VC210

Mid 2 review

Chapter 10 Physical Equilibria

UM-SJTU Joint Institute

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Contents

- Vapor pressure
- Solubility
- Molality
- Freezing and bowling point
- Osmosis

Vapor Pressure

For liquids, which of the following factors affect vapor pressure? Check all that apply.

- [x] ermolecular forces
- [x] temperature
- [ ] surface area
- [ ] humidity
- [ ] volume

$$\ln \frac{P_2}{P_1} = -\frac{\Delta H_{\text{vap}}{}^\circ}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Vapor Pressure

- **Normal boiling point,** T_b :
- a liquid boils when the external pressure is 1 atm.

- Boiling occurs when the vapor pressure of a liquid is equal to the external (atmospheric) pressure.

- Strong intermolecular forces usually lead to high normal boiling points.

Vapor Pressure

Map

Arsine, AsH_3, is a highly toxic compound used in the production of semiconductors. At –22.75 °C, the vapor pressure of AsH_3 is 58.00 Torr and at 25.05 °C the vapor pressure is 512.0 Torr.

Calculate the standard enthalpy of vaporization, ΔH°_{vap}, of arsine.

$\Delta H^\circ_{vap} =$ Number 28.29 kJ / mol

Calculate the standard entropy of vaporization, ΔS°_{vap}, of arsine.

$\Delta S^\circ_{vap} =$ Number 91.6 J / (mol · K)

Calculate the standard Gibbs free energy of vaporization, ΔG°_{vap}, of arsine.

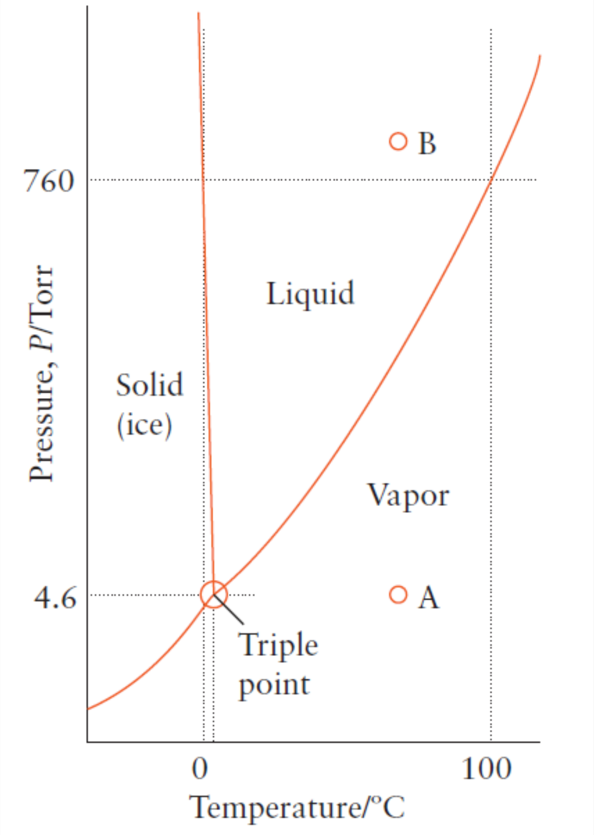
$\Delta G^\circ_{vap} =$ Number 0.98 kJ / mol

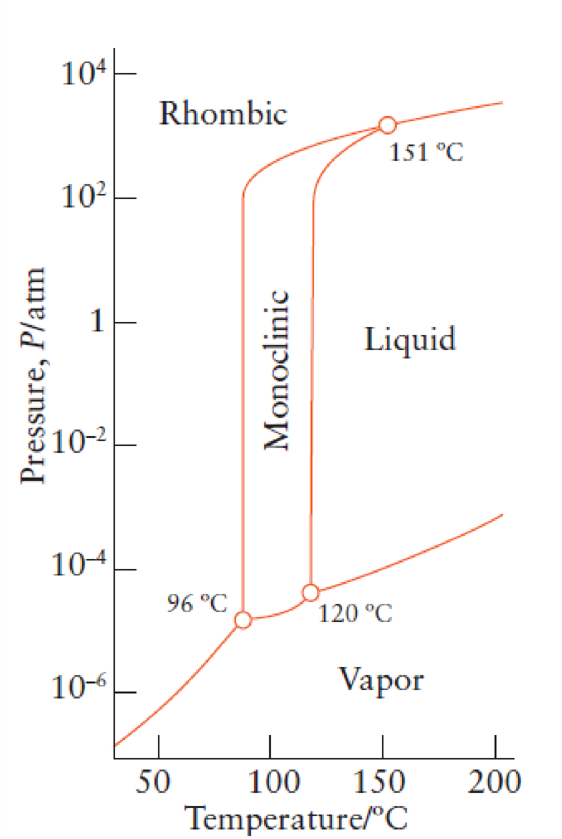
Calculate the normal boiling point temperature, T_B, of arsine.

