1. Which of the following equations explains almost all of the chemical behavior that we studied this semester?
   a. Newton's second law of motion
   b. \( E = mc^2 \)
   c. Schrödinger's equation
   d. The Pythagorean theorem
   e. The ideal gas equation

2. Which species functions as the reducing agent in the following reaction:
   \[ 2\text{Fe}_2\text{O}_3(s) + 3\text{C}(s) \rightarrow 4\text{Fe}(s) + 3\text{CO}_2(g) \]
   a. \( \text{Fe}_2\text{O}_3(s) \)
   b. \( \text{C}(s) \)
   c. \( \text{Fe}(s) \)
   d. \( \text{CO}_2(g) \)
   e. None: this is not a redox reaction

3. Iron oxide ores are reduced to iron metal by exothermic reaction with carbon monoxide:
   \[ \text{FeO}(s) + \text{CO}(g) \leftrightarrow \text{Fe}(s) + \text{CO}_2(g) \]
   Which of the following changes will cause the equilibrium to shift to the right?
   a. increase the temperature
   b. add \( \text{FeO} \)
   c. add \( \text{CO}_2 \)
   d. add \( \text{CO} \)
   e. remove \( \frac{1}{2} \text{ of Fe} \)
4. Magnesium has three naturally occurring isotopes: $^{24}\text{Mg}$ (23.985 amu) with 78.99% abundance, $^{25}\text{Mg}$ (24.986 amu) with 10% abundance, and $^{26}\text{Mg}$. If the atomic mass of Mg is 24.3050 amu, what is the mass of the third isotope?

   a. 24.023 amu  
   b. 25.431 amu  
   c. 25.982 amu  
   d. 26.001 amu  
   e. 26.031 amu

5. Which statement is true for a reaction with $K_c = 2.43 \times 10^{-12}$?

   a. The reaction proceeds hardly at all towards completion  
   b. The reaction proceeds nearly all the way to completion  
   c. Increasing the temperature will not change the value of $K_c$.  
   d. The reaction has not yet reached equilibrium  
   e. There are appreciable concentrations of both reactants and products.

6. Which of the following can form hydrogen bonds with itself?

   a. $\text{H}_2$  
   b. $\text{HCl}$  
   c. $\text{KNO}_3$  
   d. $\text{CH}_3\text{CH}_3$  
   e. $\text{CH}_3\text{NH}_2$

7. If $K_c$ is less than 1 and decreases with a small increase in temperature, then:

   a. $\Delta G^\circ$ is negative and $\Delta H^\circ$ is negative  
   b. $\Delta G^\circ$ is negative and $\Delta H^\circ$ is positive  
   c. $\Delta G^\circ$ is positive and $\Delta H^\circ$ is negative  
   d. $\Delta G^\circ$ is positive and $\Delta H^\circ$ is positive  
   e. We cannot know without knowing the sign of $\Delta S^\circ$
8. Acetic acid is shown below. The geometry about the C1 is tetrahedral, C2 is trigonal planar and O1 is bent. What is the hybridization of the orbitals around C1, C2, and O1, respectively?

![Acetic acid molecular structure]

a. \(sp^3, sp, sp\)
b. \(sp^3, sp^2, sp^2\)
c. \(sp^3, sp^2, sp^3\)
d. \(sp^2, sp^3, sp^2\)
e. \(sp^3, sp^2, sp\)

9. Based on formal charge considerations, the electron-dot structure of \(CO_3^{2-}\) ion has:

a. Two resonance structures involving two single bonds and one double bond
b. Two resonance structures involving one single bond and two double bonds
c. Three resonance structures involving two single bonds and one double bond
d. Three resonance structures involving one single bond and two double bonds
e. No resonance structures
10. If the following unbalanced reaction goes to completion:

\[ \text{P}_4\text{O}_{10} + \text{H}_2\text{O} \rightarrow \text{H}_4\text{PO}_4 \]

Then when 100 g of \( \text{P}_4\text{O}_{10} \) and 100 g of \( \text{H}_2\text{O} \) are mixed, how much \( \text{H}_4\text{PO}_4 \) is created?

