CHEM 1423 - Exam 4 – April 21, 2016

Name _Solutions_

The Gas Constant is: $R = 8.31$ J/mol-K $= 8.31 \times 10^{-3}$ kJ/mol-K

(63) PART I.   MULTIPLE CHOICE (Circle the ONE correct answer)

For #1 - #2: Consider the sparingly soluble compound, Lanthanium Iodate, $[La(IO_3)_3]$. The solubility product constant is $K_{sp} = 7.5 \times 10^{-12}$.

1. What is the solubility of $La(IO_3)_3$ in pure water?

    (A) 1.7×10^{-3} M   **(B) 7.3×10^{-4}**   (C) 6.5×10^{-5} M   (D) 1.2×10^{-4} M

2. What is the **concentration of iodate ions**, $[IO_3^-]$, in a solution containing 2.0 M $La(NO_3)_3$ (which is a strong electrolyte)?

    (A) 4.7×10^{-4} M   (B) 5.2×10^{-5} M   **(C) 1.6×10^{-4} M**   (D) 6.5×10^{-7} M

3. The solubility products of two sparingly soluble Lead(II) $[Pb^{2+}]$ salts are:
    $Pb(ClO_3)_2$ - $K_{sp} = 5.6 \times 10^{-13}$, $PbSO_4$ - $K_{sp} = 1.6 \times 10^{-8}$.

    Consider a solution which initially contains 1.0×10^{-5} M ClO_3^-(aq) and 1.0×10^{-5} M SO_4^{2-}(aq). $Pb(NO_3)_2$ (a strong electrolyte) is added until $[Pb^{2+}] = 7.0 \times 10^{-3}$ M.

    Which of the above salts will form any solid precipitate?

    (A) $Pb(ClO_3)_2$ only   (B) $PbSO_4$ only   (C) Neither $Pb(ClO_3)_2$ nor $PbSO_4$

    (D) Both $Pb(ClO_3)_2$ and $PbSO_4$

4. Which of the following statements is/are **NOT** correct?

    (1) The entropy change on crystallizing liquid is positive
    (2) The entropy usually increases when a liquid is dissolved in a second liquid
    (3) The entropy of CaO(s) is higher than the entropy of $CaCO_3$(s)
    (4) The entropy increases when a gas dissolves in a liquid

    (A) 1 & 4   **(B) 1 & 3 & 4**   (C) 1 & 3   (D) 2 only

5. Consider the reaction: N_2(g) + 2 O_2(g) → 2 NO_2(g) , $\Delta H° > 0$. This reaction is:

    (A) Reactant Favored at all temperatures

    (B) Product Favored at all temperatures

    (C) Product Favored at low temperature

    (D) Product Favored at high temperature

6. For the hypothetical reaction, $A \rightleftharpoons B$, ΔS° = -70 J/K (independent of temperature). The equilibrium constant for the reaction at 150 °C is 2.0×10^{-3}. What is the enthalpy change, ΔH° for this reaction?

(A) +51.5 kJ   (B) -37.3 kJ   (C) -7.8 kJ   (D) -51.5 kJ

7. For the reaction, $CH_3OH(g) \rightleftharpoons CO(g) + 2H_2(g)$, ΔH° = +91 kJ and ΔS° = +221 J/K. What is the entropy change of the **surroundings**, ΔS_{surr}, for the related reaction, $\frac{1}{2}CH_3OH(g) \rightleftharpoons \frac{1}{2}CO(g) + 1H_2(g)$, at 25 °C?

(A) +111 J/K   (B) +153 J/K   (C) -111 J/K   (D) -153 J/K

8. The normal boiling point of methane [CH_4, M=16] is -162 °C. The Enthalpy of Vaporization of methane is 8.5 kJ/mol. What is the entropy change of the **system** when 40 g of methane gas condenses to the liquid at -162 °C?