$T_B =$ Number 36 °C

Phase diagram

- Phase boundaries
- Triple point
- Critical temperature





Phase diagram

Based on these data,

Solid	Triple point	Normal melting point
A	0.91 atm, 124 °C	108 °C
B	0.35 atm, – 17 °C	50 °C
C	0.0072 atm, 88 °C	89 °C

which solids will melt under applied pressure? Check all that apply.

- [x] A
- [ ] B
- [ ] C

Vapor pressure with two components

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- **The Vapor Pressure of Mixtures**
- **Raoult's law:**
  the vapor pressure of a liquid is proportional to its mole fraction.

- **Ideal solution / Real solution:**
  Obey Raoult's law at all concentrations?

- **Binary Liquid Mixtures**

$$P = P_A + P_B = x_A(l)P_A^* + x_B(l)P_B^*$$

Raoult’s law

When two volatile liquids (X and Y) are mixed, the solution process involves
1. breaking the intermolecular X---X and Y---Y attractions, and
2. forming new X---Y attractions.

Complete this table describing how the relative strengths of these attractive forces affect vapor pressure and enthalpy of solution.

Strength of the attractive forces	Raoult's law deviations	ΔH_{soln}
X---X, Y---Y, and X---Y are equal	zero	zero
X---Y is strongest	negative	negative
X---Y is weakest	positive	positive

positive

negative

zero

Raoult's law

1-propanol (P_1° = 20.9 Torr at 25 °C) and 2-propanol (P_2° = 45.2 Torr at 25 °C) form ideal solutions in all proportions.

Let x_1 and x_2 represent the mole fractions of 1-propanol and 2-propanol in a liquid mixture, respectively, and y_1 and y_2 represent the mole fractions of each in the vapor phase.

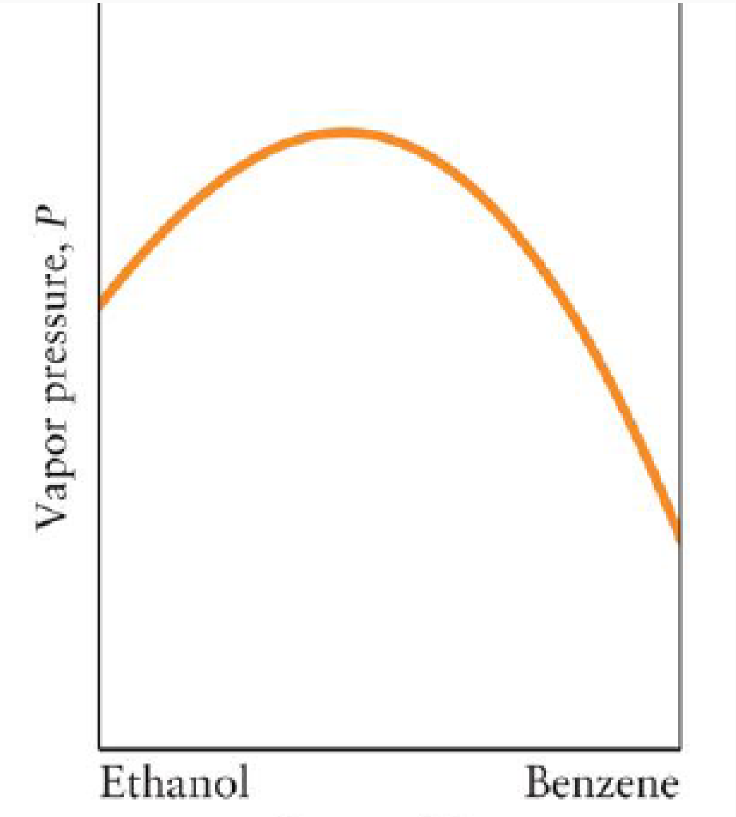
For a solution of these liquids with x_1 = 0.310, calculate the composition of the vapor phase at 25 °C.

