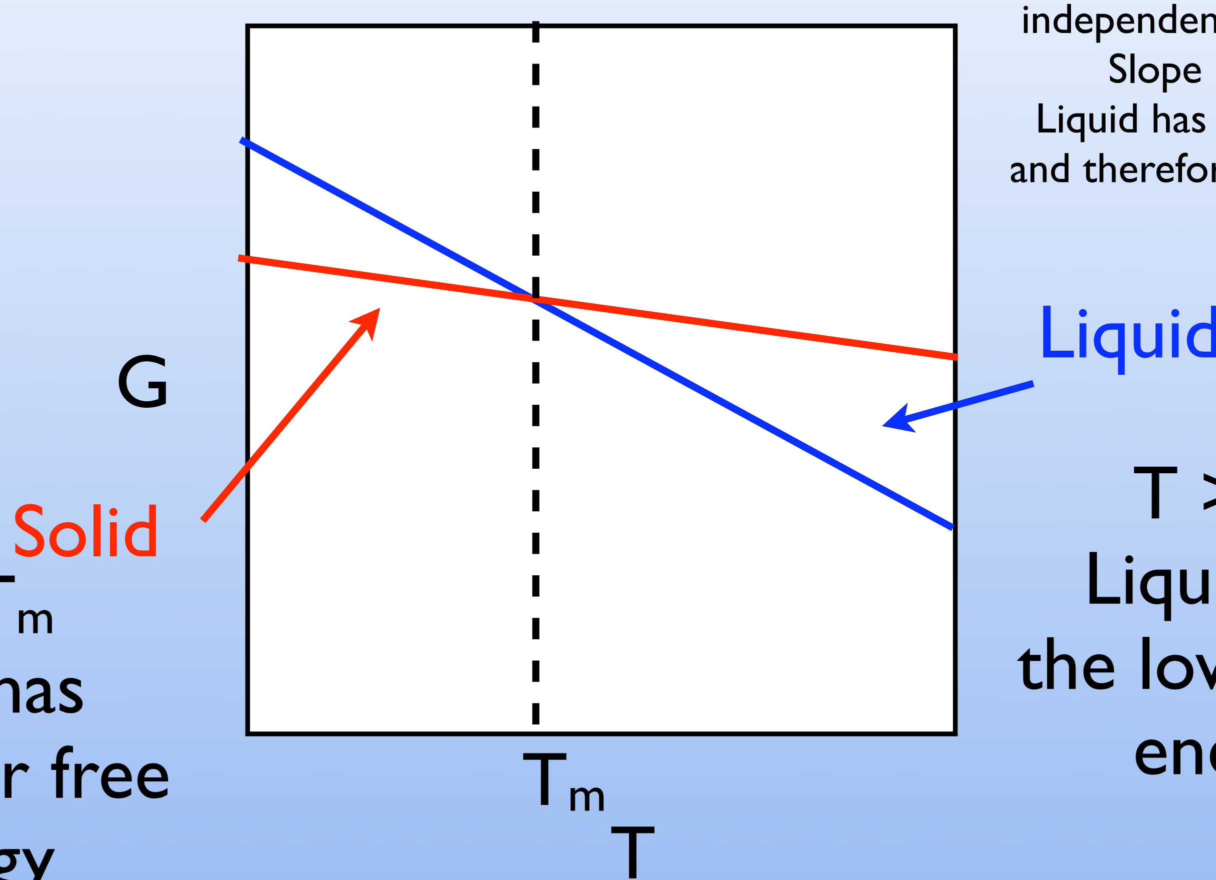
Just to be clear about Free Energy

$$G = H - TS$$

straight line assumes
that H and S are
independent of temperature
Slope is given by S
Liquid has a larger entropy
and therefore a steeper slope



$T < T_m$
Solid has
the lower free
energy

$T > T_m$
Liquid has
the lower free
energy

Last Phase change

What is a key difference between evaporation and boiling?

