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INCLUDE LABELS AND PROPER NUMBER OF SIG FIGS
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Signed ____________________________
If you feel you can’t sign this, contact the instructor (email, or in person)

Silver Group: Ag, Hg, Pb
Aluminum-Nickel Group: Ni, Fe, Co, Mn, Al, Cr, Zn
Copper-Arsenic Group: Cu, Hg, Pb, As, Sb, Bi, Sn, Cd
Barium-Magnesium Group: Na, K, Mg, Ca, Ba, NH₄⁺¹

Charge of 1 e⁻ = 1.602 x 10⁻¹⁹ coul

F = 96485 coul/mole
R = 8.314 J/K·mole

1 amu = 1.66054 x 10⁻²⁷ kg
h = 6.626 x 10⁻³⁴ J·s/photons

Nₐ = 6.022 x 10²³ particles/mole
k = Aₑ⁻¹/kₑ⁺⁻¹

Integrated Rate Laws: zero: [A] = [A]₀, -kt
first: ln[A] = -kt + ln[A]₀
second: \( \frac{1}{[A]} = kt + \frac{1}{[A]₀} \)

Circle the correct answer. (multiple choice = 2 pts. Each)

1. Which one of the following is amphiprotic in aqueous solution?
   a) HI       b) NH₃       c) H₂PO₄⁻¹       d) HSO₄⁻¹

2. The following pictures represent equal volumes of aqueous solutions of three acids HA (A = X, Y, or Z); water molecules have been omitted for clarity. Which acid is the weakest?
   ![Diagram](image)
   a) X       b) Y       c) Z       d) all three are weak acids so they are the same strength

3. Which of the following yields a basic solution when dissolved in water?
   A. NO₂       B. Cu(NO₃)₂       C. NaClO₂       D. KCl

4. Which of these species is a Lewis acid, but not a Bronsted acid?
   A. HCN       B. Ba²⁺       C. OH⁻       D. Al³⁺
5. What is the net ionic equation for the reaction that occurs when small amounts of hydrochloric acid are added to a HOCl/NaOCl buffer solution?

A. \( H^+ + H_2O \rightarrow H_3O^+ \)  
B. \( H^+ + OCl^- \rightarrow HOCl \)  
C. \( HOCl \rightarrow H^+ + OCl^- \)  
D. \( H^+ + HOCl \rightarrow H_2OCl^- \)

6. Which of the following would decrease the \( K_{sp} \) for \( PbI_2 \)?

A. Lowering the pH of the solution  
B. Adding a solution of \( Pb(NO_3)_2 \)  
C. Adding a solution of KI  
D. None of the above—the \( K_{sp} \) of a compound is constant at constant temperature.

7. \( NaCl \) is added slowly to a solution that is 0.010 M each in \( Hg_2^{2+} \) and \( Ag^+ \). If the \( K_{sp} \) of \( Hg_2Cl_2 \) is less than the \( K_{sp} \) of \( AgCl \), which compound will precipitate first?

a) \( Hg_2Cl_2 \)  
b) \( AgCl \)  
c) no ppt forms, chlorides are soluble  
d) can’t tell from information given

8. What is the shorthand notation that represents the following galvanic cell reaction?

\[ Fe(s) + Cu(NO_3)_2(aq) = Fe(NO_3)_2(aq) + Cu(s) \]

a) \( Cu(s)|Cu^{2+}(aq) \parallel Fe^{2+}(aq) | Fe(s) \)  
b) \( Fe(s) | Fe^{2+}(aq) \parallel Cu^{2+}(aq) | Cu(s) \)  
c) \( Cu(s) | Cu(NO_3)_2(aq) \parallel Fe(NO_3)_2(aq) | Fe(s) \)  
d) \( Fe(s) | NO_3^-(aq) \parallel NO_3^-(aq) | Cu(s) \)

9. Which one of the following is not a redox reaction?

a. \( Al(OH)_4^-(aq) + 4H^+ \rightarrow Al^{3+}(aq) + 4H_2O(l) \)  
b. \( C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l) \)  
c. \( Na_6FeCl_8(s) + 2Na(l) \rightarrow 8NaCl(s) + Fe(s) \)  
d. \( 2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g) \)

10. Consider the following balanced redox reaction

\[ Mn^{2+}(aq) + S_2O_8^{2-}(aq) + 2H_2O(l) \rightarrow MnO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \]

Which of the following statements is true?

a. \( Mn^{2+}(aq) \) is the oxidizing agent and is reduced.  
b. \( Mn^{2+}(aq) \) is the oxidizing agent and is oxidized.  
c. \( Mn^{2+}(aq) \) is the reducing agent and is oxidized.  
d. Manganese does not change its oxidation number in this reaction.