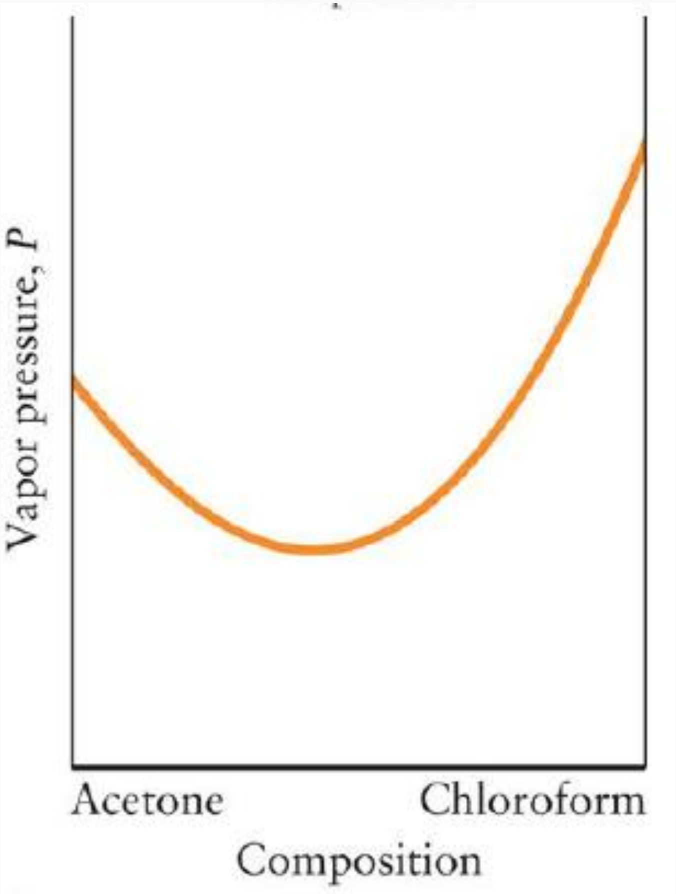
y_1 = Number **0.172**

y_2 = Number **0.828**

Raoult's law

Most (non-ideal) liquid do not follow Raoult's law.





Solubility

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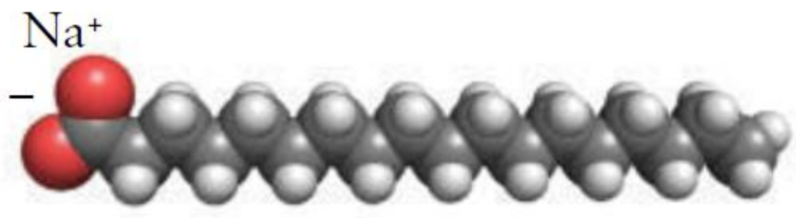
- The **molar solubility:** molar concentration in a saturated solution.
- **Saturated solution:** the dissolved and undissolved solute are in dynamic equilibrium and no more solute can dissolve.

- **The Like-Dissolves-Like Rule**
- **Hydrophilic:** water attracting
- **Hydrophobic:** water repelling.



1 Sodium stearate, $NaCH_3(CH_2)_{16}CO_2$

Solubility

Rank these compounds by their expected solubility in hexane, C_6H_{14}.

