Circle the letter corresponding to the best answer for each of the following multiple choice questions. Each multiple choice question is worth 3 points.

For questions 1 - 4, consider the following compounds designated by the letters A, B, and C.

A: CH₃Cl  B: CH₃F  C: CH₃Br

1. Which of the compounds above would exhibit London dispersion forces as an intermolecular force?
   a. A only  b. B only  c. C only  d. None of them  e. All of them
   Answer: e. All of them

2. Which of the compounds above would exhibit dipole-dipole interactions as intermolecular forces?
   a. A and B  b. A and C  c. B and C  d. None of them  e. All of them
   Answer: e. All of them

3. Which of the compounds above would exhibit H-bonding as an intermolecular force?
   a. A only  b. B only  c. C only  d. A and B  e. None of them
   Answer: e. None of them

4. The order of boiling point for these compounds from low to high would be:
   Answer: c. B < C < A

5. In addition to London dispersion forces, which intermolecular forces are present between molecules of the compound NH₃?
   a. None  b. dipole-dipole  c. H-bonding  d. dipole-dipole and H-bonding  e. dipole-dipole and ion-dipole
   Answer: d. dipole-dipole and H-bonding
Consider the phase diagram below as you answer questions 6 – 8.

6. Which lettered region corresponds to the vapor phase?
   a. w
   b. x
   c. y
   d. z
   e. y and z

7. What is the normal boiling point of the substance?
   a. 2 °C   b. -10 °C   c. 30 °C   d. 0 °C   e. 33 °C

8. What is the critical pressure of the substance?
   a. 180 torr   b. 940 torr   c. 410 torr   d. 760 torr   e. 33 torr
9. What is the proper ranking for the three solutions below from low osmotic pressure to high osmotic pressure?

   a. \[ 0.10 \text{ M \text{BaCl}_2} < 0.17 \text{ M NaCl} < 0.20 \text{ M \text{C}_6\text{H}_12\text{O}_6} \]

   b. \[ 0.20 \text{ M \text{C}_6\text{H}_12\text{O}_6} < 0.17 \text{ M NaCl} < 0.10 \text{ M \text{BaCl}_2} \]

   c. \[ 0.20 \text{ M \text{C}_6\text{H}_12\text{O}_6} < 0.17 \text{ M NaCl} < 0.10 \text{ M \text{BaCl}_2} \]

   d. \[ 0.20 \text{ M \text{C}_6\text{H}_12\text{O}_6} < 0.10 \text{ M \text{BaCl}_2} < 0.17 \text{ M NaCl} \]

   e. \[ 0.17 \text{ M NaCl} < 0.10 \text{ M \text{BaCl}_2} < 0.20 \text{ M \text{C}_6\text{H}_12\text{O}_6} \]

10. The freezing point of \( 0.10 \) m \text{BaCl}_2 is predicted to be (\( K_f \) for water is \( 1.86 \) °C/m and its normal freezing point is \( 0 \) °C):

   a. \(-0.186 \) °C

   b. \(-0.372 \) °C

   c. \(-0.558 \) °C

   d. \(0.558 \) °C

   e. \(0.372 \) °C
Problem Section. Show your work on the following problems to receive credit.

11. (10 points) Tausonite has the crystal structure shown to the right. The corner atoms are strontium, the face-centered atoms are oxygen, and the atom in the center of the structure is titanium.

a. What is the chemical formula for tausonite?

\[ \text{SrTiO}_3 \]

b. If one treats the unit cell as a cube with sides of length 0.39 nm, what is the volume of one unit cell in \( \text{nm}^3 \) and in \( \text{cm}^3 \)? (1 m = 10^9 nm)

\[ V = (0.39 \text{ nm})^3 = \left[ 5.9 \times 10^{-23} (\text{nm})^3 \right] \]

\[ 1 \text{ m} = 10^9 \text{ nm} ; \quad 1 \text{ cm} = 10^{-2} \text{ m} \]

\[ \text{In cm}^3: \quad V = \frac{5.9 \times 10^{-23} \text{ m}^3}{(10^{-2})^3 \text{ m}^3} = \frac{5.9 \times 10^{-23} \text{ cm}^3}{1} \]

\[ \text{c. Based on your formula from part a, what is the mass in grams of the atoms in one unit cell? (1 amu = 1.6606 \times 10^{-24} \text{ g})} \]

\[ \text{SrTiO}_3 \rightarrow \text{Formula mass} = 1 \text{ Sr} + 17 \text{ Ti} + 30 = 88 + 98 + 48 = 184 \]

