1. For a solution, colligative properties  
   A) depend on the number of solute particles in solution. - True  
   B) depend on the type of solvent. - False  
   C) are intensive properties. - False (extensive)  
   D) are due to solvent-container adhesive interactions. - False  
   E) are due to solvent-solvent interactions. - False

2. A magnesium sulfate solution, which is 18.00% by mass, has a density of 1.20 g/mL at 20 °C. What is the molarity of the solution?  
   A) 1.80 M  
   B) 5.54 M  
   C) 0.877 M  
   D) 1.25 M  
   E) 1.49 M  
   Assume 1 L.
   \[ M_{\text{soln}} = \frac{1.20 \text{ g}}{1 \text{ mL}} = 1200 \text{ g/L} \]  
   \[ M_{\text{MgSO}_4} = \frac{18 \text{ g}}{100 \text{ g}} \times \text{mol/L} = 0.18 \text{ mol/L} \]  
   \[ M = \frac{179.4 \text{ g mol}^{-1}}{1 \text{ L}} = 1.794 \text{ M} \]

3. A 3.2 g sample of a compound with a molar mass of 96 g/mol dissolved in 50 g of water gave a solution that freezes at -1.50 °C. K_f for water is 1.86 °C/molal. The van't Hoff factor i for this solution is  
   A) 1.2  
   B) 2.1  
   C) 2.0  
   D) 2.3  
   E) 1.8  
   \[ \Delta T = c K_f m \]  
   \[ 1.5 = c (1.86 °C/m) (0.666) \]  
   \[ c = 1.2 \]

4. Which one of the following will be affected by increasing the solution temperature from 5.0 °C to 95 °C?  
   A) molarity - True  
   B) percent by weight - independent of T  
   C) molality - independent of T  
   D) molar percent - independent of T  
   E) mole fraction - independent of T
5. Calculate the vapour pressure of a solution made by dissolving 120. g of urea (molar mass of urea is 60.06 g/mol) in 495 g of water at 25 °C. (The pressure of water at 25 °C is 23.8 mmHg.)

   \[ \text{mol urea} = \frac{120 \text{ g}}{60.06 \text{ g/mol}} = 1.998 \text{ mol urea} \]

A) 22.2 mmHg
B) 15.8 mmHg
C) 35.6 mmHg
D) 16.2 mmHg
E) 31.1 mmHg

6. The concentrated sulfuric acid used in the chemical laboratory is 98.0% H₂SO₄ by mass. Calculate the molality of this acid solution. (The density of the acid solution is 1.83 g/mL.)

   M = \frac{1830 \text{ g} \times 0.980}{1000 \text{ mL} \times 1 \text{ L}} = 1793.4 \text{ g H₂SO₄/L}

A) 500. m
B) 200. m
C) 99.9 m
D) 999 m
E) 345 m

\[ \text{mol H₂SO₄} = \frac{1793.4 \text{ g H₂SO₄/L}}{98.08 \text{ g/mol}} = 18.28 \text{ mol/L} \]

6. Which of the molecule(s) below would you expect to show no hydrogen bonding?

\[ \text{I CH₄, II H₃C O CH₃ , III HF, IV NH₃} \]

A) I and II only
B) I, II and III only
C) I only
D) II and IV only
E) II, III and IV only
8. The binary compounds of the Group 4A elements and their boiling points are:

<table>
<thead>
<tr>
<th>Compound</th>
<th>CH₄</th>
<th>SiH₄</th>
<th>GeH₄</th>
<th>SnH₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling point</td>
<td>-162 °C</td>
<td>-112 °C</td>
<td>-89 °C</td>
<td>-52 °C</td>
</tr>
</tbody>
</table>

The trend of increasing boiling points can be explained by:

A) Increasing molecular size and increasing dispersion forces in going from CH₄ to SnH₄. **True**
B) Increasing molecular size and decreasing dispersion forces in going from CH₄ to SnH₄. **False**
C) Because of the increase in dipole-dipole forces. **False**, no dipole-dipole.
D) Because of the decrease in dipole-dipole forces. **False**, no dipole-dipole.
E) Decreasing molecular size and increasing dispersion forces in going from CH₄ to SnH₄. **False**, increasing molecular size.