11. The overall reaction \( 2Co^{3+}(aq) + 2Cl^-(aq) \rightarrow 2Co^{2+}(aq) + Cl_2(g) \) has the standard cell voltage \( E^{\circ}_{cell} = 0.46 \) V. Given that \( Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq) \), \( E^{\circ} = 1.36 \) V, calculate the standard reduction potential for the following the half reaction at 25°C:

\( Co^{3+} + e^- \rightarrow Co^{2+} \)

A. 1.82 V  
B. -0.90 V  
C. 0.90 V  
D. -1.82 V

12. Which statement is true for a spontaneous redox reaction carried out at standard-state conditions?

A. \( E^{\circ}_{red} \) is always negative.  
B. \( E^{\circ}_{cell} \) is always positive.  
C. \( E^{\circ}_{ox} \) is always positive.  
D. \( E^{\circ}_{red} \) is always positive.

13. Which ion will form a precipitate with \( KCl(aq) \) and with \( CuCl_2(aq) \)?

a) \( Na^{+} \)  
b) \( Mg^{2+} \)  
c) \( Al^{3+} \)  
d) \( Ag^{+} \)

14. Which reagent will dissolve \( PbCl_2 \) and not \( Hg_2Cl_2 \)?

a) \( NH_3(aq) \)  
b) \( HCl(aq) \)  
c) hot \( H_2O \)  
d) \( HNO_3(aq) \)

15. Which of the following insoluble salts will dissolve in concentrated \( NH_3 \) solution (15 M)?

a) \( PbSO_4 \)  
b) \( SnS_2 \)  
c) \( AgCl \)  
d) \( HgS \)
16. (16 pts) When H₂S is bubbled through a Cu-As group unknown, a yellow precipitate forms. What ions are present? Absent? Undetermined? Explain your reasoning.

17. (10 pts) NOᵢ and SO₃ are blamed for acid rain. How do these compounds, which contain no hydrogen, make rain acidic?

18. (12 pts) What is the Kₐ for a monoprotic acid if a 0.050 M solution of that acid has a pH of 4.00?

19. (15 pts) Balance the following redox reaction that takes place in basic solution.

\[ \text{Bi(OH)}_3 + \text{Sn(OH)}_4^{2-} \rightarrow \text{Bi} + \text{Sn(OH)}_6^{2-} \]

20. (17 pts) Solid sodium iodide is slowly added to a solution that is 0.0050 M Pb²⁺ and 0.0050 M Ag⁺. Calculate the Ag⁺ concentration when PbI₂ just begins to precipitate. (K_sp (PbI₂) = 1.4 \times 10^{-8}; K_sp (AgI) = 8.3 \times 10^{-17}).

Chem 222  
Exam 2  
Name ______________________  
January 14, 2011  

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Aluminum-Nickel Group: Ni, Fe, Co, Mn, Al, Cr, Zn  
Barium-Magnesium Group: Na, K, Mg, Ca, Ba, NH₄⁺

Circle the correct answer. (multiple choice = 2 pts. Each)

1. How many 3d electrons does a Mn²⁺ ion have?
   A. 2  
   B. 3  
   C. 4  
   D. 5

2. In the coordination compound K₂[Co(en)Cl₄], the coordination number (C.N.) and oxidation number (O.N.) of cobalt are
   A. C.N. = 6; O.N. = +2.  
   B. C.N. = 6; O.N. = +3.  
   C. C.N. = 5; O.N. = +2.  
   D. C.N. = 5; O.N. = +4.

3. A bidentate ligand always
A. forms bonds to two metal ions.  
B. has a charge of 2+ or 2-.  
C. forms complex ions with a charge of 2+ or 2-.  
D. has two donor atoms.

4. Which of these square planar complex ions can have cis-trans isomers?
   A. [Pt(NH₃)₄]²⁺  
   B. [Ni(NH₃)₃Cl]⁺  
   C. [Pt(NH₃)₂Cl₂]  
   D. [Pt(NH₃)Cl₃]⁻  

5. A complex with the composition [MA₂B₂]X₂ is found to have no geometrical isomers. Both A and B are monodentate ligands. The structure of the complex is
   A. linear.  
   B. square planar.  
   C. tetrahedral.  
   D. octahedral.

