1. A 0.72 g of a polymer is dissolved in 250. mL of a suitable solvent at 25 °C. The solution has an osmotic pressure of 1.67 mmHg. What is the molar mass of the polymer?

A) $3.2 \times 10^4$ g/mol  
B) $8.8 \times 10^3$ g/mol  
C) $2.3 \times 10^4$ g/mol  
D) $4.4 \times 10^5$ g/mol  
E) $2.2 \times 10^5$ g/mol

2. A certain aqueous solution is 3.87 % NaCl by mass. A 75.0 mL sample weighs 76.9 g. How many liters of this solution should be evaporated to dryness to obtain 725 kg of NaCl?

A) $1.83 \times 10^4$ L  
B) $2.77 \times 10^6$ L  
C) $1.97 \times 10^5$ L  
D) $1.37 \times 10^6$ L  
E) $6.37 \times 10^3$ L

3. Convert 46.1 ppm sulfate ion (SO$_4^{2-}$) into molarity ($M$) concentration. (The density of the solution is 1.00 g/mL)

A) $4.8 \times 10^{-4}$ $M$  
B) $4.6 \times 10^{-2}$ $M$  
C) $4.4$ $M$  
D) $3.5 \times 10^{-2}$ $M$  
E) $1.7 \times 10^{-3}$ $M$
4. Which of the following would play significant role(s) in forming a solution?
   I. the polarities of the solute and solvent
   II. the densities of the solute and solvent
   III. $\Delta H_{\text{solution}}$
   IV. the state of matter of the solute (solid, liquid, gas)

A) I and III only.
B) I, II and III only.
C) I, III and IV only.
D) all of them
E) II only.

5. An ideal solution is formed from a mixture of the nonvolatile solute urea, CO(NH$_2$)$_2$, and methanol, CH$_3$OH. The vapor pressure of pure methanol at 20°C is 89 mmHg. If 4.4 g of urea is mixed with 39.9 g of methanol, calculate the vapor pressure of the methanol solution

A) 84 mmHg
B) 4.9 mmHg
C) 80 mmHg
D) 74 mmHg
E) 15 mmHg

6. The observed van't Hoff factor for an electrolyte is usually less than the expected factor because of ___________________.

A) ion pairing
B) complete dissociation
C) electrolytic repulsion
D) ion repulsion
E) dilution of the solution
7. A flask used in the determination of densities has a mass of 16.3179 g when empty, and it has a mass of 48.0250 g when filled with water at 20.0°C. When this same flask is filled with ethyl alcohol at 20.0°C, it is found to have a mass of 41.3934 g. Find the density of ethyl alcohol at 20.0°C.

(Given: at 20.0°C, the density of water is 0.9982 g/mL)

A) 0.7894 g/mL  
B) 0.7993 g/mL  
C) 0.7408 g/mL  
D) 1.303 g/mL  
E) 0.7674 g/mL

8. Which of the following statements are true for uranium-238?

I. Its chemical properties will be exactly like those of uranium-235.  
II. It will contain a different number of protons than an atom of uranium-235.  
III. It will contain same number of neutrons as an atom of uranium-235.  
IV. Its mass will be slightly different from that of an atom of uranium-235.

A) I and IV only  
B) II and IV only  
C) I, II and III only  
D) II and III only  
E) all of them

9. What species is represented by the following information?

protons = 47 ;    neutrons = 62         ;    electrons = 46

A) Ag⁺  
B) Mt  
C) Pd  
D) Sm  
E) Pd⁺
10. Use the following data to calculate standard enthalpy formation ($\Delta H^\circ_f$) for KCl(s):

\[
\begin{align*}
\text{KCl (s)} & \rightarrow \text{K}^+ (g) + \text{Cl}^- (g) \quad \Delta H^\circ = 690 \text{ kJ/mol} \\
\text{K (g)} & \rightarrow \text{K}^+ (g) + \text{e}^- \quad \Delta H^\circ = 419 \text{ kJ/mol} \\
\text{Cl(g) + e}^- & \rightarrow \text{Cl}^- (g) \quad \Delta H^\circ = -349 \text{ kJ/mol} \\
\text{Cl}_2(g) & \rightarrow 2\text{Cl} (g) \quad \Delta H^\circ = 239 \text{ kJ/mol} \\
\text{K(s)} & \rightarrow \text{K(g)} \quad \Delta H^\circ = 64 \text{ kJ/mol}
\end{align*}
\]