(A) -191 J/K   (B) +191 J/K   (C) -131 J/K

(D) Requires the value of the Entropy of Vaporization

For #9 - #10: Consider the reaction: $2 Fe_2O_3(s) \rightarrow 4 Fe(s) + 3 O_2(g)$

	$Fe_2O_3(s)$	$Fe(s)$	$O_2(g)$
S_m°(25 °C)	87 J/mol-K	27 J/mol-K	205 J/mol-K
ΔG_f°(25 °C)	-742 kJ/mol		

9. What is ΔG° for the above reaction [at 25 °C] ?

(A) -1484 kJ   (B) +742 kJ   (C) +1484 kJ

(D) Insufficient Information is Given

10. What is the Enthalpy Change, ΔH°, for the above reaction [at 25 °C]

(A) +1648 kJ   (B) -1320 kJ   (C) +1320 kJ

(D) Insufficient Information is Given

11. The reaction, $A \rightarrow B$, is **endergonic** at 25 °C and the entropy change is +40 J/K. What can be concluded about the enthalpy change for this reaction?

(A) ΔH < -11.9 kJ   (B) ΔH > +11.9 kJ   (C) ΔH > 18.4 kJ
(D) No conclusion can be made about ΔH

12. For the **exergonic** reaction, $C \rightarrow D$, ΔH = +25 kJ. For this reaction,

(A) ΔG<0 & ΔS<0   (B) ΔG>0 & ΔS<0   (C) ΔG>0 & ΔS>0   (D) ΔG<0 & ΔS>0

For #13 - #14: The Enthalpy of Vaporization of Br_2(liq) is 29.5 kJ/mol. The Entropy of Vaporization of Br_2(liq) is 89.0 J/mol-K.

13. The Entropy change of the universe, ΔS_{univ}, when one mole of Br_2(gas) condenses to Br_2(liq) at 90 °C is approximately:

    (A) +7.7 J/mol-K   (B) -7.7 J/mol-K   (C) +14.3 J/mol-K

    (D) None of the above

14. The normal boiling point of Br_2(liq) is approximately:

    (A) 58 °C   (B) 83 °C   (C) 331 °C

    (D) Depends upon the magnitude of ΔS_{univ}

15. Consider the gas phase reaction, $2\ NO(g) + Cl_2(g) \rightleftharpoons 2\ NOCl(g)$. The Gibbs Free Energy of Formation of NOCl(g) is ΔG_f^0(NOCl) = +66.1 kJ/mol. The value of the equilibrium constant, K, at 25 °C is approximately:

    (A) 2.6×10^{-12} (B) 6.5×10^{-24} (C) 1.5×10^{23}

    (D) Insufficient data is given to determine the equilibrium constant

16. The equilibrium constant for the reaction, $2\ N_2O_5 \rightleftharpoons 2\ N_2(g) + 5\ O_2(g)$, is 2.4×10^{41} at 25 °C. What is the approximate value of the Gibbs Free Energy of Formation of N_2O_5(g)?

    (A) -118. kJ/mol   (B) -236. kJ/mol   (C) +118 kJ/mol

    (D) Insufficient data is given to determine ΔG_f^0(N_2O_5)

17. For the reaction, $2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$, the equilibrium constant is K = 150. at 300 °C. What is the approximate value of ΔG for this reaction at 300 °C when P(SO_2) = 0.10 bar, P(O_2) = 0.50 bar, and P(SO_3) = 2.5 bar?

    (A) +10.1 kJ   (B) -23.9 kJ   (C) +34.0 kJ   (D) -57.8 kJ

18. For the reaction, $2\ HI(g) \rightleftharpoons H_2(g) + I_2(g)$, $\Delta H° = -53$ kJ and $\Delta S° = -166$ J/K. This reaction is _____ favored at temperatures **above** _____ °C (Celsius).

    (A) Product , 319 °C   (B) Product , 46 °C

    (C) Reactant , 319 °C   (D) Reactant , 46 °C

19. As discussed in class, hydrophobic (non-polar) amino acid sidechains tend to reside in the interior of proteins' tertiary structure. The reason they do **not** reside on the exterior of the protein is that they would

    (A) lower the entropy of the surrounding water molecules

    (B) raise the entropy of the surrounding water molecules

    (C) raise the enthalpy of the non-polar sidechain

    (D) hydrogen bond with the surrounding water moleciules

20. In class, we discussed the thermodynamics of the formation of doubly stranded DNA by base-pairing of nucleic acids in the individual strands. Let's consider the **breaking** of one base-pair (e.g. Adenine-Thymine)in the unravelling of doubly stranded DNA. For this process, $\Delta H°$ is _____ and $\Delta S°$ is _____