6. Which aqueous reagent will dissolve Al(OH)₃ and not ZnS?
   a) HCl  
   b) NH₃  
   c) NaOH  
   d) H₂S

7. Which aqueous reagent will form a precipitate with Cr⁺³ and not with Ni⁺²?
   a) Na₂S  
   b) NH₃  
   c) HCl  
   d) H₂O₂

8. Which reagent will form a precipitate with HNO₃ and not with HCl?
   a) Pb⁺²  
   b) S⁻²  
   c) Hg₂⁺²  
   d) CrO₄⁻²

9. What is the color of Co(OH)₃?
   a) amber  
   b) white  
   c) blue  
   d) black

10. Examine the following half-reactions and select the strongest reducing agent among the species listed.
    PbI₂(s) + 2e⁻ → Pb(s) + 2I⁻(aq); E° = -0.365 V
    Ca²⁺(aq) + 2e⁻ → Ca(s); E° = -2.868 V
    Pt²⁺(aq) + 2e⁻ → Pt(s); E° = 1.18 V
    Br₂(l) + 2e⁻ → 2Br⁻(aq); E° = 1.066 V
    A. Pb(s)  
    B. Ca²⁺(aq)  
    C. Pt(s)  
    D. Br⁻(aq)

11. The E°cell for the reaction below is 2.35 V at 200°C. ΔG° at this temperature is:
    2Na(l) + FeCl₂(s) → 2NaCl(s) + Fe(s)
    A. 453 kJ  
    B. -453 kJ  
    C. 907 kJ  
    D. -907 kJ

12. Based on the following three reduction half reactions, which reaction in the list will be spontaneous?
    Cu²⁺(aq) + 2e⁻ → Cu(s) E° = 0.337V
    Al³⁺(aq) + 3 e⁻ → Al(s) E° = -1.66V
    Na⁺(aq) + e⁻ → Na(s) E° = -2.714V
    A. 2Na⁺(aq) + Cu(s) → Cu²⁺(aq) + 2Na(s)  
    B. Al(s) + 3Na⁺(aq) → Al³⁺(aq) + 3Na(s)  
    C. 2Al(s) + 3Cu(s) → 3Cu²⁺(aq) + 2Al³⁺(aq)  
    D. 2Al(s) + 3Cu⁺²(aq) → 3Cu(s) + 2Al³⁺(aq)

13. Silver in the +3 oxidation state forms stable, diamagnetic complexes. The coordination geometry of Ag⁺³ in these complexes is
    A. tetrahedral  
    B. octahedral  
    C. square planar  
    D. trigonal bipyramid

14. How many unpaired electrons are there in the complex ion [Mn(CN)₆]³⁻?
    A. 0  
    B. 1  
    C. 2  
    D. 3  
    E. 4
15. Which of these complex ions would absorb light with the longest wavelength?
A. [Co(H2O)6]2+
B. [Co(NH3)6]2+
C. [CoF6]4−
D. [Co(CN)6]4−
E. [Co(en)6]2+

16. (4 pts each) Name the following compounds:

Na2[Ni(NO2)4] ____________________________________________

[Pt(Cl)2(NH3)2]Br2 ____________________________________________

17. (4 pts each) Write the formula for the following compounds:

Hexacarbonylcobalt (III) sulfate ____________________________________________

Copper(II) hexacyanoferrate(II) ____________________________________________

18. (8 pts) The equilibrium constant for the reaction below is $8.30 \times 10^{-7}$. Calculate $E^{\circ}_{\text{cell}}$ for the reaction at 25°C.

$$3I_2(s) + 2MnO_2(s) + 8OH^-(aq) \rightarrow 6I^-(aq) + 2MnO_4^-(aq) + 4H_2O(l)$$

19. (8 pts) How many minutes would be required to electroplate 25.0 grams of chromium by passing a constant current of 4.80 amperes through a solution containing CrCl3?

20. (10 pts) Consider the following electrochemical cell: (left) Zn(s)||Zn2+(1.0 M)||Zn2+(1.0 M)||Zn(s) (right) Note that both sides are at standard conditions, so $E_{\text{cell}} = 0$ V (no current is flowing in this cell). If you add ethylenediamine (en), a good chelator for Zn2+, to the left cell, will the cell potential ($E_{\text{cell}}$) become positive, negative or stay at 0 V? Explain your reasoning.

21. (10 pts) Calculate the cell emf for the following reaction at 25°C: ($Ag^+(aq) + e^- \rightarrow Ag(s)$ $E^{\circ} = +0.7991$ V)

$$2Ag^+(0.010 M) + H_2(1 \text{ atm}) \rightarrow 2Ag(s) + 2H^+(\text{pH} = 6.0)$$

22. (10 pts) An aqueous solution of a Ba-Mg group unknown has a neutral pH. When Na2C2O4 is added to the solution, a white precipitate forms. A flame test on the original solution produces a faint green flame. Which ions are present? absent? undetermined? Explain your reasoning.