Most soluble in hexane

C_3H_8

C_2H_5OH

H_2O

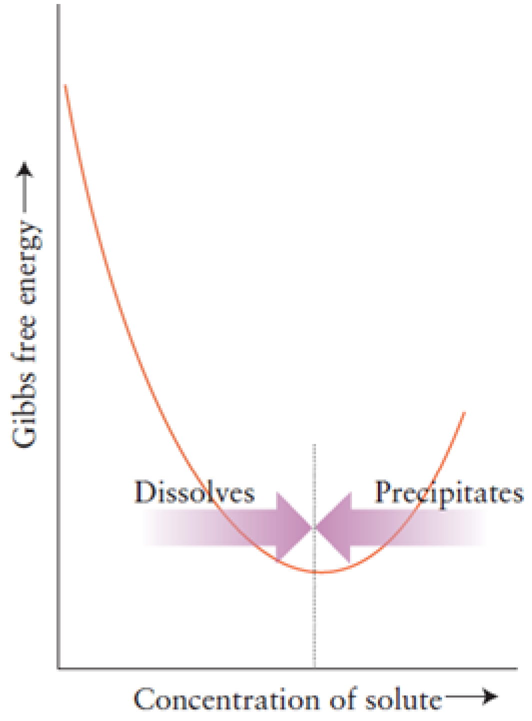
Least soluble in hexane

Solubility

- **The Thermodynamics of Dissolving**
- **Enthalpy of solution** ΔH_{sol}
- **Enthalpy of hydration** ΔH_{hyd}
- $\Delta H_{sol} = \Delta H_L + \Delta H_{hyd}$

- Dissolving depends on the balance between the change in entropy of the solution and the change in entropy of the surroundings.

Remember that ΔG is a measure of the overall change in entropy at constant temperature and pressure: ΔS is the change in entropy of the system and $-\Delta H/T$ is the change in entropy of the surroundings (Topic 4J).



Solubility

In an ionic compound, the size of the ions affects the internuclear distance (the distance between the centers of adjacent ions), which affects lattice energy (a measure of the force need to pull ions apart), which affects the enthalpy of solution.

Based on ion sizes, rank these compounds by their expected heats of solution.

Most exothermic ΔH_{soln}

MgI_2

$MgBr_2$

$MgCl_2$

MgF_2

Most endothermic ΔH_{soln}

Solubility

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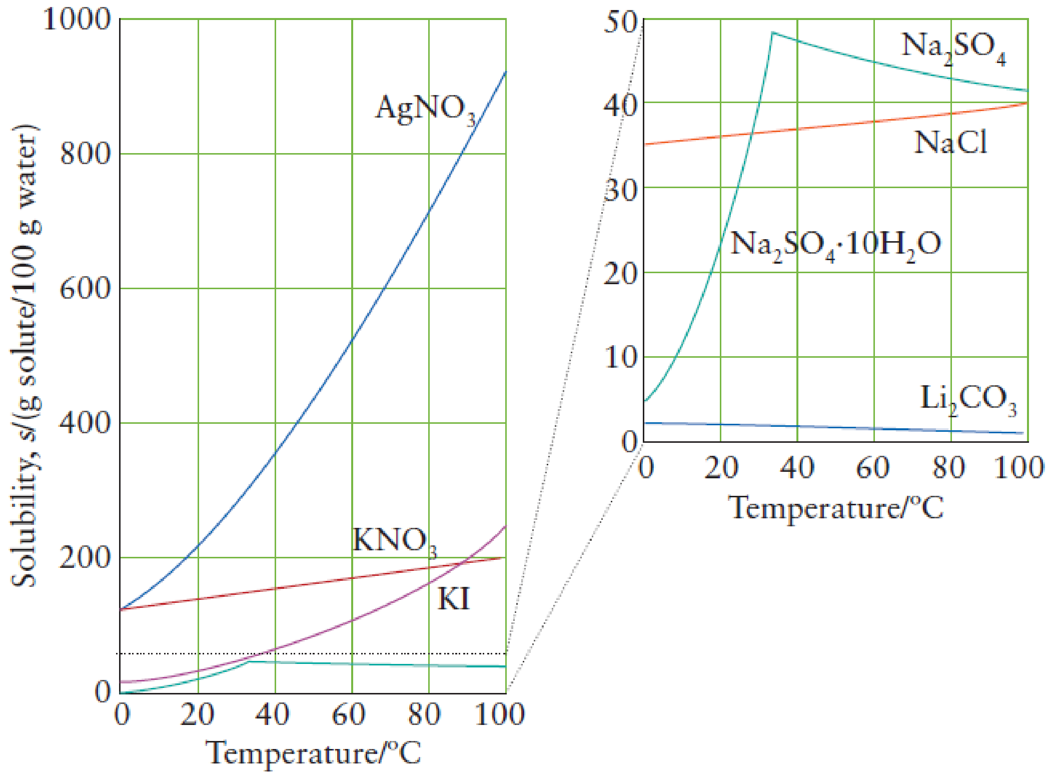
- **Temperature and Solubility**