A) -437 kJ/mol  
B) -317 kJ/mol  
C) 1063 kJ/mol  
D) 1761 kJ/mol  
E) 28 kJ/mol

11. Consider the following energies for the different $n$ values for hydrogen atom:

\[
\begin{align*}
\text{n = 4} & \quad -0.1361 \times 10^{-18} \text{ J} \\
\text{n = 3} & \quad -0.2420 \times 10^{-18} \text{ J} \\
\text{n = 2} & \quad -0.5445 \times 10^{-18} \text{ J} \\
\text{n = 1} & \quad -2.178 \times 10^{-18} \text{ J}
\end{align*}
\]

For which of the following transitions does the light emitted have the longest wavelength?

A) $n = 4$ to $n = 3$  
B) $n = 4$ to $n = 2$  
C) $n = 4$ to $n = 1$  
D) $n = 3$ to $n = 2$  
E) $n = 2$ to $n = 1$

12. The quantum numbers of the last electron of nickel (Ni) could be:

A) $n = 3, \ell = 2, m_\ell = 0, m_s = 1/2$  
B) $n = 4, \ell = 2, m_\ell = 0, m_s = 1/2$  
C) $n = 3, \ell = 1, m_\ell = 0, m_s = 1/2$  
D) $n = 3, \ell = 0, m_\ell = 0, m_s = 1/2$  
E) $n = 3, \ell = 2, m_\ell = 3, m_s = 1/2$
13. In the following reaction, 81.2 mL of O$_2$ (g) is collected over water at 23.0 °C and pressure of 751 mmHg. What mass of Ag$_2$O(s) decomposed? (The vapor pressure of water at 23.0 °C is 21.1 mmHg)

\[2\text{Ag}_2\text{O(s)} \rightarrow 4\text{Ag(s)} + \text{O}_2(\text{g})\]

A) 1.49 g  
B) 0.00321 g  
C) 0.961 g  
D) 0.481 g  
E) 2.32 g

14. A 2.45 g sample of CHX$_3$ gas has a volume of 496 mL at 375.8 mmHg and 35 °C. Identify the element X.

A) Br  
B) Cl  
C) F  
D) I  
E) OH

15. A gas cylinder of 53.7 L volume contains N$_2$ (g) at a pressure of 28.2 atm and 26.0 °C. How many grams of neon (Ne) gas must we add to this same cylinder to raise the total pressure of 75.0 atm?

A) $2.06 \times 10^3$  
B) 164  
C) 617  
D) $2.03 \times 10^4$  
E) $2.03 \times 10^2$

16. A 502 mL of a gas was heated to 150.°C so its final volume was 840. mL. What was its initial temperature? (assuming the pressure and number of mole remain constant).

A) -20.4 °C  
B) -10.5 °C  
C) 5.50 °C  
D) -147 °C  
E) 32.5 °C
17. Nickel forms a gaseous compound of the formula Ni(CO)\(_x\). What is the value of \(x\) given the fact that under the same conditions of temperature and pressure, methan (CH\(_4\)) effuses 3.3 faster than the compound?

A) 4  
B) 3  
C) 2  
D) 1  
E) 6

18. Deviations from the ideal gas law occurs mostly at

A) low temperatures and high pressures.  
B) high temperatures and low pressures.  
C) high temperatures and high pressures.  
D) low temperatures and low pressures.  
E) high temperatures only

19. The boiling point of H\(_2\)O is 100 °C, however, the boiling point of H\(_2\)S is -60 °C. This is due to:

A) the formation of hydrogen bonds in H\(_2\)O, but not in H\(_2\)S.  
B) the molar mass of H\(_2\)O is lower than that of H\(_2\)S.  
C) H\(_2\)O is liquid, while H\(_2\)S is gas at room temperature.  
D) both H\(_2\)O and H\(_2\)S are molecular compounds having dipole-dipole interactions.  
E) S has more electrons than O.

20. The types of crystals of LiF, SiO\(_2\), CO\(_2\) and Fe are respectively classified as:

A) Ionic, covalent, molecular and metallic  
B) Ionic, molecular, covalent and metallic  
C) Molecular, ionic, covalent and metallic  
D) Covalent, ionic, molecular, and metallic  
E) Covalent, molecular, ionic, and metallic
21. Calculate the heat released when 50.00 g of steam at 125.0 °C is converted to water at 100.0 °C. (Assume that the specific heat of steam is 1.99 J/g. °C, and the molar heat of vaporization of water is 40.79 kJ/mol).