(A) Negative, Negative

(B) Positive, Positive

(C) Positive, Negative

(D) Negative, Positive

21. Regarding the following reaction, which of the statements below is/are **Not correct?**
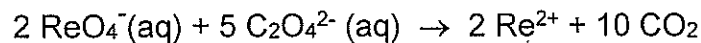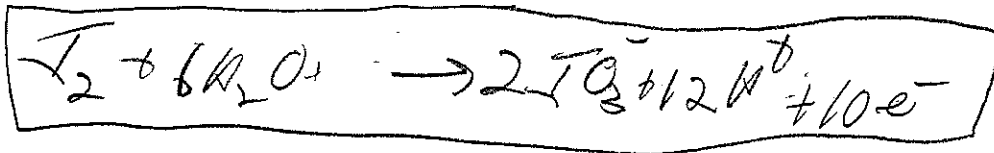
$$2\ ReO_4^-(aq) + 5\ C_2O_4^{2-}\ (aq) \rightarrow 2\ Re^{2+} + 10\ CO_2$$

(1) Re^{2+} is reduced

(2) $C_2O_4^{2-}$ is Oxidized

(3) $C_2O_4^{2-}$ is the reducing agent

(4) Five (5) electrons are transfered

(A) 1 & 4   (B) 2 & 3   (C) 2 & 4   (D) 4 only

PART II.   FOUR (4) PROBLEMS : REMEMBER TO SHOW WORK FOR CREDIT

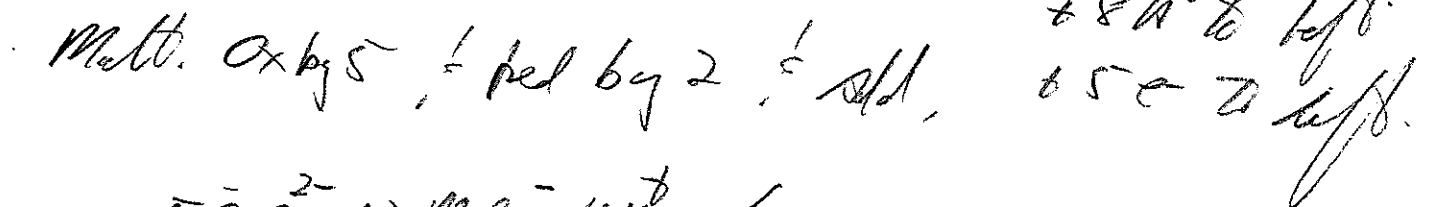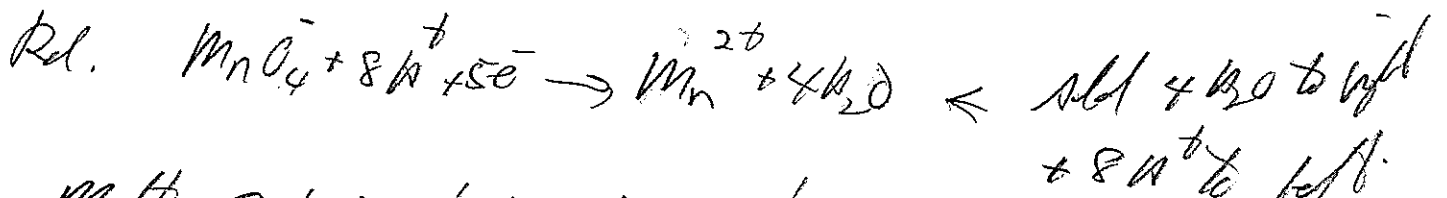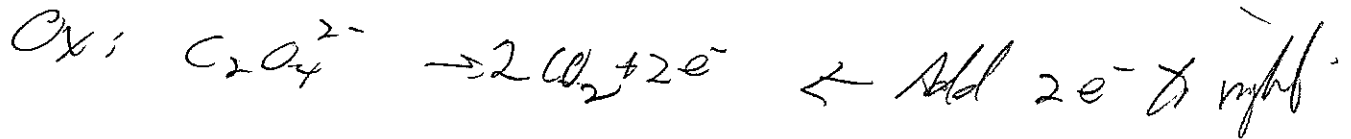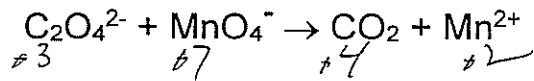## The Gas Constant is: $R = 8.31$ J/mol-K $= 8.31\times10^{-3}$ kJ/mol-K

