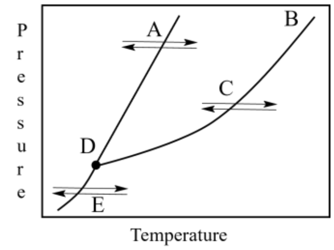
Chemistry 212 Key 1 Name: ______________________

Spring 2025 (Please print)

Multiple Choice (5 points each, Put answers in CAPS in the left margin.)

R = 8.314 J/mol•K = 0.0821 L•atm/mol•K



1. For the phase diagram, which of the following is associated with "B?"

   A) Boiling
   B) Critical point
   C) Deposition
   D) Melting
   E) Triple point

2. Which molecules can form a hydrogen bond with another identical molecule?

   A) HI B) H_2S C) H_2NNH_2 D) CH_3CH_2F E) All of these

3. In general, which of the following forces is weakest?

   A) dipole-dipole
   B) hydrogen bonding
   C) ion-dipole
   D) ion-ion
   E) London dispersion forces

4. What is the freezing point of a 0.22 *m* aqueous solution of sodium chloride (K_b = 1.86 ºC/*m*)?

   A) -0.82 ºC B) -0.41 ºC C) 0 ºC D) 0.41 ºC E) 0.82 ºC

5. Consider the following statements about vapor pressure:

   i) Vapor pressures generally increase with increasing temperature.
   ii) High vapor pressure substances evaporate more quickly than those with low vapor pressures.
   iii) When the external pressure equals the vapor pressure of a liquid, it boils.

   A) All are true.
   B) Only (i) is true.
   C) Some are true.
   D) Only (i) and (iii) are true.
   E) None are true.

6. What is the best explanation for why electrolyte solutions conduct electricity?

   A) The presence of free-flowing ions
   B) The presence of free-flowing electrons
   C) The presence of water
   D) The presence of atoms
   E) None of these

7. For the reaction $N_{2\,(g)} + 3\,H_{2\,(g)} \longrightarrow 2\,NH_{3\,(g)}$ which of the following is a valid equation for rate (i.e. rate =)? (recall Δ can be used for *d*, i.e. Δt for *d*t)

   A) $\frac{d[N_2]}{dt}$
   B) $-2\,\frac{d[NH_3]}{dt}$
   C) $3\,\frac{d[H_2]}{dt}$
   D) $-\frac{1}{3}\frac{d[H_2]}{dt}$
   E) $-\frac{1}{2}\frac{d[NH_3]}{dt}$

8. A reaction with an activation energy of 125 kJ and a frequency factor of 1.00×10^{10} is conducted at 100 ºC. What is its rate constant?

   A) 5.06×10^{-66} B) 5.01×10^{-41} C) 3.15×10^{-8} D) 9.60×10^{9} E) 3.18×10^{27}

Discussion Questions (You must show your work to receive credit):

Quantity	per gram
Enthalpy of fusion at 0°C	333.6 J/g
Enthalpy of vaporization at 100°C	2257 J/g
Specific heat of solid H_2O (ice)	2.087 J/(g·°C) *
Specific heat of liquid H_2O (water)	4.184 J/(g·°C) *
Specific heat of gaseous H_2O (steam)	2.000 J/(g·°C) *

1. At 1 atm, how much energy is required to heat 87.0 g $H_2O_{(s)}$ at −14.0 ºC to $H_2O(g)$ at 169.0 ºC? (8 points)

   Calculate the heat required to warm ice from -14 ºC to 0 º, melting the ice at 0 ºC, warming the water from 0 º to 100 ºC. boiling it at 100 ºC, then warming it to 169 ºC separately, then add the amounts.

   $$\text{heat} = (87.0\text{ g})\left[\left(\frac{2.087\text{ J}}{\text{g•°C}}\right)(14.0\text{ °C}) + \frac{333.6\text{ J}}{\text{g}} + \left(\frac{4.184\text{ J}}{\text{g•°C}}\right)(100.0\text{ °C}) + \frac{2257\text{ J}}{\text{g}} + \left(\frac{2.000\text{ J}}{\text{g•°C}}\right)(69.0\text{ °C})\right]$$

   $$= (87.0\text{ g})\left(\frac{3176\text{ J}}{\text{g}}\right)\left(\frac{1\text{ kJ}}{1000\text{ J}}\right)$$

   $$= 276\text{ kJ}$$

2. Why are ionic solids typically harder and more brittle than molecular solids? (8 points)

   Ionic solids generally form lattices with oppositely charged ions maximizing attractions (of oppositely charged ions) and minimizing repulsions (of like charged ions). When those ions are moved, the attractions are reduced and repulsions increased so there is considerable resistance to moving them. The result is a hard, brittle material. In contrast, molecular solids are made up of neutral molecules which can be displaced much more easily because the attractions are only intermolecular forces, rather than chemical bonds. The result is a material that deforms relatively easily, rather than shatters.