9. If the vapor pressure of benzene (C₆H₆) is 40.05 mmHg at 7.5 °C, what is its vapor pressure at 61.8 °C? (Molar heat of vaporization of benzene is 31.2 kJ/mol).

\[ T_1 = 7.5 \text{ °C} \]
\[ T_2 = 61.8 \text{ °C} \]
\[ T_2 - T_1 = 54.3 \text{ °C} \]
\[ \Delta H_{vap} = 31.2 \text{ kJ/mol} \]
\[ \frac{T_2}{T_1} = \frac{61.8}{7.5} = 8.24 \]
\[ P_2 = P_1 \left( \frac{T_2}{T_1} \right) \]
\[ P_2 = 40.05 \text{ mmHg} \left( \frac{61.8}{7.5} \right) = 312.0 \text{ mmHg} \]

10. A metallic solid with atoms arranged in a face-centered cubic unit cell with an edge of 392 pm and has a density of 21.45 g/cm³. Identify the metallic solid.

A) Pt (atomic number = 78)
B) Ag (atomic number = 47)
C) Re (atomic number = 75)
D) Os (atomic number = 76)
E) W (atomic number = 74)
11. How much energy is needed to convert 54.1 grams of water from ice at 0.00 °C to liquid at 75.0 °C?

- specific heat (ice) = 2.10 J/g °C
- specific heat (water) = 4.18 J/g °C
- heat of fusion = 333 J/g
- heat of vaporization = 2258 J/g

\[ q = \Delta H_{fus} \cdot m + \Delta H_{vap} \cdot m \Delta T \]

\[ q = 333 \cdot \frac{54.1}{18} + 4.18 \cdot \frac{54.1}{9} \cdot (75.0 - 0) \cdot 8 \]

\[ q = 3.5 \cdot 10^3 \text{ kJ} \]

A) 35.0 kJ
B) 139 kJ
C) 26.5 kJ
D) 1.94 kJ
E) 17.0 kJ

12. A certain substance has the phase diagram shown below. At which of the following values of T and P is the substance a pure liquid?

A) T = 70°C, P = 1.2 atm
B) T = 10°C, P = 1 atm — solid
C) T = 80°C, P = 0.5 atm — vapor
D) T = 20°C, P = 0.3 atm — vapor
E) T = 8°C, P = 1 atm — solid

13. Perform the following mathematical operations and express the result in correct number of significant figures:

\[ \frac{57.423 + 6.243}{5.729 + 0.238} = \frac{31.53}{1.090} + 25.8 \]

A) 56.2
B) 56.2443
C) 56.24
D) 56.244
E) 56.24430
14. Which one of these represents a chemical change?
   A) Apples turn brown when exposed to air.
   B) Boiling water to form steam.
   C) NaCl solid when dissolved in water gives ionic solution.
   D) Sugar when dissolved in water gives non-electrolytic solution.
   E) Solid I₂ sublimed to form I₂ vapor at room temperature.

15. Indium has two naturally occurring isotopes with an average atomic mass of 114.818 amu. In-113 has a mass of 112.904 amu and an abundance of 4.20%. What is the identity of the other indium isotope?
   A) In-115
   B) In-116
   C) In-112
   D) In-117
   E) In-114

16. Which is the correct formula for copper(II) phosphate?
   A) Cu₃(PO₄)₂
   B) Cu₃PO₄
   C) Cu₂PO₃
   D) Cu(PO₄)₂
   E) Cu₂(PO₄)₂

17. What is the oxidation number of carbon atom in the compound sodium hydrogen carbonate?
   A) +4
   B) +2
   C) +6
   D) -2
   E) -4

18. The following reactions are examples of

   2K(s) + Br₂(l) → 2KBr(s) — redox
   AgNO₃(aq) + NaCl(aq) → AgCl(s) + NaNO₃(aq) — precipitation
   HCl(aq) + KOH(aq) → H₂O(l) + KCl(aq) — acid-base