22. (8 pts) Draw all the stereoisomers for an octahedral cobalt(III) complex with 3 chlorides and 3 bromides. How many total stereoisomers are there? How many enantiomer pairs are there? (Use wedges and dashes in your structures).

Total # of stereoisomers = _________   # of pairs of enantiomers = _________

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Barium-Magnesium Group: Na, K, Mg, Ca, Ba, NH₄⁺

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Anions: $\text{C}_2\text{H}_3\text{O}_2^-$, $\text{AsO}_4^{3-}$, $\text{BO}_3^{3-}$ or $\text{BO}_2^{3-}$, $\text{Cl}^-$, $\text{Br}^-$, $\text{I}^-$, $\text{S}^{2-}$, $\text{PO}_4^{3-}$, $\text{CrO}_4^{2-}$, $\text{CO}_3^{2-}$, $\text{SO}_3^{2-}$, $\text{SO}_4^{2-}$, $\text{NO}_3^-$

$$R = 8.314 \text{ J mol}^{-1}\text{K}^{-1}$$
$$\Delta H = 0.0821 \text{ L atm mol}^{-1}\text{K}^{-1}$$
$$F = 96500 \text{ C mol}^{-1}$$
$$c = 2.998 \times 10^8 \text{ m s}^{-1}$$
$$0^\circ C = 273.15 \text{ K}$$

Arrhenius Equation: $k = A e^{-E_a/RT}$

Graham's Law of Effusion:
$$\frac{\text{rate}_A}{\text{rate}_B} = \left(\frac{\text{M}_B}{\text{M}_A}\right)^{1/2}$$

Nernst Equation: $E = E^\circ - \frac{RT}{nF} \ln(Q)$

Nernst Equation at $25^\circ C$: $E = E^\circ - \frac{0.05916}{n} \ln(Q)$

Integrated Rate Laws
- zero: $[A] = [A]_0 - kt$
- first: $\ln[A] = \ln[A]_0 - kt$
- second: $\frac{1}{[A]} = kt + \frac{1}{[A]_0}$

Circle the correct answer. (multiple choice = 2 pts. Each)

1. At $25^\circ C$, the second-order reaction $\text{NOCl}(g) \rightarrow \text{NO}(g) + \text{1/2Cl}_2(g)$ is 50% complete after 5.82 hours when the initial concentration of NOCl is 4.46 mol/L. How long will it take for the reaction to be 75% complete?
   - A. 8.22 hr
   - B. 11.6 hr
   - C. 15.5 hr
   - D. 17.5 hr

2. The Arrhenius equation is $k = A e^{(-E_a/RT)}$. The slope of a plot of $\ln k$ vs. $1/T$ is equal to
   - A. $-k$
   - B. $\ln A$
   - C. $E_a$
   - D. $-E_a/R$

3. The gas phase reaction of nitrogen dioxide and carbon monoxide was found by experiment to be second-order with respect to NO$_2$, and zeroth-order with respect to CO below $25^\circ C$.
   $\text{NO}_2 + \text{CO} \rightarrow \text{NO} + \text{CO}_2$
   Which one of the following mechanisms is consistent with the observed reaction order?
   - A. $\text{NO}_2 + \text{2CO} \rightleftharpoons \text{N} + \text{2CO}_2$
   - B. $\text{N} + \text{NO}_2 \rightarrow \text{2NO}$
   - C. $\text{NO}_3 + \text{CO} \rightarrow \text{NO}_2 + \text{CO}_2$
   - D. $\text{NO}_2 + \text{NO}_2 \rightarrow \text{NO}_3 + \text{NO}$

4. The slowest step in a reaction mechanism is called the _____________ step.
   - A. activation
   - B. rate-determining
   - C. rate law
   - D. elementary

5. According to the collision theory, all collisions do not lead to reaction. Which choice gives both reasons why not all collisions between reactant molecules lead to reaction?
   1. The total energy of two colliding molecules is less than some minimum amount of energy.
   2. Molecules cannot react with each other unless a catalyst is present.
   3. Molecules that are improperly oriented during collision will not react.
   - A. 1 and 2
   - B. 1 and 3
   - C. 1 and 4
   - D. 2 and 3
6. For the reaction \( X + Y \rightarrow Z \), the reaction rate is found to depend only upon the concentration of \( X \). A plot of \( 1/X \) verses time gives a straight line (shown below to the right). What is the rate law for this reaction?