- Most gases are less soluble in warm water than in cold water;
- Most solids are more soluble in warm water than in cold water; but there are exceptions.



Solubility-Henry's law

- **Pressure and Gas Solubility**
- **Henry's law:**
- the solubility of a gas is directly proportional to its partial pressure, P.

$$s = k_{\mathrm{H}} P$$

- An increase in pressure corresponds to an increase in the rate at which gas molecules strike the surface of the solvent.
- Most gases are less soluble in warm water than in cold water

Solubility-Henry's law

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At 298 K, the Henry's law constant for oxygen is 0.00130 M/atm. Air is 21.0% oxygen.

At 298 K, what is the solubility of oxygen in water exposed to air at 1.00 atm?

Number

2.73×10^{-4} M

At 298 K, what is the solubility of oxygen in water exposed to air at 0.893 atm?

Number

2.45×10^{-4} M

If atmospheric pressure suddenly changes from 1.00 atm to 0.893 atm at 298 K, how much oxygen will be released from 3.00 L of water in an unsealed container?

Number

8.4×10^{-5} mol

Solubility-Henry's law

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e volume of blood in the body of a deep sea diver is about 4.70 L. Blood cells make up about 45% of the blood volume and the remaining 55% is the aqueous solution called plasma. The diver dives to a depth of 93.0 m where the pressure is 10.0 atm. What is the maximum volume of nitrogen gas, in liters, that can dissolve in the diver's blood plasma where the diver's body pressure is 1.00 atm and temperature is 37 °C? (This is the volume that could come out of solution suddenly, causing the painful and dangerous condition called the bends if the diver were to ascend too quickly.) Assume that Henry's constant for nitrogen at 37 °C is 5.80×10^{-4} mol· L^{-1}· atm^{-1}.

Number

0.382 **L**

Molality

- **Molarity**

$$c = \frac{n_{\text{solute}}}{V_{\text{solution}}}$$

- **Molality**

$$b = \frac{n_{\text{solute}}}{m_{\text{solvent}}}$$

Pay attention to unit!!!

Molality

a. Calculate the molality of chloride ions in an aqueous solution of magnesium chloride in which the mole fraction of magnesium chloride is 0.0700.

Number

8.36 *m*

b. Calculate the molality of 6.95 g of sodium hydroxide dissolved in 3.30×10^2 g of water.

Number

0.527 *m*

c. Calculate the molality for 1 L of a 1.50 M HCl aqueous solution that has a density of $1.0745\ g \cdot cm^{-3}$.

