1. Sulfuric acid is a very strong inorganic used in commercial and non-commercial laboratories. What is the molarity of a 70.00 wt % solution of sulfuric acid in water? The density of the solution is 1.6503 g/mL.
   a) 0.7137 M
   b) 7.141 M
   c) 11.78 M
   d) 4.328 M
   e) 0.01178 M

2. Determine the freezing point of a solution containing 5.55 g of Na3PO4 (molar mass = 163.94 g/mol) dissolved in 100.0 g of water.
   \( \text{K}_f \) for water is 1.86 °C·kg/mol.
   a) -0.63°C
   b) -1.26°C
   c) -1.88°C
   d) -2.52°C
   e) -5.04°C

3. The solubility of oxygen gas in water at 25°C and 1.0 atm pressure is 0.041 g/L. What is the solubility of oxygen in water at 3.0 atm and 25°C?
   a) 0.041 g/L
   b) 0.14 g/L
   c) 0.31 g/L
   d) 3.0 g/L
   e) 0.12 g/L

4. Determine the rate law for the reaction below, given the following data.
   \[ \text{O}_2(g) + 2\text{NO}(g) \rightarrow 2\text{NO}_2(g) \]
   \[
   \begin{array}{c|cc|c}
   \text{Experiment Number} & [\text{O}_2]_0 & [\text{NO}]_0 & \text{Initial rate (M·s}^{-1}) \\
   \hline
   1 & 0.0350 & 0.0240 & 0.143 \\
   2 & 0.0350 & 0.0150 & 0.0559 \\
   3 & 0.0450 & 0.0240 & 0.184 \\
   \end{array}
   \]
   a) \( \text{rate} = k [\text{O}_2] [\text{NO}]^2 \)
   b) \( \text{rate} = k [\text{O}_2]^2 [\text{NO}] \)
   c) \( \text{rate} = k [\text{O}_2]^2 [\text{NO}]^2 \)
   d) \( \text{rate} = k [\text{O}_2]^2 [\text{NO}] \)
   e) \( \text{rate} = k [\text{O}_2]^2 [\text{NO}] \)

5. The half-life of a particular first-order reaction is 12.2 min. How long would it take for 65.0% of the reactant to react?
   a) 7.58 min
   b) 14.8 min
   c) 15.9 min
   d) 18.5 min
   e) The initial concentration of the reactant must be known in order to answer this question.

6. A certain first order reaction has a rate constant of 6.5 \( \times \) 10^2 s\(^{-1}\) at 25°C. If the reaction rate doubles when the temperature is increased to 35°C, what is the activation energy for this reaction?
   a) 8.3 kJ/mol
   b) 41 kJ/mol
   c) 53 kJ/mol
   d) 83 kJ/mol
   e) 89 kJ/mol

7. Consider the reaction:
   \[ \text{NO}_2(g) + \text{CO}(g) \rightarrow \text{NO}(g) + \text{CO}_2(g) \]
   The experimentally determined rate law for this reaction is: \( \text{rate} = k[\text{NO}_2]^2 \). Which of the following mechanisms is consistent with the observed rate law?
   a) \( \text{NO}_2(g) + \text{CO}(g) \rightarrow \text{NO}(g) + \text{CO}_2(g) \)
   b) \( \text{NO}_2(g) + \text{NO}_2(g) \rightarrow \text{NO}(g) + \text{O}(g) \) (slow)
   \( \text{CO}(g) + \text{CO}(g) \rightarrow \text{CO}_2(g) + \text{O}(g) \) (fast)
   c) \( \text{CO}(g) + \text{CO}(g) \rightarrow \text{CO}_2(g) + \text{C}(g) \) (slow)
   \( \text{NO}_2(g) + \text{C}(g) \rightarrow \text{NO}(g) + \text{CO}(g) \) (fast)
   d) \( \text{NO}_2(g) + \text{NO}_2(g) \rightarrow \text{NO}(g) + \text{NO}_3(g) \) (slow)
   \( \text{NO}_3(g) + \text{CO}(g) \rightarrow \text{NO}_2(g) + \text{CO}_2(g) \) (fast)
   e) All of these mechanisms are consistent with the rate law.