A. liquids only boil at 1 atm total pressure

B. liquids only evaporate at room temperature

C. bubble form in liquids when boiling

D. nothing

Boiling demo

Solutions

Solutions are homogeneous mixtures of multiple compounds

Solution

salt water
air
steel

Major component = Solvent
(language typically used for liquids)

Minor component = Solute

Let's look at the following "reaction"

water + salt ------> "salt water"

Which has the higher entropy?

A. The water + the solid salt

B. The solution ←

C. They are exactly the same

Let's look at the following "reaction"

water + salt ------> "salt water"

Which has the higher enthalpy?

A. The water + the solid salt

B. The solution

C. They are essentially the same ←

Let's look at the following "reaction"

water + salt ------> "salt water"

Which has the lower free energy?

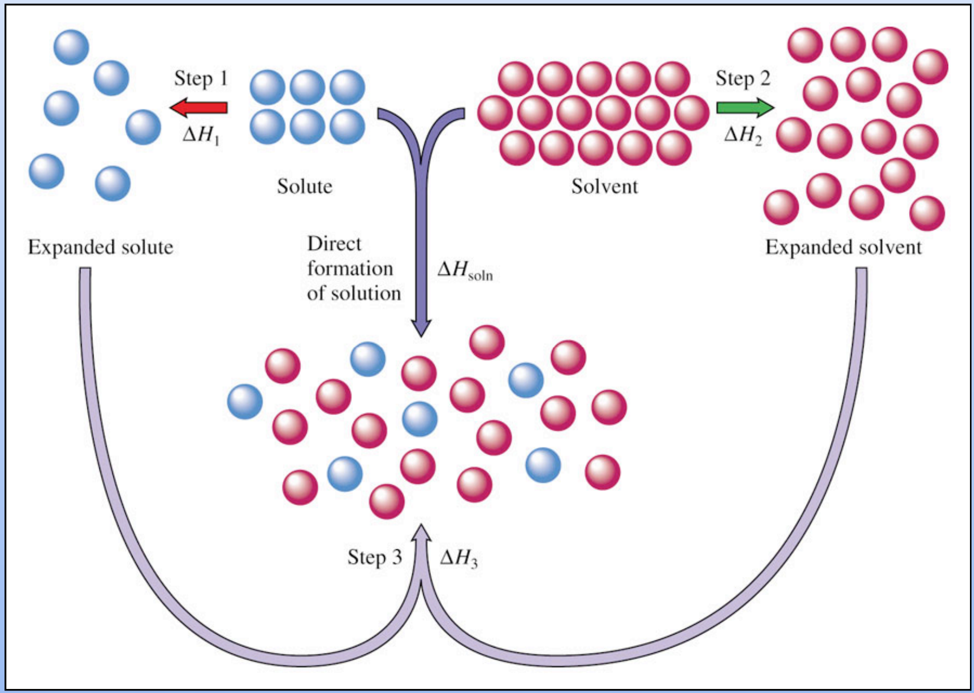
A. The water + the solid salt

B. The solution ←

C. They are exactly the same

What is enthalpy change for making a solution?

Lose solute-solute interactions (IMF)
Lose solvent-solvent interactions (IMF)
Gain solute-solvent interactions



Enthalpy of Solvation $\Delta H_{solvation}$ hard to predict

$\Delta H_{solvation} = 0$

Ideal solution

Solute-solvent interactions are identical to solute-solute and solvent-solvent

$\Delta H_{solvation} > 0$

Typical

Solute-solvent interactions are weaker than solute-solute and solvent-solvent

$\Delta H_{solvation} < 0$

Unusual but possible

Solute-solvent interactions are stronger than solute-solute and solvent-solvent

Solvation Demo

For the dissolution of ammonium nitrate the free energy

A. decreases

B. increases

C. stays the same

Entropy of Solvation $\Delta S_{solvation}$ usually easy to predict

Solutions have a higher entropy than the unmixed compounds

Therefore

$$\Delta S_{solvation} > 0$$

For most cases

Not true for small high charge density ions

TABLE 17.2 Values of ΔS°_{soln} for Several Salts Dissolving in Water

Process	ΔS° ($J\ K^{-1}\ mol^{-1}$)
$KCl(s) \rightarrow K^+(aq) + Cl^-(aq)$	75
$LiF(s) \rightarrow Li^+(aq) + F^-(aq)$	−36
$CaS(s) \rightarrow Ca^{2+}(aq) + S^{2-}(aq)$	−138