a. 362 g  
b. 200 g  
c. 138 g  
d. 98 g  
e. 35 g

11. 0.5 L of a 1.2 M solution of boric acid is titrated with 100 mL of 10.0 M \( \text{NaOH} \). What are the principal species (other than \( \text{H}_2\text{O} \) and \( \text{Na}^+ \)) present after this process?

a. \( \text{BO}_3^{3-}, \text{OH}^- \)  
b. \( \text{BH}_3\text{O}_3^-, \text{H}^+ \)  
c. \( \text{BHO}_2^-, \text{BO}_3^{3-} \)  
d. \( \text{BH}_2\text{O}_3^-, \text{BHO}_2^- \)  
e. \( \text{BH}_2\text{O}_3, \text{BH}_2\text{O}_3^- \)

12. The \( \text{H}_{\text{vap}} \) of ethanol is 38.6 kJ/mole. If the normal boiling point is 78.4° C, what is the vapor pressure at 50° C?

a. 238 mm Hg  
b. 251 mm Hg  
c. 297 mm Hg  
d. 326 mm Hg  
e. 392 mm Hg
13. Which of the following atoms has more than one unpaired electron in its ground state?

a. Ca  
b. Cl  
c. Cu  
d. Mo  
e. Zn

14. Sodium hypochlorite, NaOCl, is the active ingredient in household bleach. What is the concentration of hypochlorite ion if 20.00 mL of NaOCl solution requires 28.30 mL of 0.500 M HCl to reach the equivalence point?

a. 1.210 M  
b. 0.708 M  
c. 0.500 M  
d. 0.353 M  
e. 0.208 M

15. The dioxin 2,3,7,8-TCCD, which is a suspected carcinogen and mutagen, has a decomposition half-life in the soil of approximately 9 years, independent of initial concentration. If a soil sample has a 0.01 M concentration of 2,3,7,8-TCCD, how long should the soil sample take in years to reach a concentration of 1.0 x 10⁻⁶ M?

a. 209  
b. 145  
c. 91  
d. 63  
e. 21
16. A graph created from data collected from the reaction $3A(s) \rightarrow B(s) + C(g)$ is shown to the right. What is the order of the reaction?
   a. 3rd order
   b. 2nd order
   c. 1st order
   d. 0th order
   e. Cannot tell from the data given

17. Iodide oxidizes in acidic solution to triiodide ion upon the addition of hydrogen peroxide according to the following chemical equation:

$$H_2O_2(aq) + 3I^- (aq) + 2H^+ (aq) \rightarrow I_3^- (aq) + 2H_2O(l).$$

Determine the rate law for this reaction based on the following experimental data:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial $[H_2O_2]$, M</th>
<th>Initial $[I^-]$, M</th>
<th>Initial pH</th>
<th>Initial Rate, M$\cdot$s$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.010</td>
<td>0.010</td>
<td>3.0</td>
<td>$2.2 \times 10^{-6}$</td>
</tr>
<tr>
<td>2</td>
<td>0.020</td>
<td>0.010</td>
<td>3.0</td>
<td>$4.4 \times 10^{-6}$</td>
</tr>
<tr>
<td>3</td>
<td>0.010</td>
<td>0.020</td>
<td>3.0</td>
<td>$4.4 \times 10^{-6}$</td>
</tr>
<tr>
<td>4</td>
<td>0.010</td>
<td>0.020</td>
<td>3.3</td>
<td>$4.4 \times 10^{-6}$</td>
</tr>
</tbody>
</table>

a. Rate = $k[H_2O_2]$
b. Rate = $k[H^+][H_2O_2]$
c. Rate = $k[I^-]$
d. Rate = $k[H][H_2O_2]$e. Rate = $k[H_2O_2][I^-][H^+]$
18. CaCO₃(s) decomposes to create CaO(s) and CO₂(g). If 150.0 g of CaCO₃ produces 30.0 L of CO₂ at 50°C and atmospheric pressure, what is the percent yield of the reaction?