3. Why is it that, at the melting point of a substance, as the material transitions from being a solid to being a liquid, energy input does not result in a temperature increase? (7 points)

   The solid is a material with ions or molecules (species) held in place by their neighbors. As the materials warm, the energy causes the species to begin to move in place (e.g. “wiggle” or rotate), that motion results in increased temperature. At the melting point, however, the individual species break free of their fixed locations, so the energy is used to overcome the intermolecular forces rather than increase the speed of the molecules.

4. Explain how dissolving sugar lowers the freezing point of water. (10 points)

   Imagine an ice cube immersed in water, both at 0 ºC. If heat is removed from the water, the cube grows; if added the ice cube shrinks. As long as ice is present, the temperature remains constant. If there is no heat change, the system is at equilibrium. What happens if we add a little sugar to the water? The rate at which water molecules break free of the ice cube doesn’t change, but now some of the sites adjacent to the ice are occupied by sugar molecules, so the rate at which water molecules re-adhere to the ice slows. Lowering the temperature slows the rate of loss of water molecules from the ice and increases the rate of adding water molecules to the ice. When the rates become equal, the solution begins to freeze.

5. 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? (5 points)

$[\text{pure}_{O2}] = (1\text{ atm})\left(\frac{0.00130\text{ M}}{\text{atm}}\right) = 0.00130\ M$

$[\text{air}_{O2}] = (1\text{ atm})\left(\frac{0.00130\text{ M}}{\text{atm}}\right)(0.21) = 0.000273\ M$

6. For the reaction: $H_2O_2 + 3\,I^- + 2\,H^+ \longrightarrow I_3^- + 2\,H_2O$ (all aqueous) the following rate data were obtained:

$[H_2O_2]$ (M)	$[I^-]$ (M)	$[H^+]$ (M)	initial rate (M/s)
1.0	1.0	0.050	0.012
1.8	1.0	0.050	0.022
1.8	0.6	0.050	0.013
1.0	1.0	0.025	0.012

a) What is the rate law? (Assume the reaction is zero-order in H^+.)
b) What is the rate constant? (10 points)

a) rate = $k[H_2O_2]^x[I^-]^y$

$$\frac{\text{rate}_1}{\text{rate}_2} = \frac{k(1.0\,\text{M})^x(1.0\,\text{M})^y}{k(1.8\,\text{M})^x(1.0\,\text{M})^y} = \frac{0.012\,M/\text{s}}{0.022\,M/\text{s}}$$

$$\frac{(1.0\,M)^x}{(1.8\,M)^x} = \left(\frac{1.0\,M}{1.8\,M}\right)^x = (0.56)^x = 0.56 \Rightarrow x = 1$$

similarly: y = 1, so the rate law is rate = $k[H_2O_2][I^-]$

b) from any set of data: $k = \text{rate}/[H_2O_2][I^-] = 0.012\ M^{-1}s^{-1}$

7. The following mechanism has been proposed for the gas-phase reaction of H_2 with ICl:

$H_{2\,(g)} + ICl_{(g)} \rightarrow HI_{(g)} + HCl_{(g)}$ (1)

$HI_{(g)} + ICl_{(g)} \rightarrow I_{2\,(g)} + HCl_{(g)}$ (2)

(a) Write the balanced equation for the overall reaction.
(b) Identify the intermediates in the reaction.
(c) Write the rate laws for each elementary step.
(d) If the first step is the 'slow' step, write the rate law for the overall reaction. (12 points)

a) $H_{2\,(g)} + 2\,ICl_{(g)} \rightarrow I_{2\,(g)} + 2\,HCl_{(g)}$
b) HI
c) $\text{rate}_1 = k_1[H_2][ICl]$ and $\text{rate}_2 = k_2[HI][ICl]$
d) rate = $k[H_2][ICl]$ (Problem 14.59)