8. 1.0 mol of I\(_2\) and 1.0 mol of Br\(_2\) are placed in a 2.00 L flask and allowed to reach equilibrium. At equilibrium, the flask contains 1.68 mol of IBr. What is the value of \( K_c \) for this reaction?
   \[ \text{I}_2(g) + \text{Br}_2(g) \rightleftharpoons 2\text{IBr}(g) \]
   a) 11
   b) 4.0
   c) 110
   d) 6.1

9. Consider the following reaction:
   \[ \text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g) \quad \Delta H^\circ = -92 \text{ kJ} \]
   In order to increase the equilibrium yield of ammonia, we could:
   1. increase the temperature
   2. decrease the temperature
   3. increase the pressure by compression
   4. decrease the pressure by expansion
   a) 1 only
   b) 2 only
   c) 1 and 3 only
   d) 2 and 3 only
   e) 1 and 4 only

10. In an experiment, 0.100 mol H\(_2\) and 0.100 mol I\(_2\) are mixed in a 1.00 L container and the reaction forms HI. If \( K_c = 50.0 \) for this reaction, what is the equilibrium concentration of HI?
   \[ \text{H}_2(g) + \text{I}_2(g) \rightleftharpoons 2\text{HI}(g) \]
   a) 0.156 M
   b) 0.0780 M
   c) 7.07 M
   d) 0.200 M
   e) 0.0384 M
11. A 0.10 M solution of a weak monoprotic acid is 5.0% dissociated. What is the equilibrium constant, $K_a$, for this acid?

a) $5.0 \times 10^{-2}$  
b) $5.0 \times 10^{-3}$  
c) $2.5 \times 10^{-4}$  
d) $2.5 \times 10^{-5}$  
e) $2.5 \times 10^{-6}$

12. The $K_a$ for formic acid ($HCHO_2$) is $1.8 \times 10^{-4}$. What is the pH of a 0.35 M solution of sodium formate ($NaCHO_2$)?

a) 10.71  
b) 5.36  
c) 3.29  
d) 8.64  
e) 7.00

13. A 200.0 mL solution of 0.40 M $CH_3COOH(aq)$ and 0.40 M $NaCH_3COO(aq)$ has 20.0 mL of 1.0 M HCl(aq) added to it. What is the pH after the HCl has been added? ($K_a$ = $1.8 \times 10^{-5}$ for $CH_3COOH$)

a) 4.7  
b) 4.5  
c) 4.9  
d) 7.0  
e) 9.5

14. Consider the titration of 40.0 mL of 0.100 M acetic acid ($CH_3COOH$, $K_a = 1.8 \times 10^{-5}$) with 0.150 M NaOH. What is the pH after the addition of 15.0 mL of NaOH?

a) 4.74  
b) 4.92  
c) 4.49  
d) 4.64  
e) 4.85

15. Consider the titration of 50.00 mL of 0.100 M hydrofluoric acid ($HF$, $K_a = 6.76 \times 10^{-3}$) with 0.125 M NaOH. What is the pH at the equivalence point?

a) 7.96  
b) 7.00  
c) 3.17  
d) 10.83  
e) 12.74

16. A particular saturated solution of $Ca_3(PO_4)_2$ has $[Ca^{2+}] = [PO_4^{3-}] = 2.9 \times 10^{-7}$ M. What is the value of $K_{sp}$ for $Ca_3(PO_4)_2$?

a) $2.2 \times 10^{-31}$  
b) $5.0 \times 10^{-13}$  
c) $2.1 \times 10^{-33}$  
d) $8.4 \times 10^{-14}$  
e) $7.2 \times 10^{-31}$