(5)   1.   Write a balanced half reaction in **aqueous Acid** solution for the reaction of I_2 to form the IO_3^- ion.
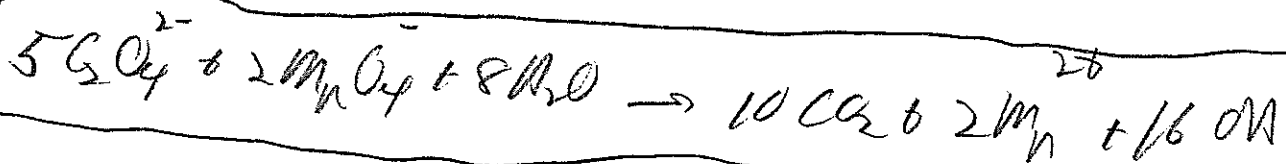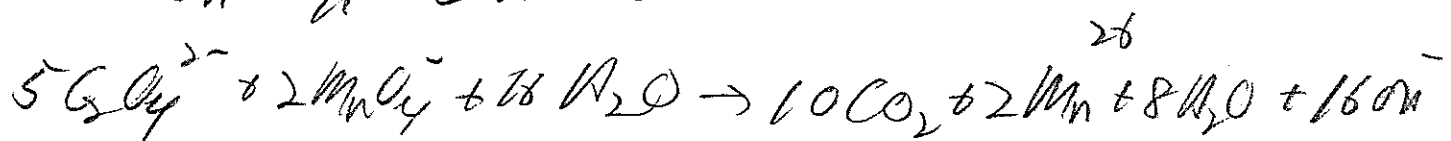
$I_2 \rightarrow 2 IO_3^-$ Mult right by 2

$I_2 + 6H_2O \rightarrow 2 IO_3^- + 12 H^+ + 10 e^-$

Add $6 H_2O$ to left
$+ 12 H^+$ to right
$+ 10 e^-$ to right

(10) 2. Balance the following oxidation-reduction reaction in **aqueous Basic** solution.

$$C_2O_4^{2-} + MnO_4^- \rightarrow CO_2 + Mn^{2+}$$

+3   +7   +4   +2

Ox: $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ ← Add $2e^-$ to right

Red. $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ ← Add $4H_2O$ to right
+ $8H^+$ to left
+ $5e^-$ to left

Mult. Ox by 5, red by 2, add,

$5C_2O_4^{2-} + 2MnO_4^- + 16H^+ + 10e^-$
$\rightarrow 10CO_2 + 10e^- + 2Mn^{2+} + 8H_2O$

Add $16OH^-$ to each side

$5C_2O_4^{2-} + 2MnO_4^- + 16H_2O \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O + 16OH^-$

$$5C_2O_4^{2-} + 2MnO_4^- + 8H_2O \rightarrow 10CO_2 + 2Mn^{2+} + 16OH^-$$

(cancelled H_2O's)

(08) 3. Barium Phosphate, $Ba_3(PO_4)_2(s)$, is a sparingly soluble salt with $K_{sp} = 3.0 \times 10^{-23}$.

6.0 L of 1.50×10^{-4} M $Ba(NO_3)_2(aq)$ is mixed with 4.0 L of 1.00×10^{-5} M $Na_3PO_4(aq)$.

Use this data to **calculate whether or not** any $Ba_3(PO_4)_2(s)$ will precipitate when the two solutions are mixed.

You **MUST** show your calculation to receive credit.

Use $C_{fin} = C_{init} \times \dfrac{V_{init}}{V_{fin}}$.

$$[Ba^{2+}] = 1.5 \times 10^{-4} M \times \frac{6}{6+4} = 9.0 \times 10^{-5} M$$

$$[PO_4^{3-}] = 1.0 \times 10^{-5} M \times \frac{4}{6+4} = 4.0 \times 10^{-6} M$$

$$Ba_3(PO_4)_2 \rightleftharpoons 3 Ba^{2+} + 2 PO_4^{3-}$$
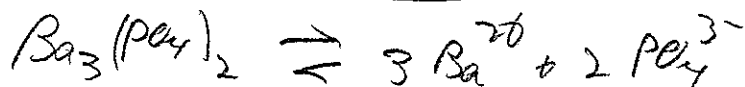
$$Q = [Ba^{2+}]^3 [PO_4^{3-}]^2$$

$$= (9.0 \times 10^{-5})^3 (4.0 \times 10^{-6})^2$$

$$\boxed{Q = 1.17 \times 10^{-23} \quad < K_{sp} \left(= 3 \times 10^{-23}\right)}$$

$$\boxed{\text{Does NOT precipitate} \\ \text{since } Q < K_{sp}}$$

(14) 4.   Consider the gas phase equilibrium $2\ PBr_3(g) + O_2(g) \rightleftharpoons 2\ POBr_3(g)$. The equilibrium constant for this reaction is K = 0.04 at 200 °C.

