CH 223 Sample Exam
Exam II Name: ____ Lab Section: ______

Part I: Multiple Choice Questions (100 Points) There is *only* one best answer for each question.

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1. Which of the following equations is the solubility product for magnesium iodate, $Mg(IO_3)_2$?

   a. $K_{sp} = [Mg^{2+}][I^{-1}]^2[O^{-2}]^6$
   b. $K_{sp} = [Mg^{2+}][I^{-1}]^2[3O^{-2}]^2$
   c. $K_{sp} = [Mg^{2+}][IO_3^{-1}]$
   d. $K_{sp} = [Mg^{2+}]^2[IO_3^{-1}]$
   e. $K_{sp} = [Mg^{2+}][IO_3^{-1}]^2$

2. The solubility of $SrSO_4$ in water is 0.107 g in 1.0 L at 25 °C. What is the value of K_{sp} for $SrSO_4$?

   a. 3.4×10^{-7}
   b. 5.8×10^{-4}
   c. 1.2×10^{-3}
   d. 1.1×10^{-2}
   e. 2.1×10^{-1}

3. The solubility of lead (II) chloride, $PbCl_2$, is 1.6 x 10^{-2} M. What is the K_{sp} of $PbCl_2$?

   a. 5.0 x 10^{-4}
   b. 4.1 x 10^{-6}
   c. 3.1 x 10^{-7}
   d. 1.6 x 10^{-5}
   e. 1.6 x 10^{-2}

4. Calculate the maximum concentration (in M) of silver ions (Ag^+) in a solution that contains 0.025 M of CO_3^{2-}. The K_{sp} of Ag_2CO_3 is 8.1 x 10^{-12}.

   a. 1.8 x 10^{-5}
   b. 1.4 x 10^{-6}
   c. 2.8 x 10^{-6}
   d. 3.2 x 10^{-10}
   e. 8.1 x 10^{-12}

5. The K_{sp} for $Zn(OH)_2$ is 5.0 x 10^{-17}. Determine the molar solubility of $Zn(OH)_2$ in a buffer solution with a pH of 11.5.

   a. 5.0 x 10^{6}
   b. 1.2 x 10^{-12}
   c. 1.6 x 10^{-14}
   d. 5.0 x 10^{-12}
   e. 5.0 x 10^{-17}

6. The molar solubility of __________ is not affected by the pH of the solution.

   a. Na_3PO_4
   b. NaF
   c. KNO_3
   d. $AlCl_3$
   e. MnS

7. Consider the reaction

$Zn(OH)_2(s) + 2\ OH^-(aq) \rightleftharpoons Zn(OH)_4^{2-}(aq)$ **$K = 8.7 \times 10^{-2}$**

If $\boldsymbol{K_{sp}}$ for $Zn(OH)_2$ is **3.0×10^{-17}**, what is the value of the formation constant, K_{form}, for the reaction below?

$Zn^{2+}(aq) + 4\ OH^-(aq) \rightleftharpoons Zn(OH)_4^{2-}(aq)$

a. 2.6×10^{-18}
b. 3.4×10^{-16}
c. 2.9×10^{15}
d. 3.3×10^{16}
e. 3.8×10^{17}

8. The following anions can be separated by precipitation as silver salts: Cl^{-1}, Br^{-1}, I^{-1}, CrO_4^{2-}. If Ag^+ is added to a solution containing the four anions, each at a concentration of 0.10 M, in what order will they precipitate?

Compound	K_{sp}
AgCl	1.8×10^{-10}
Ag_2CrO_4	1.1×10^{-12}
AgBr	5.4×10^{-13}
AgI	8.5×10^{-17}

a. $AgCl \rightarrow Ag_2CrO_4 \rightarrow AgBr \rightarrow AgI$
b. $AgI \rightarrow AgBr \rightarrow Ag_2CrO_4 \rightarrow AgCl$
c. $Ag_2CrO_4 \rightarrow AgCl \rightarrow AgBr \rightarrow AgI$
d. $Ag_2CrO_4 \rightarrow AgI \rightarrow AgBr \rightarrow AgCl$
e. $AgI \rightarrow AgBr \rightarrow AgCl \rightarrow Ag_2CrO_4$

9. A statement of the second law of thermodynamics is that

a. spontaneous reactions are always exothermic.
b. energy is conserved in a chemical reaction.
c. the Gibbs free energy is a function of both enthalpy and entropy.
d. $\Delta S = -\Delta H$ for any chemical reaction.
e. in a spontaneous process, the entropy of the universe increases.