17. What is the molar solubility of $CaF_2$ in pure water at 25°C? ($K_{sp}$ for $CaF_2$ is $1.5 \times 10^{-10}$.)

a) $5.0 \times 10^{-11}$ M  
b) $5.3 \times 10^{-10}$ M  
c) $8.7 \times 10^{-10}$ M  
d) $4.2 \times 10^{-10}$ M  
e) $3.3 \times 10^{-10}$ M

18. What is the molar solubility of $MgF_2$ in a solution containing 0.100 M NaF? ($K_{sp}$ for $MgF_2$ is $7.4 \times 10^{-11}$.)

a) $3.7 \times 10^{-10}$  
b) $1.8 \times 10^{-9}$  
c) $7.4 \times 10^{-11}$  
d) $7.4 \times 10^{-9}$  
e) $2.6 \times 10^{-4}$

19. $K_{sp}$ for BaF$_2$ is $1.8 \times 10^{-7}$. If 50.0 mL of 0.010 M Ba(NO$_3$)$_2$ is added to 50.0 mL of 0.010 M NaF, will a precipitate form?

a) Yes, a precipitate will form.  
b) No, a precipitate will not form.

20. Consider the following reaction, which is spontaneous at room temperature:

\[ NH_3(g) + BF_3(g) \rightarrow H_3NBF_3(s) \]

Which of the following statements must be true of this reaction?

a) $\Delta H < 0$  
b) $\Delta H > 0$  
c) $\Delta G > 0$ at all temperatures  
d) $\Delta G < 0$ at all temperatures

21. Determine the normal boiling point of ethanol ($CH_3CH_2OH$), given that its enthalpy of vaporization is 38.6 kJ/mol and its entropy of vaporization is 110 J/mol K.

a) 128 °C  
b) 92 °C  
c) 78 °C  
d) 61 °C  
e) 86 °C  
c) 78 °C

22. Use the thermodynamic data below to determine the standard free energy change, $\Delta G^\circ$, for the following reaction at 25°C.

\[ CaO(s) + CO_2(g) \rightarrow CaCO_3(s) \quad \Delta H^\circ = -178.7 \text{ kJ} \]

The standard molar entropies of these substances at 25 °C are as follows:

\begin{align*}
CaO(s) & \quad S^\circ = 39.7 \text{ J/K} \\
CO_2(g) & \quad S^\circ = 213.6 \text{ J/K} \\
CaCO_3(s) & \quad S^\circ = 92.9 \text{ J/K}
\end{align*}

a) -160 kJ  
b) +47.6 kJ  
c) +3830 kJ  
d) -226 kJ  
e) -131 kJ
23. Urea (NH₂CONH₂), an important nitrogen fertilizer, is produced industrially by the reaction

\[ 2\text{NH}_3(g) + \text{CO}_2(g) \rightarrow \text{NH}_2\text{CONH}_2(aq) + \text{H}_2\text{O}(l) \]

\[ \Delta G° = -13.6 \text{ kJ at 25°C} \]

What is the value of \( \Delta G \) at 25°C for this reaction under the following set of conditions?

- 25.0 atm NH₃(g)
- 0.500 atm CO₂(g)
- 1.00 M NH₂CONH₂

a) 0.63 kJ  d) -27.8 kJ
b) 14.2 kJ  e) -20.0 kJ
c) -18.1 kJ

24. Consider the following reaction:

\[ \text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g) \]

\[ \Delta G° = 4.73 \text{ kJ/mol at 25°C} \]

What is the equilibrium constant for this reaction at 25°C?

a) 0.15  d) 9.8 \times 10^{-10}
b) 1.0  e) 2.5 \times 10^{5}
c) 2.7 \times 10^{-3}

25. Solid carbon dioxide is commonly known as dry ice. What are the signs of \( \Delta G \), \( \Delta H \), and \( \Delta S \) for the sublimation of dry ice at 25°C?