Number

1.47 *m*

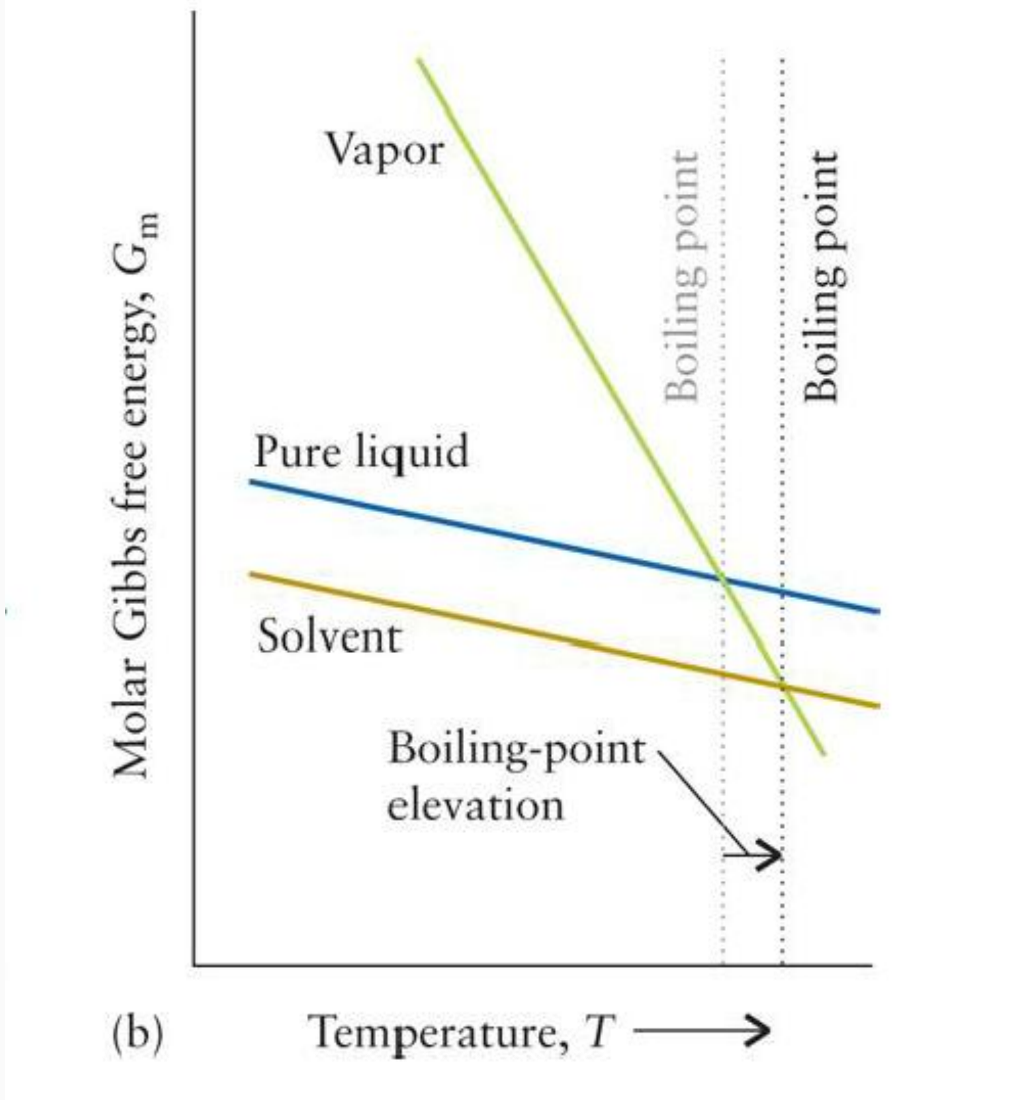
Colligative properties of solution

