Properties of Solutions

Heat of Solution

Heat of Solution

The **Heat of Solution** is the amount of heat energy absorbed (endothermic) or released (exothermic) when a specific amount of solute dissolves in a solvent.

Substance	Heat of Solution (kJ/mol)
NaOH	-44.51
NH_4NO_3	+25.69
KNO_3	+34.89
HCl	-74.84

Heat of Solution

- When some compounds, such as NaOH, dissolve in water, a lot of heat is released.
  - The container gets hot.

- When other compounds, such as NH_4NO_3, dissolve in water, heat is absorbed from the surroundings.
  - The container gets cold.

- Why is this?

Energetics of Solution Formation: The Enthalpy of Solution

- To make a solution you must

1. overcome all attractions between the solute particles; therefore, ΔH_{solute} is endothermic. ΔH_1

2. overcome some attractions between solvent molecules; therefore, $\Delta H_{solvent}$ is endothermic. ΔH_2

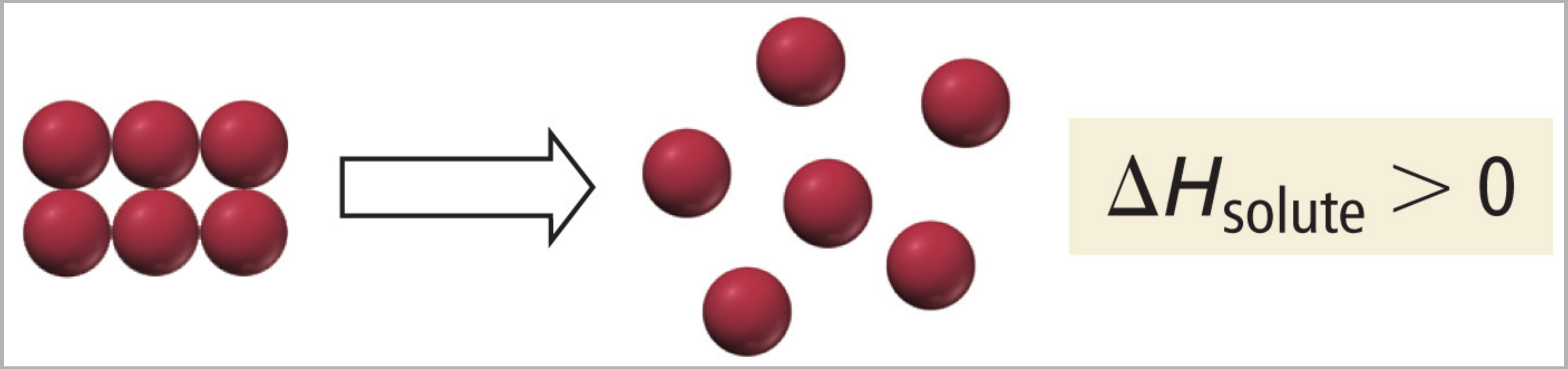
3. form new attractions between solute particles and solvent molecules; therefore, ΔH_{mix} is exothermic. ΔH_3

- The overall ΔH for making a solution depends on the relative sizes of the ΔH for these three processes.