<table>
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<tr>
<th></th>
<th>( \Delta G )</th>
<th>( \Delta H )</th>
<th>( \Delta S )</th>
</tr>
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</table>
a) | - | + | - |
b) | + | - | - |
c) | + | + | + |
d) | - | - | + |
e) | - | + | + |

26. The oxidation state of nitrogen given for all of the following species is correct except

- a) \( \text{N}_2\text{H}_4 \) -2
- b) \( \text{NH}_2\text{OH} \) -3
- c) \( \text{N}_2 \) 0
- d) \( \text{HNO}_2 \) +3
- e) \( \text{N}_2\text{O} \) +1

27. Which substance in the reaction below is the oxidizing agent?

\[ 5\text{Fe}^{3+}(aq) + \text{MnO}_4^- (aq) + 8\text{H}^+(aq) \rightarrow \text{Mn}^{2+}(aq) + 5\text{Fe}^{2+}(aq) + 4\text{H}_2\text{O}(l) \]

a) \( \text{Fe}^{2+} \)  d) \( \text{Mn}^{2+} \)
b) \( \text{MnO}_4^- \)  e) \( \text{Fe}^{3+} \)
c) \( \text{H}^+ \)

28. Balance the following oxidation-reduction reaction which occurs in basic solution:

\[ \text{Cr(OH)}_3(s) + \text{ClO}^-(aq) \rightarrow \text{CrO}_4^{2-}(aq) + \text{Cl}_2(g) \]

When this equation is balanced using the smallest whole-number coefficients, what is the coefficient on \( \text{H}_2\text{O} \), and on which side of the reaction is \( \text{H}_2\text{O} \) found, product side or reactant side?

a) 2, reactant side  b) 8, product side
c) 12, reactant side  d) 2, product side
e) 14, product side

29. Given these standard reduction potentials:

- \( \text{Fe}^{3+}(aq) + \text{e}^- \rightarrow \text{Fe}^{2+}(aq) \) \( E°_{\text{red}} = 0.77 \text{ V} \)
- \( \text{Zn}^{2+}(aq) + 2\text{e}^- \rightarrow \text{Zn}(s) \) \( E°_{\text{red}} = -0.76 \text{ V} \)

What is the cell potential of the galvanic cell at 25°C which uses the following reaction?

\[ \text{Zn}(s) + 2\text{Fe}^{3+}(aq) \rightarrow \text{Zn}^{2+}(aq) + 2\text{Fe}^{2+}(aq) \]

(0.015 M)  (0.30 M)  (1.5 M)

a) 1.53 V  d) 0.09V
b) 1.63 V  e) 1.43 V
c) 1.49 V

30. What is the product of the alpha decay of uranium-238?

- a) \(^{234}\text{Th}\)
- b) \(^{238}\text{Np}\)
- c) \(^{238}\text{Pa}\)
- d) \(^{235}\text{U}\)
- e) \(^{242}\text{Pu}\)

31. 100.0 mL of an aqueous solution containing 0.120 g of an unknown molecular compound generates an osmotic pressure of 18.0 mm Hg at 20.0°C. What is the molar mass of the unknown compound?

a) 86 g/mol  d) 860 g/mol
b) 122 g/mol  e) 1220 g/mol
c) 164 g/mol

32. Place the following aqueous solutions in order of decreasing freezing point (from highest freezing point to lowest freezing point).

- I. 0.075 m \( \text{Zn(NO}_3\text{)}_2 \)
- II. 0.15 m glucose (\( \text{C}_6\text{H}_{12}\text{O}_6 \), a nonelectrolyte)
- III. 0.050 m \( \text{Al}_2\text{(SO}_4\text{)}_3 \)
- IV. 0.20 m \( \text{NH}_4\text{NO}_3 \)

a) II > IV > I > III  b) I > IV > III > II
c) II > I > III > IV  d) III > I > II > IV
e) III > II > IV > I

Answers