Gibb's Free Energy of Solvation $\Delta G_{solvation}$

If $\Delta G_{solvation} < 0$ solution strongly favored

If $\Delta G_{solvation} > 0$ undissolved state is strongly favored

$$\Delta G_{solvation} = \Delta H_{solvation} - T\,\Delta S_{solvation}$$

Typically $\Delta S_{solvation} > 0$, $\Delta H_{solvation} > 0$

need $|T\Delta S| > |\Delta H|$

What makes an ideal solution?

Same IMF for solute-solvent and solute-solute and solvent-solvent

"like dissolves like"

Polar compounds dissolve polar compounds (ionic)

Nonpolar compound dissolve nonpolar compounds

This minimize ΔH

Miscibility Demo

Definitions:

Miscible: capable of being mixed
Immiscible: incapable of bieng mixed

Which is most likely to dissolve best in water?

A. methanol CH_3OH ←

B. butanol C_4H_9OH

C. octanol $C_8H_{17}OH$

D. didodecanol $C_{12}H_{25}OH$

Which is most likely to dissolve best in hexane (C_6H_{14})?

A. methanol CH_3OH

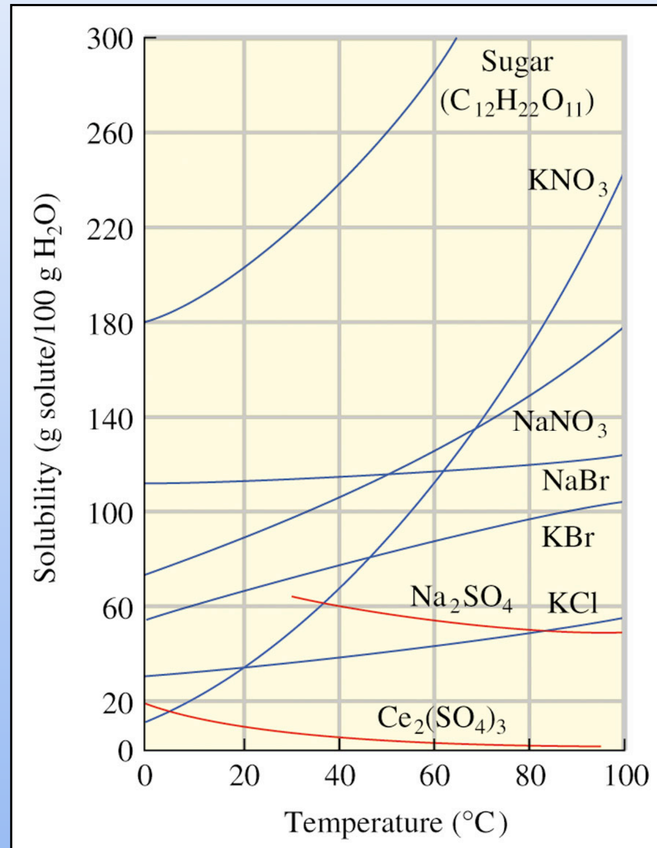
B. butanol C_4H_9OH

C. octanol $C_8H_{17}OH$

D. didodecanol $C_{12}H_{25}OH$ ←

Temperature Dependence

Generally at T goes up solubility increases



Gas Dissolved in a Liquid

Henry's Law

TABLE 17.3 The Values of Henry's Law Constants for Several Gases Dissolved in Water at 298 K

Gas	k_H (atm)
CH_4	4.13×10^2
CO_2	1.64×10^3
O_2	4.34×10^4
CO	5.71×10^4
H_2	7.03×10^4
N_2	8.57×10^4

$$P_{solute} = K_{solvent} X_{solute}$$

↑ mole fraction

In General

Henry's Law constants increase with increasing Temperature

Less gas is dissolved at higher temperatures

$\Delta H < 0$

going from no attractions to being in a liquid