10. As defined by Ludwig Boltzmann, the third law of thermodynamics states that

a. in a spontaneous process, the entropy of the universe increases.
b. there is no disorder in a perfect crystal at 0 K.
c. the total entropy of the universe is always increasing.
d. the total energy of the universe is constant.
e. mass and energy are conserved in all chemical reactions.

11. Which of the following processes involves a decrease in entropy?

a. the decomposition of $NH_3(g)$ into $H_2(g)$ and $N_2(g)$ gas
b. the dissolution of NaCl in water
c. the condensation of steam to liquid water
d. the evaporation of ethanol
e. the sublimation of dry ice (i.e., $CO_2(s)$)

12. Calculate the standard entropy change for the following reaction,

$$2\ HgO(s) \rightleftharpoons 2\ Hg(l) + O_2(g)$$

given $S°[HgO] = 70.3$ J/K·mol, $S°[Hg(l)] = 76.0$ J/K·mol, and $S°[O_2(g)] = 205.1$ J/K·mol.

a. -216.5 J/K
b. +210.8 J/K
c. +216.5 J/K
d. +351.4 J/K
e. +497.7 J/K

13. Predict the signs of ΔH, ΔS, and ΔG for the evaporation of water 25 °C.

a. $\Delta H > 0, \Delta S < 0, \Delta G < 0$
b. $\Delta H > 0, \Delta S > 0, \Delta G > 0$
c. $\Delta H < 0, \Delta S > 0, \Delta G < 0$
d. $\Delta H < 0, \Delta S > 0, \Delta G > 0$
e. $\Delta H < 0, \Delta S < 0, \Delta G < 0$

14. The dissolution of ammonium nitrate occurs spontaneously in water at 25 °C. As NH_4NO_3 dissolves, the temperature of the water decreases. What are the signs of ΔH, ΔS, and ΔG for this process?

a. $\Delta H > 0, \Delta S < 0, \Delta G > 0$
b. $\Delta H > 0, \Delta S > 0, \Delta G > 0$
c. $\Delta H > 0, \Delta S > 0, \Delta G < 0$
d. $\Delta H < 0, \Delta S < 0, \Delta G < 0$
e. $\Delta H < 0, \Delta S > 0, \Delta G > 0$

15. Diluting concentrated sulfuric acid with water can be dangerous. The temperature of the solution can increase rapidly. What are the signs of ΔH, ΔS, and ΔG for this process?

a. $\Delta H < 0, \Delta S > 0, \Delta G < 0$
b. $\Delta H < 0, \Delta S < 0, \Delta G < 0$
c. $\Delta H < 0, \Delta S > 0, \Delta G > 0$
d. $\Delta H > 0, \Delta S > 0, \Delta G < 0$
e. $\Delta H > 0, \Delta S < 0, \Delta G > 0$

16. At what temperatures will a reaction be spontaneous if ΔH = -76.0 kJ and ΔS = +231 J/K?

a. All temperatures below 329 K
b. Temperatures between 0 K and 231 K
c. All temperatures above 329 K
d. The reaction will be spontaneous at any temperature.
e. The reaction will never be spontaneous.

17. Calculate $\Delta G°_{rxn}$ for the reaction below at 25.0 °C

$$CO(g) + H_2O(l) \rightarrow H_2(g) + CO_2(g)$$

given $\Delta G°_f[CO(g)] = -137.2$ kJ/mol, $\Delta G°_f[H_2O(l)] = -237.2$ kJ/mol and $\Delta G°_f[CO_2(g)] = -394.4$ kJ/mol.

a. -768.8 kJ
b. -294.4 kJ
c. -20.0 kJ
d. +20.0 kJ
e. +768.8 kJ

18. __________ is reduced in the following reaction: $\mathbf{Cr_2O_7^{2-} + 6\ S_2O_3^{2-} + 14\ H^{+1} \rightarrow 2\ Cr^{3+} + 3\ S_4O_6^{2-} + 7\ H_2O}$

a. Cr^{6+}
b. S^{2+}
c. H^{+1}
d. O^{2-}
e. $S_4O_6^{2-}$

19. Which substance is the reducing agent in the following reaction: $\mathbf{Cr_2O_7^{2-} + 3\ Ni + 14\ H^{+1} \rightarrow 2\ Cr^{3+} + 3\ Ni^{2+} + 7\ H_2O}$

a. Ni
b. H^{+1}
c. $Cr_2O_7^{2-}$
d. H_2O
e. Ni^{2+}

20. The balanced half-reaction in which one mole of chlorine gas is reduced to the aqueous chloride ion is a __________ process.