$$\Delta H_{sol'n} = \Delta H_{solute} + \Delta H_{solvent} + \Delta H_{mix}$$

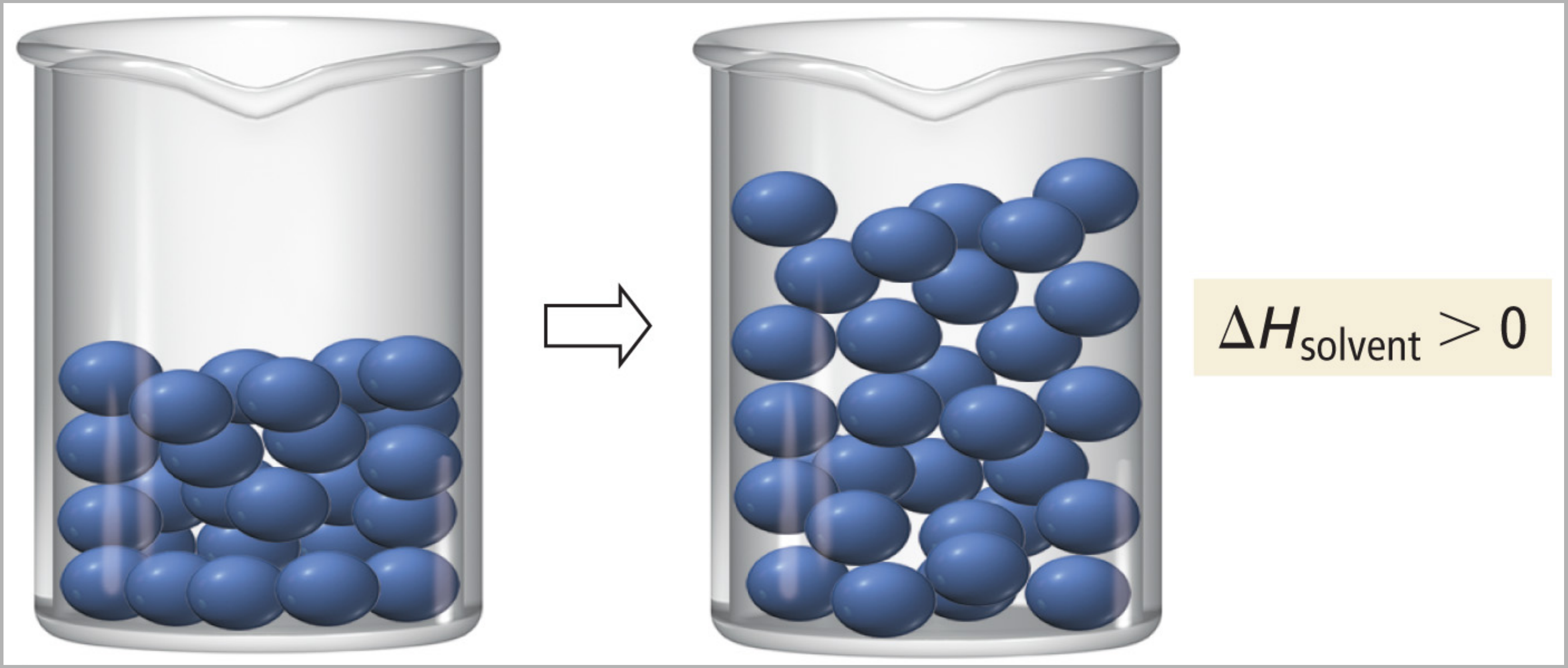
Solution Process

Step 1: Separating the solute into its constituent particles



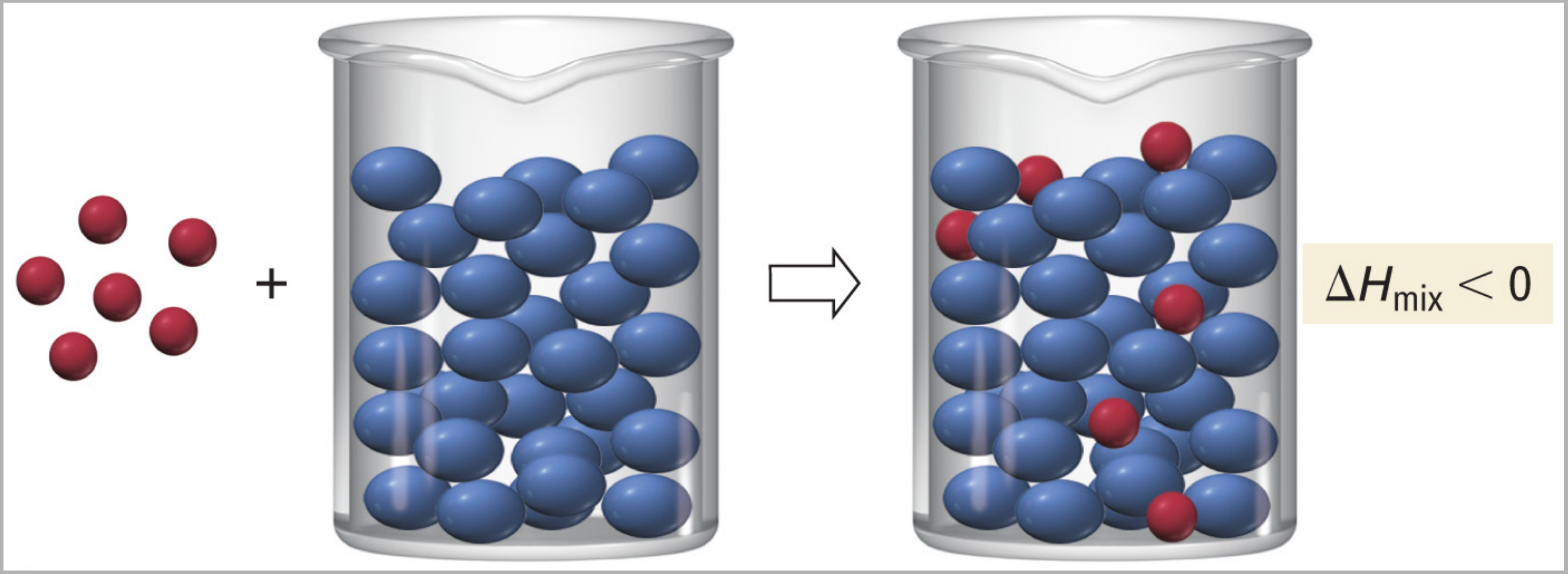
Solution Process

Step 2: Separating the solvent particles from each other to make room for the solute particles