   A) redox, precipitation, and acid-base, respectively
   B) all of them are precipitation reactions
   C) precipitation, precipitation and acid-base reactions, respectively
   D) all of them are redox reactions
   E) all of them are acid-base reactions
19. If 44.39 mL of 0.111 M NaOH is required to completely neutralize a 0.580 g sample of an unknown diprotic acid, calculate the molar mass of the acid.

\[ 2\text{NaOH} + \text{H}_2\text{A} \rightarrow 2\text{H}_2\text{O} + \text{A}^{2-} \]

\[
\begin{align*}
\text{A} &: 235 \text{ g/mol} \\
\text{B} &: 39 \text{ g/mol} \\
\text{C} &: 118 \text{ g/mol} \\
\text{D} &: 203 \text{ g/mol} \\
\text{E} &: 406 \text{ g/mol}
\end{align*}
\]

20. A sample of a compound consisting of Cl and O, reacts with an excess Hz to give 0.233 g HCl and 0.403 g of H₂O. Assume all Cl and O in the original sample are converted to HCl and H₂O, respectively. Determine the empirical formula of the compound.

\[ \text{Cl}_x\text{O}_y + \text{H}_2 \rightarrow \text{HCl} + \text{H}_2\text{O} \]

\[
\begin{align*}
\text{A} &: \text{Cl}_2\text{O}_3 \\
\text{B} &: \text{Cl}_2\text{O}_7 \\
\text{C} &: \text{Cl}_2\text{O}_5 \\
\text{D} &: \text{Cl}_2\text{O}_4 \\
\text{E} &: \text{Cl}_2\text{O}_3
\end{align*}
\]

21. How many grams of lead(II) chloride is produced when 13.87 g lead(II) nitrate combines with excess hydrochloric acid?

\[ \text{Pb(NO}_3\text{)}_2 + 2\text{HCl(aq)} \rightarrow \text{PbCl}_2 + 2\text{HNO}_3 \]

\[
\begin{align*}
\text{A} &: 11.65 \text{ g} \\
\text{B} &: 5.820 \text{ g} \\
\text{C} &: 0.08600 \text{ g} \\
\text{D} &: 1.194 \text{ g} \\
\text{E} &: 16.52 \text{ g}
\end{align*}
\]

22. Calculate the molar mass of rubidium carbonate.

\[
\text{Rb}_2\text{CO}_3
\]

\[
\begin{align*}
\text{A} &: 230.95 \text{ amu} \\
\text{B} &: 255.00 \text{ amu} \\
\text{C} &: 340.43 \text{ amu} \\
\text{D} &: 145.47 \text{ amu} \\
\text{E} &: 113.48 \text{ amu}
\end{align*}
\]

23. According to molecular orbital theory, which of the following species is the most likely to exist:

\[
\begin{align*}
\text{A} &: \text{Li}_2 \quad \text{yes} \\
\text{B} &: \text{He}_2 \quad \text{no} \\
\text{C} &: \text{H}_2^+ \quad \text{no} \\
\text{D} &: \text{Li}_2^+ \quad \text{no} \\
\text{E} &: \text{Be}_2 \quad \text{no}
\end{align*}
\]
24. Which one of these is not a state function, but q+w is one. (Sun)

A) work (not a state function, but q+w is one.)
B) heat measured at constant pressure (q_p)
C) pressure
D) temperature
E) volume

25. A 4.117 g impure sample of glucose (C_6H_{12}O_6) was burned in a constant-volume calorimeter having a heat capacity of 19.65 kJ/°C. If the rise in temperature is 3.134 °C, calculate the % by mass of the glucose in the sample.