A) -115.7 kJ  
B) -110.7 kJ  
C) -2042 kJ  
D) -2040. kJ  
E) - 1041 kJ

22. Considering the following phase diagrams of substance A and B. what is the true statement about these two diagrams:

A) The pressure at the triple point, normal boiling and normal melting point for substance B are lower than those for substance A.  
B) The pressure at the triple point, normal boiling and normal melting point for substance A are lower than those of substance B.  
C) The pressure at the triple point for substance A is higher than that of substance B, but the normal boiling and normal melting point for substance A are lower than those of substance B.  
D) The pressure at the triple point, normal boiling and normal melting point for substance B and for substance A are the same.  
E) The pressure at the triple point for substance B is higher than that of substance A, but the normal boiling and normal melting point for substance A are lower than those of substance B.
23. The vapor pressure of a liquid increases four times when the temperature is raised from 50.0 °C to 100. °C. Calculate the molar heat of vaporization.

A) 27.8 kJ/mol  
B) 23.2 kJ/mol  
C) 272 kJ/mol  
D) 238 kJ/mol  
E) 23.8 kJ/mol

24. Silicon (Si) crystallizes in a simple cubic structure. The density of silicon is 2.33 g/cm³. Calculate the unit cell edge length.

A) 272 pm  
B) 1088 pm  
C) 816 pm  
D) 136 pm  
E) 423 pm

25. Which species has the same molecular geometry as the NO₃⁻ ion?

A) SO₃  
B) SO₃²⁻  
C) ClO₃⁻  
D) PCl₃  
E) NO₂

26. The nitrogen atoms in NH₃, NH₂⁻, and NH₄⁺ are all surrounded by eight electrons. When these three species are arranged in order of increasing H-N-H bond angle, what is the correct order (smallest to largest)?

A) NH₂⁻, NH₃, NH₄⁺  
B) NH₄⁺, NH₂⁻, NH₃  
C) NH₃, NH₄⁺, NH₂⁻  
D) NH₃, NH₂⁻, NH₄⁺  
E) NH₂⁻, NH₄⁺, NH₃
27. From the following pairs, choose the species with stronger bond from each pair.

I. $O_2^-$, $O_2$  
II. $N_2^-$, $N_2^+$  
III. $B_2^-$, $B_2^+$

A) $O_2$, $N_2$, and $B_2^-$  
B) $O_2^-$, $N_2^-$ and $B_2^+$  
C) $O_2$, $N_2$, and $B_2^+$  
D) $O_2^-$, $N_2^-$ and $B_2^-$  
E) $O_2$, $N_2^-$ and $B_2^+$

28. The geometry of ICl$_3$ is best the described as

A) T-shape  
B) trigonal planar  
C) trigonal pyramidal  
D) trigonal bipyramidal  
E) bent

29. Which is/are nonpolar molecule(s)?

I. NCl$_3$  
II. BF$_3$  
III. BrCl$_5$

A) II only  
B) I and II only  
C) II and III only  
D) III only  
E) I only

30. What is the hybridization of AsF$_4^-$ ion?

A) $sp^3d$  
B) $sp$  
C) $sp^2$  
D) $sp^3$  
E) $sp^3d^2$
31. A sample of \((\text{N}_2\text{H}_3\text{)}_2\text{C}_3\text{H}_4\text{O}_4\) contains \(1.084 \times 10^{24}\) carbon atoms. How many moles of hydrogen atoms are in the same sample?

A) 8.400 moles  
B) 4.200 moles  
C) 4.725 moles  
D) 7.000 moles  
E) 2.400 moles

32. When \(\text{BaCl}_2\) reacts with \(\text{Na}_3\text{PO}_4\), the products formed are \(\text{Ba}_3(\text{PO}_4)_2\) and \(\text{NaCl}\). How many moles of \(\text{Ba}_3(\text{PO}_4)_2\) are formed for each mole of \(\text{BaCl}_2\) that is consumed?

A) 0.3333  
B) 3.000  
C) 1.000  
D) 1.500  
E) 2.333

33. A solute is

A) a substance which dissolves in a solvent.  
B) a liquid that does not dissolve in another liquid.  
C) a solid substance that does not dissolve at a given temperature.  
D) a solid substance which does not dissolve in water.  
E) a substance containing a solid, liquid, or gas.