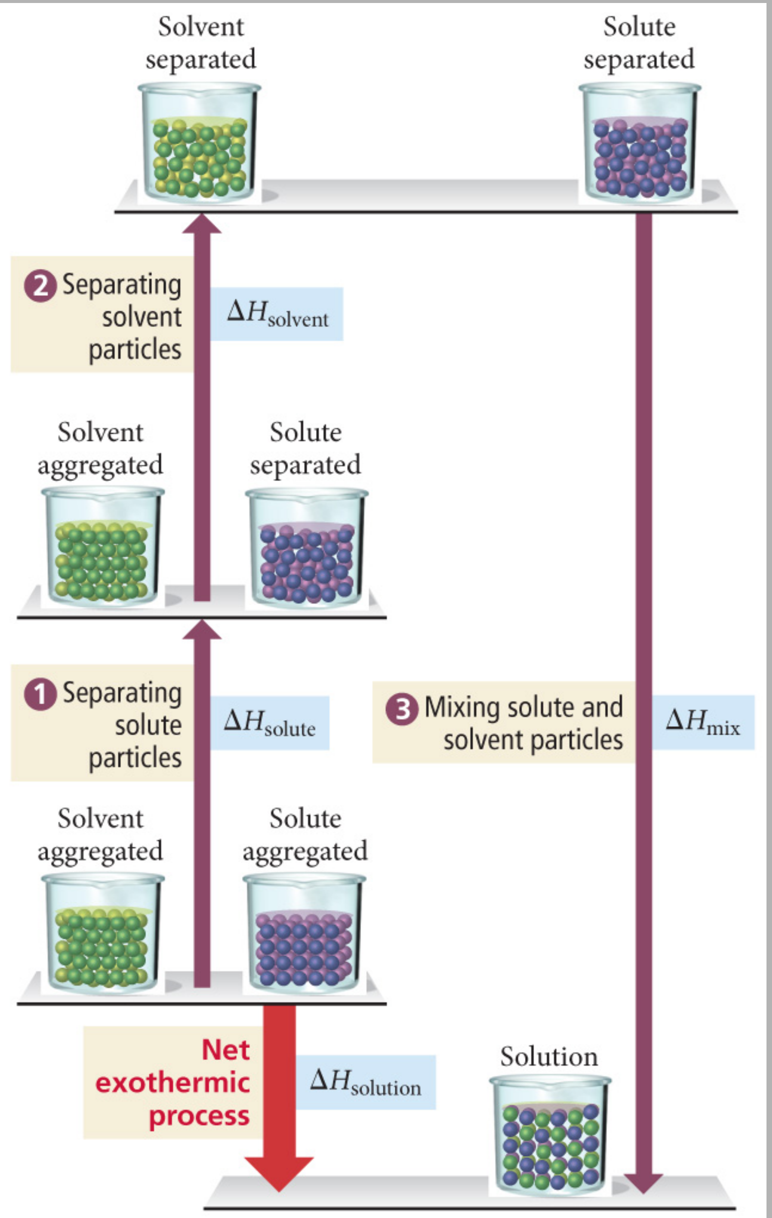
Solution Process

Step 3: Mixing the solute particles with the solvent particles



Energetics of Solution Formation

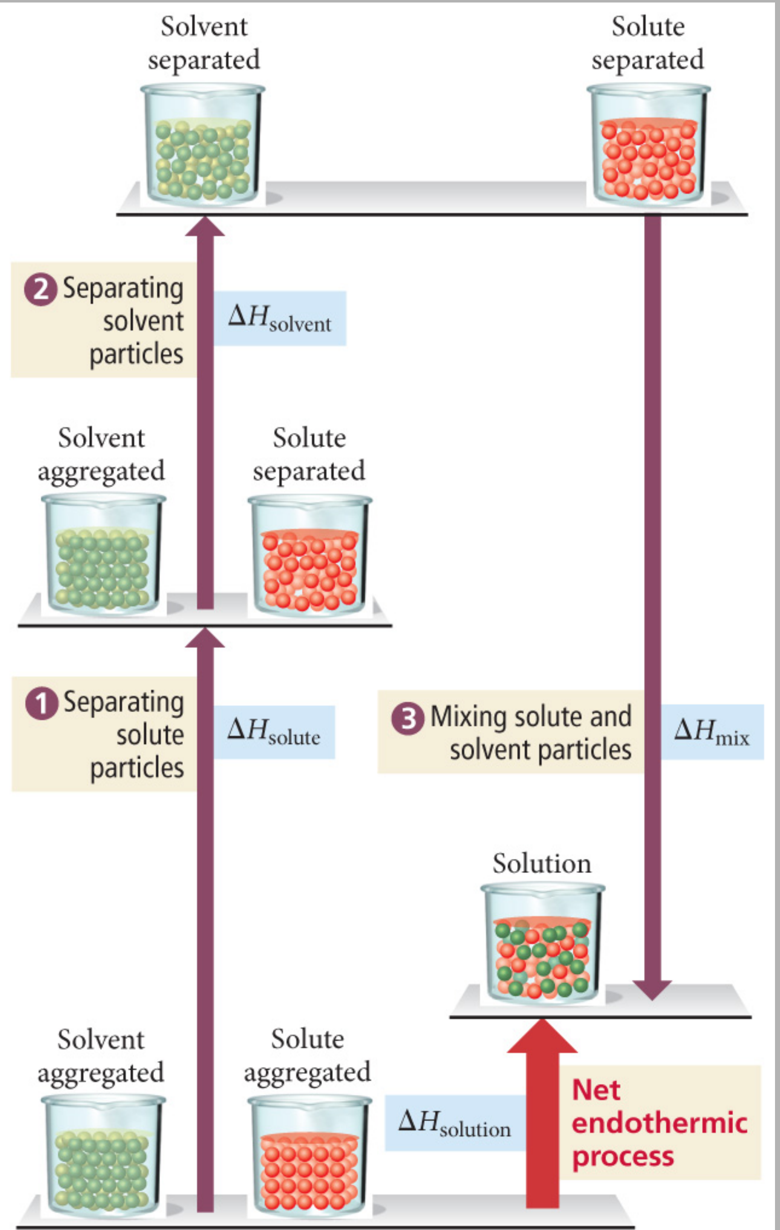
If the total energy cost for breaking attractions between particles in the pure solute and pure solvent is **less than** the energy released in making the new attractions between the solute and solvent, the overall process will be **exothermic**.



(a) Exothermic

Energetics of Solution Formation

If the total energy cost for breaking attractions between particles in the pure solute and pure solvent is greater than the energy released in making the new attractions between the solute and solvent, the overall process will be endothermic.



(b) Endothermic

Relative Interactions and Solution Formation

TABLE 12.2 Relative Interactions and Solution Formation

Solvent-solute interactions	$>$	Solvent-solvent and solute-solute interactions	Solution forms
Solvent-solute interactions	$=$	Solvent-solvent and solute-solute interactions	Solution forms
Solvent-solute interactions	$<$	Solvent-solvent and solute-solute interactions	Solution may or may not form, depending on relative disparity

- **When the solute-to-solvent attractions are weaker than the sum of the solute-to-solute and solvent-to-solvent attractions, the solution will only form if the energy difference is small enough to be overcome by the increase in entropy from mixing.**

"Like Dissolves Like"

Nonpolar solutes dissolve best in nonpolar solvents

Fats	Benzene
Steroids	Hexane
Waxes	Toluene

Polar and ionic solutes dissolve best in polar solvents

Inorganic Salts	Water
Sugars	Small alcohols
	Acetic acid

Predicting Solution Formation

Solvent/ Solute	ΔH_1	ΔH_2	ΔH_3	$\Delta H_{sol'n}$	Outcome
Polar/ Polar	+ large	+ large	- large	+/- small	Solution forms
Polar/ Nonpolar	+ small	+ large	+/- small	+ large	No solution forms
Nonpolar/ Nonpolar	+ small	+ small	+/- small	+/- small	Solution forms
Nonpolar/ polar	+ large	+ small	+/- small	+ large	No solution forms

Factors Favoring Sol'n formation

- Negative value of $\Delta H_{sol'n}$
- Increase entropy
- For positive values of $\Delta H_{sol'n}$ *it is the increase in entropy that outweighs the* increase in energy and causes the solution process of occur