a. 100%
b. 82%
c. 75%
d. 59%
e. 25%

19. Calculate the pH of a 0.05 M solution of ammonium chloride (NH₄Cl).

a. 5.28
b. 4.78
c. 4.64
d. 3.02
e. 2.37

20. What is the molecular geometry of TeCl₄?

a. Tetrahedral
b. Trigonal pyramidal
c. Seesaw
d. Square planar
e. Square pyramidal
21. A sample of an unknown compound with a mass of 34.6 g is burned to produce 53.6 g of $\text{CO}_2$ and 21.8 g of $\text{H}_2\text{O}$. The compound contains 14.0% by mass of oxygen. What are the values of $x$, $y$, $z$, and $w$ in the empirical formula $\text{C}_x\text{H}_y\text{O}_z\text{N}_w$ for the unknown compound?

a. $x=4$, $y=8$, $z=2$, $w=3$

b. $x=4$, $y=8$, $z=1$, $w=3$

c. $x=4$, $y=6$, $z=2$, $w=2$

d. $x=3$, $y=6$, $z=1$, $w=2$

e. $x=2$, $y=6$, $z=1$, $w=2$

22. What is the longest wavelength of light possible for a hydrogen atom to emit when its electron transitions from the n=3 principal quantum level to any other level?

a. 102 nm

b. 434 nm

c. 486 nm

d. 656 nm

e. 1875 nm

23. Mixing solutions of each of which two compounds would be best to make a buffer with pH 7.0?

a. Dimethyl amine ($\text{(CH}_3\text{)}_2\text{NH}_2\text{)}$ and dimethylammonium chloride ($\text{(CH}_3\text{)}_2\text{NH}_3\text{Cl}$)

b. Phenolic acid ($\text{HOC}_6\text{H}_5\text{)}$ and sodium phenolate ($\text{NaOC}_6\text{H}_5\text{)}$

c. Sodium hydroxide ($\text{NaOH}$) and hydrobromic acid ($\text{HBr}$)

d. Lactic acid ($\text{HC}_3\text{H}_3\text{O}_3\text{)}$ and sodium lactate ($\text{NaC}_3\text{H}_5\text{O}_4\text{)}$

e. Monosodium phosphate ($\text{NaH}_2\text{PO}_4\text{)}$ and disodium phosphate ($\text{Na}_2\text{HPO}_4\text{)}$
24. For the following reaction, determine $\Delta H_{\text{rxn}}$ using the bond dissociation energies given with the exam.

$$4 \text{H}_2 + \text{C}_2\text{F}_6 \rightarrow 3\text{F}_2 + 2\text{CH}_4$$

a. -824 kJ/mol
b. -530 kJ/mol
c. 0 kJ/mol
d. 1037 kJ/mol
e. 2530 kJ/mol

25. How many hydroxide ions are there after you balance the following reaction in basic solution?

$$\text{SeO}_3^{2-} + \text{Cl}_2 \rightarrow \text{SeO}_4^{2-} + \text{Cl}^-$$

a. zero
b. 1 on the right
c. 1 on the left
d. 2 on the right
e. 2 on the left

26. How much mechanical work is done if 230.0 g of $\text{N}_2\text{O}_4$ undergoes the decomposition reaction $\text{N}_2\text{O}_4(g) \rightarrow 2\text{NO}_2(g)$ to completion at 500° C and a constant 1 atm pressure?

a. -32.2 kJ
b. -16.1 kJ
c. 16.1 kJ
d. 0 kJ
e. 32.2 kJ
27. What is the solubility of AgCl in a solution of HCl that has pH 2.60? The $K_{sp}$ for AgCl = $1.8 \times 10^{-10}$.

a. $8.2 \times 10^{-9}$  
b. $3.2 \times 10^{-8}$  
c. $5.5 \times 10^{-8}$  
d. $7.2 \times 10^{-5}$  
e. $1.8 \times 10^{-7}$

28. Lead(II) iodide has $K_{sp} = 7.1 \times 10^{-9}$ at room temperature. If we add 1.0 g Pbl$_2$ to 1.0 L water, how much will remain in solid form at equilibrium?

a. 0.99 g  
b. 0.88 g  
c. 0.44 g  
d. 0.11 g  
e. 0.00 g

29. The $K_a$ of acetic acid is $1.8 \times 10^{-5}$ at 25° C and $1.5 \times 10^{-5}$ at 60° C. Estimate the enthalpy of the dissociation of acetic acid in this temperature range.

a. -65.0 kJ/mol  
b. 65.0 kJ/mol  
c. -28.2 kJ/mol  
d. 28.2 kJ/mol  
e. -4.3 kJ/mol