34. Which of these chemical equations describes a *displacement reaction*?

A) \(\text{Fe}_2\text{O}_3(s) + 2\text{Al}(s) \rightarrow 2\text{Fe}(s) + \text{Al}_2\text{O}_3(s)\)  
B) \(2\text{H}_2\text{O}_2(aq) \rightarrow 2\text{H}_2\text{O}(aq) + \text{O}_2(g)\)  
C) \(2\text{P}(s) + 3\text{Cl}_2(g) \rightarrow 2\text{PCl}_3(g)\)  
D) \(\text{CH}_4(g) + 2\text{O}_2(g) \rightarrow \text{CO}_2(g) + 2\text{H}_2\text{O}(l)\)  
E) \(2\text{NaN}_3(s) \rightarrow 2\text{Na}(s) + 3\text{N}_2(g)\)
35. Using the following equation for the combustion of octane, calculate the heat of reaction for 100.0 g of octane.

\[ 2\text{C}_8\text{H}_{18} + 25\text{O}_2 \rightarrow 16\text{CO}_2 + 18\text{H}_2\text{O} \]

\[ \Delta H^\circ_{\text{rxn}} = -11018 \text{ kJ} \]

A) 4.82 x 10^3 kJ  
B) 3.92 kJ  
C) 9.64 x 10^3 kJ  
D) 1.26 x 10^4 kJ  
E) 1.26 x 10^3 kJ

36. In which one of the following reactions would you expect \( \Delta H \) to be substantially greater than \( \Delta U \) (i.e., \( \Delta H > \Delta U \))? 

A) \( \text{CO}_2(\text{s}) \rightarrow \text{CO}_2(\text{g}) \)  
B) \( \text{C}_2\text{H}_2(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{C}_2\text{H}_4(\text{g}) \)  
C) \( \text{H}_2\text{O}(\text{s}) \rightarrow \text{H}_2\text{O}(\text{l}) \)  
D) \( \text{HCl}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \)  
E) \( \text{H}_2(\text{g}) + \text{Br}_2(\text{g}) \rightarrow 2\text{HBr}(\text{g}) \)

37. Which of the following is hydroiodic acid?

A) \( \text{HI}(\text{aq}) \)  
B) \( \text{HIO}(\text{aq}) \)  
C) \( \text{HIO}_2(\text{aq}) \)  
D) \( \text{HIO}_3(\text{aq}) \)  
E) \( \text{HIO}_4(\text{aq}) \)

38. Draw the Lewis structure for hydrogen peroxide, \( \text{H}_2\text{O}_2 \). Based on this structure, how many polar bonds and non-polar bonds are present?

A) 2 polar bonds and 1 non-polar bond  
B) 3 polar bonds and no non-polar bonds  
C) 1 polar bond and 2 non-polar bonds  
D) no polar bonds and 3 non-polar bonds  
E) 2 polar bonds and 2 non-polar bonds
39. Give the ground state electron configuration and number of unpaired electrons for Sb$^{3+}$.

A) [Kr] 5s$^2$ 4d$^{10}$; 0 unpaired electrons
B) [Kr] 4d$^1$ 5s$^1$; 2 unpaired electrons
C) [Xe]; 0 unpaired electron
D) [Kr] 5s$^2$ 4d$^7$; 3 unpaired electrons
E) [Kr] 4d$^{10}$ 5p$^2$; 2 unpaired electrons

40. Lead ions can be precipitated from aqueous solutions by the addition of aqueous iodide:

\[
\text{Pb}^{2+} (aq) + 2\text{I}^- (aq) \rightarrow \text{PbI}_2 (s)
\]

How many milliliters of 3.550 $M$ HI(aq) must be added to a solution containing 0.600 mol of Pb(NO$_3$)$_2$ (aq) to completely precipitate the lead?

A) 338 mL
B) 2.96 $\times$ 10$^3$ mL
C) 169 mL
D) 123 mL
E) 1.48 $\times$ 10$^3$ mL
Answer Key

1. A
2. A
3. A
4. A
5. A
6. A
7. A
8. A
9. A
10. A
11. A
12. A
13. A
14. A
15. A
16. A
17. A
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27. A
28. A
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30. A
31. A
32. A
33. A
34. A
35. A
36. A
37. A
38. A
39. A
40. A