a. one-electron
b. two-electron
c. four-electron
d. three-electron
e. six-electron

21. The half-reaction occurring at the ***anode*** in the balanced reaction shown below is __________.

$$\mathbf{3\ MnO_4^{1-}(aq) + 5\ Fe(s) + 24\ H^{+1}(aq) \rightarrow 3\ Mn^{2+}(aq) + 5\ Fe^{3+}(aq) + 12\ H_2O(l)}$$

a. $MnO_4^{1-}(aq) + 8\ H^{+1}(aq) + 5\ e^{-1} \rightarrow Mn^{2+}(aq) + 4\ H_2O(l)$
b. $2\ MnO_4^{1-}(aq) + 12\ H^{+1}(aq) + 6\ e^{-1} \rightarrow 2\ Mn^{2+}(aq) + 3\ H_2O(l)$
c. $Fe(s) \rightarrow Fe^{3+}(aq) + 3\ e^{-1}$
d. $Fe(s) \rightarrow Fe^{2+}(aq) + 2\ e^{-1}$
e. $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^{-1}$

22. The standard cell potential ($E°_{cell}$) of the reaction below is **+0.126 V**. The value of **ΔG°** for the reaction is __________ kJ/mol.

$$\mathbf{Pb(s) + 2\ H^{+1}(aq) \rightarrow Pb^{2+}(aq) + H_2(g)}$$

a. -24.3
b. +24.3
c. -12.6
d. +12.6
e. -50.8

23. How many grams of Ca metal are produced by the electrolysis of molten $CaBr_2$ using a current of 30.0 amp for 10.0 hours?

a. 22.4
b. 448
c. 0.0622
d. 224
e. 112

24. Which one of the following reactions is a redox reaction?

   a. $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$
   b. $Pb^{2+}(aq) + 2\ Cl^{-1}(aq) \rightarrow PbCl_2(aq)$
   c. $AgNO_3(aq) + HCl(aq) \rightarrow HNO_3(aq) + AgCl(s)$
   d. None of the above is a redox reaction.
   e. All of the above are redox reactions

25. What is the coefficient for Fe^{3+} when the following equation is ***balanced***? $CN^{-1} + Fe^{3+} \rightarrow CNO^{-1} + Fe^{2+}$, pH = 10.75

   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

<u>Part II</u>: Short Answer / Calculation. *Show all work!*

1. A solution contains 0.10 M Cl^- and 0.10 M Br^- ions. K_{sp} for AgCl = 1.8×10^{-10}, K_{sp} for AgBr = 3.3×10^{-13}. (10 points)
   a. $AgNO_3$ is added until a white solid just begins to precipitate. What is the identity of the precipitate?
   b. What is the concentration of the less soluble ion once the more soluble ion begins to precipitate out of solution?

Part II: Short Answer / Calculation *(continued) Show all work!*

2. Calculate $\Delta G°$ for the reaction below at 25.0 °C. (10 points)

$$P_4(s) + 6\ H_2O(l) \rightarrow 4\ H_3PO_4(l)$$

Species	$\Delta H°_f$ (kJ/mol)	$S°_f$ (J/K·mol)
$P_4(s)$	0	22.80
$H_2O(l)$	-285.8	69.95
$H_3PO_4(l)$	-1279.0	110.5

3. Calculate $\Delta G°$ and the equilibrium constant, K_{eq}, for the disproportionation reaction (below) of Cu^{+1} at 25 °C:

$$2\ Cu^{+1}(aq) \rightarrow Cu^{2+}(aq) + Cu(s)$$

given the following thermodynamic information. (10 points)

$Cu^{+}(aq) + e^{-} \rightarrow Cu(s)$ $\quad E° = +0.518$ V

$Cu^{2+}(aq) + 2\ e^{-} \rightarrow Cu(s)$ $\quad E° = +0.337$ V