(10) (a) If the pressures of $O_2(g)$ and $POBr_3(g)$ are both 0.55 bar, what is the pressure of $PBr_3(g)$ if the Gibbs Free Energy change is ΔG = 7.00 kJ at 200 °C?

$$\Delta G^0 = -RT \ln K = -(0.00831)(473)\ln(0.04) = 12.65 \, kJ$$

$$\Delta G = \Delta G^0 + RT \ln Q \rightarrow \ln Q = \frac{\Delta G - \Delta G^0}{RT} = \frac{7.00 - 12.65}{(0.00831)(473)}$$

$$= -1.437 \rightarrow Q = e^{-1.437}$$

$$= 0.237$$

$$Q = 0.237 = \frac{P_{POBr_3}^2}{P_{PBr_3}^2 \, P_{O_2}} = \frac{(0.55)^2}{P_{PBr_3}^2(0.55)} = \frac{0.55}{P_{PBr_3}^2}$$

$$P_{PBr_3}^2 = \frac{0.55}{0.137} = 2.32$$

$$P_{PBr_3} = \sqrt{2.32} = \boxed{1.52 \, bar.}$$

(4) (b) What is the value of K for the related reaction, $POBr_3(g) \rightleftharpoons PBr_3(g) + \tfrac{1}{2} O_2g)$

We have reversed & halved the reaction

$$\therefore K' = \frac{1}{K^{\frac{1}{2}}} = \frac{1}{(0.04)^{\frac{1}{2}}} = \boxed{5.0}$$

CHEM 1423 - Exam 4 — April 21, 2016

Name ___Solution___

The Gas Constant is: $R = 8.31$ J/mol-K $= 8.31 \times 10^{-3}$ kJ/mol-K

(63) PART I. MULTIPLE CHOICE (Circle the ONE correct answer)

1. The solubility products of two sparingly soluble Lead(II) [Pb^{2+}] salts are:
    $Pb(ClO_3)_2$ - $K_{sp} = 5.6 \times 10^{-13}$, $PbSO_4$ - $K_{sp} = 1.6 \times 10^{-8}$.

    Consider a solution which initially contains 1.0×10^{-5} M ClO_3^-(aq) and 1.0×10^{-5} M SO_4^{2-}(aq). $Pb(NO_3)_2$ (a strong electrolyte) is added until $[Pb^{2+}] = 7.0 \times 10^{-3}$ M.

    Which of the above salts will form any solid precipitate?

    (A) $Pb(ClO_3)_2$ only   (B) $PbSO_4$ only   **(C) Both $Pb(ClO_3)_2$ and $PbSO_4$**

    (D) Neither $Pb(ClO_3)_2$ nor $PbSO_4$

For #2 - #3: Consider the sparingly soluble compound, Lanthanium Iodate, [$La(IO_3)_3$]. The solubility product constant is $K_{sp} = 7.5 \times 10^{-12}$.

2. What is the solubility of $La(IO_3)_3$ in pure water?

    (A) 7.3×10^{-4} M   (B) 1.7×10^{-3} (C) 6.5×10^{-5} M   (D) 1.2×10^{-4} M

3. What is the **concentration of iodate ions**, [IO_3^-], in a solution containing 2.0 M $La(NO_3)_3$ (which is a strong electrolyte)?