A. rate = \( k [X] \)
B. rate = \( k [X]^2 \)
C. rate = \( k [X][Y] \)
D. rate = \( k [X]^2[Y] \)

7. Based on the energy profile below, what is the activation energy for the destruction of ozone?

A) 392 kJ
B) 406 kJ
C) 14 kJ
D) none of these

8. What is the missing symbol in this plutonium fission reaction?

\[
^{239}_{94} Pu + ^{1}_{0} n \rightarrow ^{91}_{38} Sr + ^{148}_{56} Ba + ^{143}_{54} Xe + ^{30}_{16} n
\]

A. \( \beta \)
B. \( \beta \)
C. \( \beta \)
D. \( \beta \)

9. Which is the most penetrating of the three types of nuclear radiation?

A. alpha  B. beta  C. gamma

10. On a plot of the number of neutrons versus the number of protons, a nucleus of aluminum-28 lies above the belt of stability. The most likely decay process for this isotope is

A. alpha emission  B. beta emission  C. gamma emission  D. positron emission or K-capture

11. An example of a network solid is


12. The number of atoms in a body-centered cubic unit cell is

A. 1  B. 2  C. 4  D. 8

13. A certain mineral, \( M_x M'_y A_z \), crystallizes in the cubic unit cell shown below. \( M \) and \( M' \) represent cations and \( A \) represents the anions. How many \( M \) cations are in the unit cell?

A) 4  B) 1  C) 2  D) 8
14. Which reagent will distinguish between Ag₂S and Ag₂CO₃?
   a) H₂O  b) 3 M HNO₃  c) 8 M NaOH  d) 15 M NH₄Cl

15. Which compound is insoluble in water and soluble in dilute acid?
   a) Ba(NO₃)₂  b) Ag₂CrO₄  c) BaSO₄  d) Ba₃(BO₃)₂

16. Which compound reacts with cold, concentrated H₂SO₄ to produce a colorless gas with a sharp, piercing odor?
   a) NaNO₃  b) CaSO₃  c) K₂CrO₄  d) Ag₂AsO₄

17. (10 pts) Nitric oxide gas (NO) reacts with chlorine gas according to the overall reaction NO + ½Cl₂ → NOCl. Using the initial rates data given below, determine the rate law and the value of the rate constant for this reaction.

<table>
<thead>
<tr>
<th>Expt. #</th>
<th>Rate (M/hr)</th>
<th>NO (M)</th>
<th>Cl₂ (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.19</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>2</td>
<td>4.79</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>9.59</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

18. (10 pts) Using the data below, calculate the activation energy, in kJ/mol, for the redox reaction Sn²⁺ + 2Co³⁺ → Sn⁴⁺ + 2Co²⁺.

Data: Tmp (°C)  k (1/M·s)
      2     3.12 × 10³
      27    27.0 × 10³

19. (12 pts) Palladium crystallizes in a face-centered cubic unit cell. Its density is 12.0 g/cm³ at 27°C. Calculate the length of the edge of the unit cell of Pd in picometers (1 pm = 1x10⁻¹⁰ cm).

20. (12 pts) Present-day plant life has a carbon-14 decay rate of 16 disintegrations per minute (dpm) per gram of carbon. If a contemporary wooden chair were somehow preserved for the next 3,900 years, what ¹⁴C decay rate should be expected from the wood used to make the chair? (t₁/₂ = 5,730 yr)

21. (12 pts) A solid mixture was known to contain two or more of the following compounds: silver nitrate, sodium arsenate, lead nitrate, copper nitrate, bismuth chloride, cadmium nitrate, mercury(II) nitrate, and tin(II) sulfate. The mixture dissolved completely in cold water to give a clear blue solution. When 0.1 M tin(II) sulfate was added to the solution, a precipitate formed. Addition of a second sample of the solid to hot, dilute hydrochloric acid produced a blue solution and a white precipitate. A third sample of the solution dissolved completely in dilute sulfuric acid to give a blue solution. What compounds are present, absent, and undetermined. Explain your reasoning and account for all the observations?

22. (12 pts) What is the nuclear binding energy per nucleon, in joules, for ¹² Mg (atomic mass 24.985839 amu). [proton mass = 1.007825 amu; neutron mass = 1.008665 amu; electron mass = 0.00055 amu; 1 kg = 6.022 × 10⁻²³ amu; c = 3.00 × 10⁸ m/s]