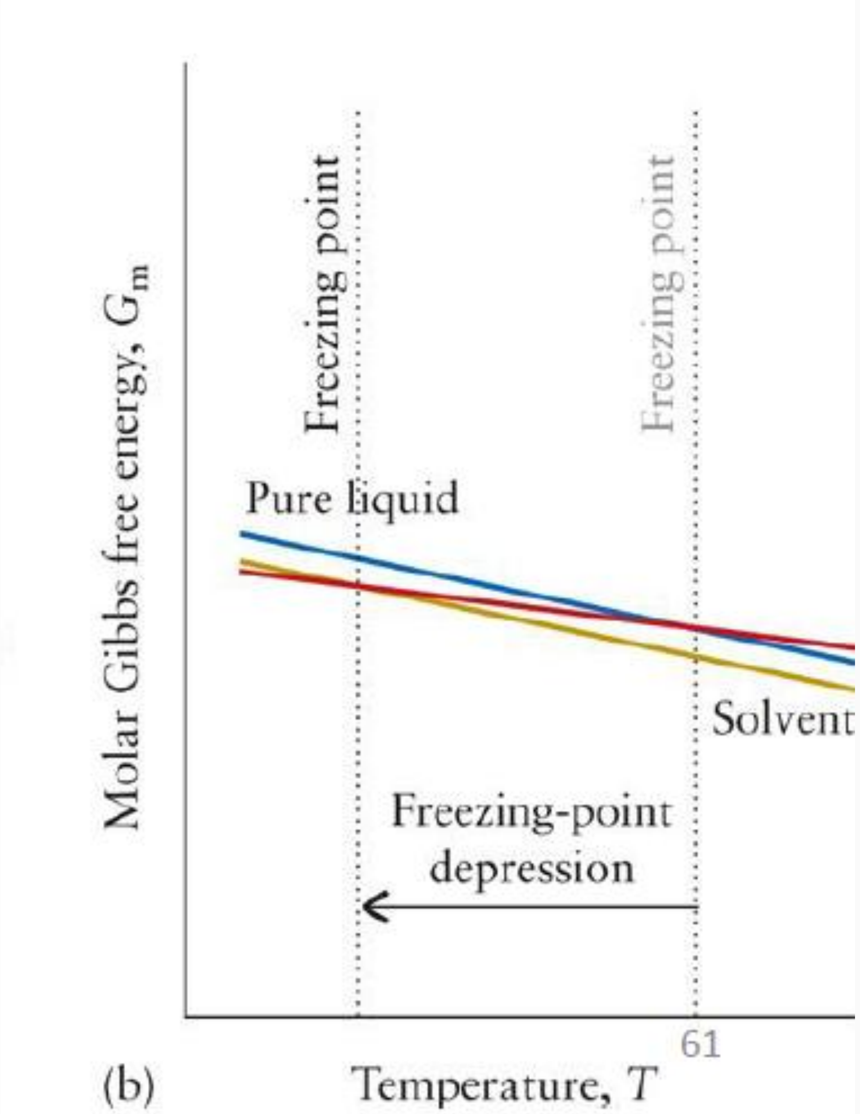
- Vapor-pressure Lowering
- Freezing point depression
- Boiling point elevation
- Osmosis