    (A) 4.7×10^{-4} M   (B) 5.2×10^{-5} M   (C) 6.5×10^{-7} M   **(D) 1.6×10^{-4} M**

4. Consider the reaction: N_2(g) + 2 O_2(g) $\rightarrow$ 2 NO_2(g) , $\Delta H° > 0$. This reaction is:

    (A) Product Favored at all temperatures

    (B) Reactant Favored at all temperatures

    (C) Product Favored at low temperature

    (D) Product Favored at high temperature

5. Which of the following statements is/are **NOT** correct?

    ✗ (1) The entropy change on crystallizing liquid is positive
    ✓ (2) The entropy usually increases when a liquid is dissolved in a second liquid
    ✗ (3) The entropy of CaO(s) is higher than the entropy of $CaCO_3$(s)
    ✗ (4) The entropy increases when a gas dissolves in a liquid

    (A) 1 & 4   (B) 1 & 3   **(C) 1 & 3 & 4**   (D) 2 only

6. The normal boiling point of methane [CH_4, M=16] is -162 °C. The Enthalpy of Vaporization of methane is 8.5 kJ/mol. What is the entropy change of the **system** when 40 g of methane gas condenses to the liquid at -162 °C?

(A) +191 J/K   (B) -191 J/K   (C) -131 J/K

(D) Requires the value of the Entropy of Vaporization

7. For the reaction, $CH_3OH(g) \rightleftharpoons CO(g) + 2H_2(g)$, $\Delta H° = +91$ kJ and $\Delta S° = +221$ J/K. What is the entropy change of the **surroundings**, ΔS_{surr}, for the related reaction, $\frac{1}{2}CH_3OH(g) \rightleftharpoons \frac{1}{2}CO(g) + 1H_2(g)$, at 25 °C?

(A) +111 J/K   (B) +153 J/K   (C) -153 J/K   (D) -111 J/K

For #8 - #9: Consider the reaction: $2\ Fe_2O_3(s) \rightarrow 4\ Fe(s) + 3\ O_2(g)$

	$Fe_2O_3(s)$	$Fe(s)$	$O_2(g)$
$S_m°$(25 °C)	87 J/mol-K	27 J/mol-K	205 J/mol-K
$\Delta G_f°$(25 °C)	-742 kJ/mol		

8. What is $\Delta G°$ for the above reaction [at 25 °C] ?

(A) +1484 kJ   (B) +742 kJ   (C) -1484 kJ

(D) Insufficient Information is Given

9. What is the Enthalpy Change, $\Delta H°$, for the above reaction [at 25 °C]

(A) -1320 kJ   (B) +1648 kJ   (C) +1320 kJ

(D) Insufficient Information is Given

10. For the hypothetical reaction, A $\rightleftharpoons$ B, $\Delta S° = -70$ J/K (independent of temperature). The equilibrium constant for the reaction at 150 °C is 2.0×10^{-3}. What is the enthalpy change, $\Delta H°$ for this reaction?

(A) +51.5 kJ   (B) -37.3 kJ   (C) -51.5 kJ   (D) -7.8 kJ

11. For the **exergonic** reaction, C $\rightarrow$ D, $\Delta H = +25$ kJ. For this reaction,

(A) $\Delta G<0$ & $\Delta S<0$ (B) $\Delta G>0$ & $\Delta S<0$ (C) $\Delta G<0$ & $\Delta S>0$ (D) $\Delta G>0$ & $\Delta S>0$

12. The reaction, A $\rightarrow$ B, is **endergonic** at 25 °C and the entropy change is +40 J/K. What can be concluded about the enthalpy change for this reaction?

(A) $\Delta H > +11.9$ kJ   (B) $\Delta H < -11.9$ kJ   (C) $\Delta H > 18.4$ kJ

(D) No conclusion can be made about ΔH

13. The equilibrium constant for the reaction, 2 $N_2O_5 \rightleftharpoons$ 2 $N_2(g)$ + 5 $O_2(g)$, is 2.4x10^{41} at 25 °C. What is the approximate value of the Gibbs Free Energy of Formation of $N_2O_5(g)$?

(A) +118. kJ/mol   (B) -236. kJ/mol   (C) -118 kJ/mol

(D) Insufficient data is given to determine $\Delta G_f^0(N_2O_5)$

14. Consider the gas phase reaction, 2 NO(g) + $Cl_2(g) \rightleftharpoons$ 2 NOCl(g). The Gibbs Free Energy of Formation of NOCl(g) is $\Delta G_f^0(NOCl)$ = +66.1 kJ/mol. The value of the equilibrium constant, K, at 25 °C is approximately:

(A) 2.6x10^{-12} (B) 6.5x10^{-24} (C) 1.5x10^{23}

(D) Insufficient data is given to determine the equilibrium constant

For #15 - #16: The Enthalpy of Vaporization of $Br_2(liq)$ is 29.5 kJ/mol. The Entropy of Vaporization of $Br_2(liq)$ is 89.0 J/mol-K.