C_6H_{12}O_6(s) + 6O_2(g) → 6CO_2(g) + 6H_2O(l) \quad \Delta H^0 = -2801.3 \text{ kJ/mol}

[A] 96.20%  \quad \text{[Assume that the impurities are unaffected by the combustion process, and } \Delta H = \Delta U] 
B) 61.58%  
C) 39.61%  
D) 72.81%  
E) 88.56%  

\[ \text{mass of C}_6\text{H}_{12}\text{O}_6 = \frac{4.117 \text{ g}}{180.1568 \text{ g/mol}} = 0.023 \text{ mol} \]
\[ \text{mass of O}_2 = 6 \times 0.023 \text{ mol} \times 32 \text{ g/mol} = 1.456 \text{ g} \]
\[ \text{mass of C}_6\text{H}_{12}\text{O}_6 : \text{mass of O}_2 = \frac{4.117}{1.456} = 2.83 \]

26. What is the ratio of the height of a column of toluene (C_7H_8) to water if they exert the same pressure. The density of toluene and water are 0.867 and 1.00 g/ml, respectively. The gravitational constant is 9.81 m/s^2.

A) \[ \frac{p_{\text{toluene}}}{p_{\text{water}}} = \frac{h_{\text{toluene}}}{h_{\text{water}}} \]
B) 0.867  
C) 1.73  
D) 0.433  
E) 1.00  

27. Calculate the ratio of the volume of 225.3 g of CO_2 to the volume of 335.2 g of CH_4, when the pressure of CO_2 is double the pressure of CH_4, at the same temperature.

A) 0.1225  
B) 0.2449  
C) 0.4899  
D) 2.041  
E) 8.163
28. A gas mixture contains 33% O₂, 60% N₂, and 7.0% He, as volume percent. The total number of atoms of all types of gases present in 5.0 L of this mixture at STP is:

A) 2.6 \times 10^{23} \text{ atoms}  \\
B) 1.3 \times 10^{23} \text{ atoms}  \\
C) 6.7 \times 10^{22} \text{ atoms}  \\
D) 1.6 \times 10^{23} \text{ atoms}  \\
E) 3.2 \times 10^{23} \text{ atoms}

\[ \text{No. of atoms} = \frac{PV}{RT} = \frac{273 \text{ K}}{0.08205 \text{ atm} \cdot \text{L/mol} \cdot \text{K}} \times 5.0 \text{ L} \]

29. Consider the following reaction:

\[ \text{O}_3 (\text{g}) + \text{NO (g)} \rightarrow \text{O}_2 (\text{g}) + \text{NO}_2 (\text{g}) \]

In a container of 0.50 L, if 0.740 g of O₃ reacts with 0.670 g of NO, what will be the pressure of NO₂ at 33.0 °C? 

A) 0.78 atm  \\
B) 1.5 atm  \\
C) 0.39 atm  \\
D) 1.2 atm  \\
E) 2.4 atm

\[ T = \frac{nRT}{V} = \frac{0.0154 \text{ mol} \times 0.08205 \text{ atm} \cdot \text{L/mol} \cdot \text{K}}{0.50 \text{ L}} \]

30. In the following reaction, a piece of sodium metal (0.54 g) reacts completely with water:

\[ 2\text{Na(s)} + 2\text{H}_2\text{O(l)} \rightarrow 2\text{NaOH(aq)} + \text{H}_2(\text{g}) \]

The generated hydrogen gas is collected over water at 25 °C. Calculate the volume of the produced gas, if the total pressure is 1.00 atm. (Vapor pressure of water at 25 °C is 0.0313 atm)

A) 3.0 \times 10^2 \text{ mL}  \\
B) 2.8 \times 10^3 \text{ mL}  \\
C) 9.1 \times 10^3 \text{ mL}  \\
D) 5.6 \times 10^2 \text{ mL}  \\
E) 1.4 \times 10^2 \text{ mL}

\[ V = \frac{nRT}{P} = \frac{(0.0154 \text{ mol}) \times (0.08205 \text{ atm} \cdot \text{L/mol} \cdot \text{K})}{(1 - 0.0313)} \]

31. The root-mean-square speed of a certain gaseous oxide is 398.5 m/s at 20 °C. What is the molecular formula of the compound?