Vapor-pressure Lowering

$$\boxed{P = \chi_{solvent} P_{pure}}$$

Freezing and boiling point





Freezing and boiling point

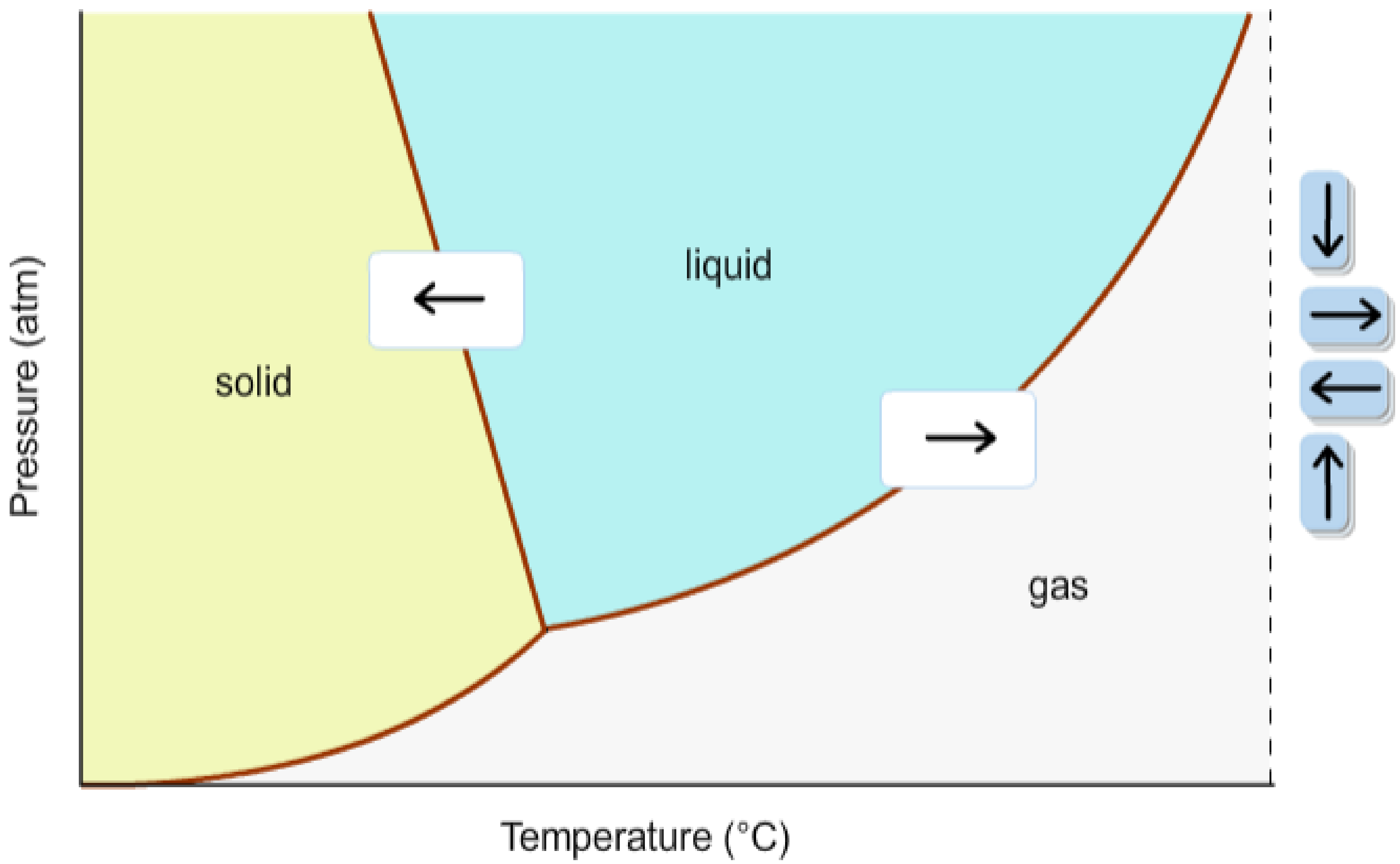
Freezing-point depression = k_f × molality, temp. **decreases**.

Boiling-point elevation = k_b × molality, temp. **increases**.

- **General equation:** $\Delta T = i \times k \times m$

Freezing and boiling point

In this phase diagram for water, indicate the direction that the solid-liquid and liquid-gas coexistence lines will move after the addition of solute.



Freezing and boiling point

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Imagine two solutions with the *same concentration* and the *same boiling point*, but one has ethanol as the solvent and the other has carbon tetrachloride as the solvent. Determine that molal concentration, m (or b), and boiling point, T_b.

$m =$ Number 0.420 m

$T_b =$ Number 78.9 °C

Solvent	Normal boiling point (°C)	K_b (°C/m)
ethanol	78.4	1.22
carbon tetrachloride	76.8	5.03

Osmosis

- **Definition:** Osmosis is the flow of solvent through a membrane into a more concentrated solution.

$$\Pi = iRTc$$

Osmosis

$$\Pi = iRTc$$

What is the minimum pressure in kPa that must be applied at 25 °C to obtain pure water by reverse osmosis from water that is 0.216 M in sodium chloride and 0.098 M in zinc sulfate?
Assume complete dissociation for electrolytes.

Number

1556 kPa

Pay attention to unit!!!

Osmosis

$$\Pi = iRTc$$

In reverse osmosis, water flows out of a salt solution until the osmotic pressure of the solution equals the applied pressure. If a pressure of 43.0 bar is applied to seawater, what will be the final concentration of the seawater at 20 °C when reverse osmosis stops?

Number

1.77 M_c

Assuming that seawater has a total ion concentration (a.k.a colligative molarity) of 1.10 M_C, calculate how many liters of seawater are needed to produce 49.7 L of fresh water at 20 °C with an applied pressure of 43.0 bar.

Number

131.9 L

Reference

1. Chemical principal
2. Sun Huai, VC210 FA2017 Chapter 10 & 11
3. Zhu keyue, VC210 FA2017 RC7
4. Sapling learning

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THANKΣ