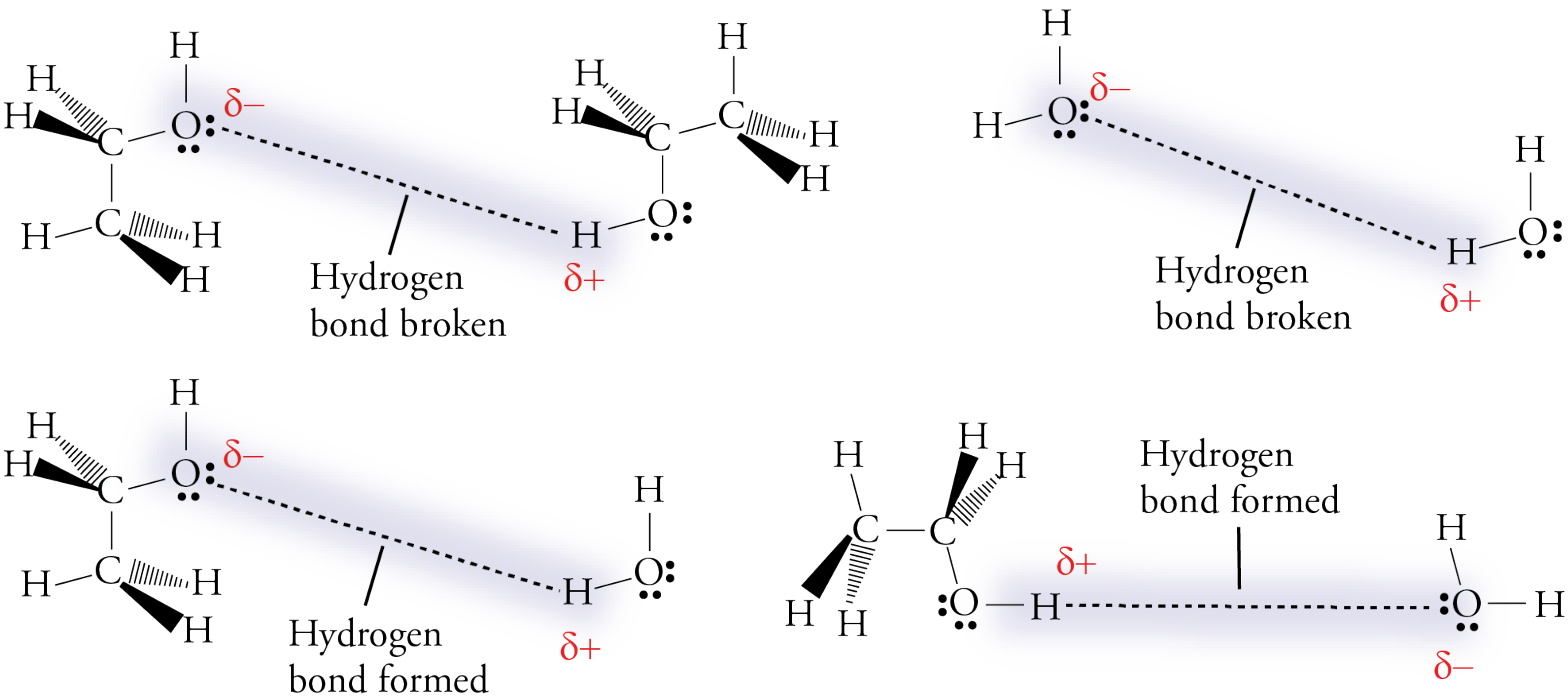


When the barrier between the two gases in the container shown in (a) is raised, it is possible that the gases will stay separated, like in (b), but it is much more likely that they will mix, like in (c).

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 nonpolar 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, such as hydrocarbons, C_aH_b,
  - Insoluble in water
  - Soluble in hexane
- Molecular Compounds with small polar molecules
  - Usually soluble in water
  - Often soluble in hexane

Water Solubility

- We call polar molecules or polar sections of molecules ***hydrophilic***.
- We call nonpolar molecules or nonpolar sections of molecules ***hydrophobic***.
- 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