\[ \text{g per formula unit} = \frac{184 \text{ amu}}{1 \text{ amu}} = 3.055 \times 10^{-22} \text{ g} \]

\[ \text{d. What is the density of tausonite in g/cm}^3?} \]

\[ D = \frac{3.055 \times 10^{-22} \text{ g}}{5.9 \times 10^{-23} \text{ cm}^3} = 5.18 \text{ g/cm}^3 \]
12. (10 points) 15.0-g of KNO₃ are dissolved in 250-g of water. The density of the resulting solution is 1.10 g/mL. Find the molality, % KNO₃ by mass, the mole fraction of water, and the molarity of the solution.

\[ \text{mol KNO₃} = \frac{15.0 \text{ g}}{101.1 \text{ g/mol}} = 0.149 \text{ mol KNO₃} \]

\[ \text{mol水} = \frac{250 \text{ g}}{18 \text{ g/mol}} = 13.9 \text{ mol.} \]

\[ \text{体积解} = \frac{\text{摩尔数}}{\text{密度}} = \frac{265 \text{ g解}}{1.10 \text{ g/mL}} = 241 \text{ mL} \]

\[ m = \frac{\text{摩尔溶质}}{\text{千克溶液}} = \frac{0.149 \text{ mol KNO₃}}{250 \text{ g水}} = 0.596 \text{ m} \]

\[ \% \text{KNO₃} = \frac{15.0 \text{ g KNO₃}}{15.0 \text{ g KNO₃} + 250 \text{ g水}} \times 100 = 5.66 \% \]

\[ X_{\text{水}} = \frac{13.9 \text{ mol水}}{0.149 \text{ mol KNO₃} + 13.9 \text{ mol水}} = 0.989 \]

\[ \lambda = \frac{\text{摩尔溶质}}{\text{溶液体积}} = \frac{0.149 \text{ mol KNO₃}}{241 \text{ mL}} = 0.618 \text{ M} \]

13. (10 points) For the solution in question 12, find the freezing point, boiling point, vapor pressure at 298 K, and the osmotic pressure at 298 K. The vapor pressure of pure water at 298 K is 23.76 torr. The value of the gas constant is 0.08206 L·atm/mol·K.

\[ \Delta T_f = K_f \times m = 1.86 ^\circ C/\text{mol} \times 0.596 \text{ mol} \times 2 = 2.2^\circ C \quad T_f = 0^\circ C - 2.2^\circ C = -2.2^\circ C \]

\[ \Delta T_b = K_b \times m = 1.19 ^\circ C/\text{mol} \times 0.596 \text{ mol} \times 2 = 0.61 ^\circ C \quad T_b = 100^\circ C + 0.61^\circ C = 100.61^\circ C \]

\[ P = X_{\text{水}} \times P_w = \frac{139 \text{ mol水}}{0.149 \text{ mol KNO₃} + 139 \text{ mol水}} = 0.979 \times 23.76 \text{ torr} = 23.3 \text{ torr} \]

\[ MRT = (2 \times 0.618 \text{ M}) \times (0.08206 \text{ L·atm/mol·K}) \times (273 \text{ K}) = 30.2 \text{ atm} \]
14. (5 points) Lysozyme is an enzyme that breaks bacterial cell walls. A solution containing 0.150 g of this enzyme in 210 mL of solution has an osmotic pressure of 0.953 torr at 25 °C. What is the molar mass of lysozyme? (R = 0.08206 L·atm/mol·K)

\[ \Pi = MRT \]

\[ \frac{0.953 \text{ torr}}{760 \text{ torr atm}} = M \left( \frac{0.08206 \text{ L·atm}}{\text{mol·K}} \right) (298 \text{ K}) \]

\[ M = \frac{0.25 \times 10^{-3} \text{ atm}}{0.08206 \text{ L·atm/mol·K} (298 \text{ K})} = 5.128 \times 10^{-5} \text{ M} \]

\[ 5.128 \times 10^{-5} \text{ M} = \frac{\text{mol lysozyme}}{\text{L solution}} \]

\[ \text{mol lysozyme} = 5.128 \times 10^{-5} \text{ M} \times 210 \text{ L} = 1.077 \times 10^{-3} \text{ mol} \]

\[ \text{Molar mass} = \frac{0.150 \text{ g}}{1.077 \times 10^{-3} \text{ mol}} = 139.00 \text{ g/mol} \]