A) NO₂ - 46.01 \text{ g/mol}  \\
B) CO - 28.01 \text{ g/mol}  \\
C) NO - 30.01 \text{ g/mol}  \\
D) \text{N}_2\text{O}_3 - 76.02 \text{ g/mol}  \\
E) \text{SO}_2 - 64.07 \text{ g/mol}  \\

\[ \text{U}_{\text{rms}} = \sqrt{\frac{3RT}{M}} \]

\[ 1.588 \times 10^2 \text{ m/s} = \sqrt{\frac{(3 \times 8.314 \frac{\text{J}}{\text{K} \cdot \text{mol}}) (293.15 \text{ K})}{M}} \]

\[ M = 0.0460 \text{ kg/mol} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 46.04 \text{ g/mol} \]

\[ \Rightarrow \text{N}_2\text{O}_3 \]
32. Which element has the **lowest** electronegativity?
   A) Cs  
   B) Cl  
   C) K  
   D) Br  
   E) O
   
   Increases from bottom to top and left to right

33. How much energy (in kJ) is required to ionize 2.78 moles of hydrogen atoms from the ground state?
   A) $3.65 \times 10^3$  
   B) $5.89 \times 10^3$  
   C) $2.74 \times 10^3$  
   D) $4.72 \times 10^3$  
   E) $1.66 \times 10^3$

   \[ 1 \text{E}_1(\text{H}) = 1312 \frac{\text{kJ}}{\text{mol}} \times 2.78 \text{ mol} = 3647 \text{ kJ} \]
   
   \[ = 3.65 \times 10^3 \text{ kJ} \]

34. Which one of the following statements is TRUE?
   A) The magnetic quantum number ($m$) describes the orientation of an orbital.  
   B) The principal quantum number ($n$) describes the shape of an orbital.  
   C) The principal quantum number ($n$) describes the orientation of an orbital.  
   D) The angular momentum quantum number ($l$) describes the orientation of an orbital.  
   E) The spin quantum number ($m_s$) describes the shape of an orbital.

35. Which of the following characteristics apply to PF$_3$?
   i. is a non-polar molecule;  
   ii. contains polar bonds  
   iii. has trigonal-pyramidal molecular geometry  
   iv. central atom is sp$^2$ hybridized

   A) ii and iii only  
   B) i, ii and iii only  
   C) i and iii only  
   D) ii, iii and iv only  
   E) all of them

   5 + 7(3) = 26
   \[ - \frac{20}{2} \]
   \[ -18 \]
   4 domains $\Rightarrow$ sp$^3$
   polar
36. The HCl(g) molecule has a bond length of 127 pm and a dipole moment (μ) of 1.08 D. The percent ionic character for H-Cl bond is approximately:

\[
\text{\% ionic} = \frac{\text{M}_{\text{actual}}}{\text{M}_{\text{calc}}} \times 100 = \frac{1.08 \times 10^{-19}}{6.099} \times 100 = 17.79\% \]

37. In the Lewis structure that obey the octet rule for BrS₃⁻, the formal charge on the central atom Br is:

- A) +2
- B) -2
- C) -1
- D) +1
- E) 0

38. What is the molecular geometry of SeF₄?

- A) seesaw
- B) square planar
- C) tetrahedral
- D) octahedral
- E) trigonal bipyramidal

39. Which of the following species have the same molecular geometry:

CO₂, H₂O, NH₃, and NNO? [The central atom in each compound is underlined]

- A) CO₂ and NNO only
- B) CO₂ and NH₃ only
- C) H₂O and NNO only
- D) H₂O and NH₃ only
- E) CO₂ and H₂O only

40. For a propane (C₃H₈) molecule, which one of the following statements is false?

- A) It has three sigma (σ) C-C bonds  \(\checkmark\)
- B) All carbons have sp³ hybridization. \(\checkmark\)
- C) It has eight C-H bonds. \(\checkmark\)
- D) All carbons have tetrahedral structures. \(\checkmark\)
- E) The bond angles at all carbon atom are 109.5°.