15. The Entropy change of the universe, ΔS_{univ}, when one mole of $Br_2(gas)$ condenses to $Br_2(liq)$ at 90 °C is approximately:

(A) +7.7 J/mol-K   (B) -7.7 J/mol-K   (C) +14.3 J/mol-K

(D) None of the above

16. The normal boiling point of $Br_2(liq)$ is approximately:

(A) 331 °C   (B) 83 °C   (C) 58 °C

(D) Depends upon the magnitude of ΔS_{univ}

17. For the reaction, 2 HI(g) $\rightleftharpoons$ $H_2(g)$ + $I_2(g)$, $\Delta H°$ = - 53 kJ and $\Delta S°$ = -166 J/K. This reaction is _____ favored at temperatures **above** _____ °C (Celsius).

(A) Reactant , 46 °C   (B) Product , 46 °C

(C) Reactant , 319 °C   (D) Product , 319 °C

18. For the reaction, 2 $SO_2(g)$ + $O_2(g) \rightleftharpoons$ 2 $SO_3(g)$, the equilibrium constant is K = 150. at 300 °C. What is the approximate value of ΔG for this reaction at 300 °C when $P(SO_2)$ = 0.10 bar, $P(O_2)$ = 0.50 bar, and $P(SO_3)$ = 2.5 bar?

(A) -57.8 kJ   (B) +10.1 kJ   (C) +34.0 kJ   (D) -23.9 kJ

19. In class, we discussed the thermodynamics of the formation of doubly stranded DNA by base-pairing of nucleic acids in the individual strands. Let's consider the **breaking** of one base-pair (e.g. Adenine-Thymine)in the unravelling of doubly stranded DNA. For this process, $\Delta H°$ is _____ and $\Delta S°$ is _____

(A) Negative, Negative   (B) Negative, Positive

(C) Positive, Negative   (D) Positive, Positive

20. As discussed in class, hydrophobic (non-polar) amino acid sidechains tend to reside in the interior of proteins' tertiary structure. The reason they do **not** reside on the exterior of the protein is that they would

(A) raise the entropy of the surrounding water molecules

(B) lower the entropy of the surrounding water molecules

(C) raise the enthalpy of the non-polar sidechain

(D) hydrogen bond with the surrounding water moleciules

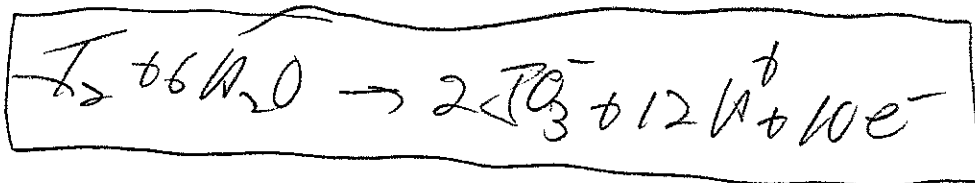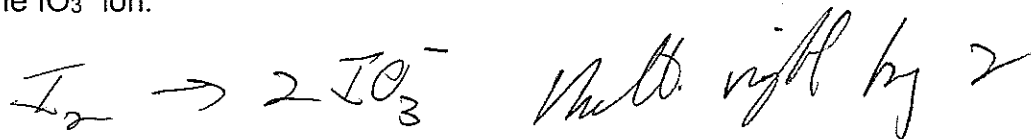21. Regarding the following reaction, which of the statements below is/are **Not correct?**
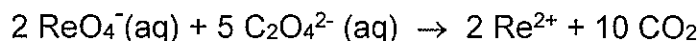
$$2\ ReO_4^-(aq) + 5\ C_2O_4^{2-}\ (aq) \rightarrow 2\ Re^{2+} + 10\ CO_2$$

(1) Re^{2+} is reduced   (2) $C_2O_4^{2-}$ is Oxidized
(3) $C_2O_4^{2-}$ is the reducing agent   (4) Five (5) electrons are transfered

(A) 4 only   (B) 2 & 3   (C) 2 & 4   (D) 1 & 4

PART II. FOUR (4) PROBLEMS : REMEMBER TO SHOW WORK FOR CREDIT

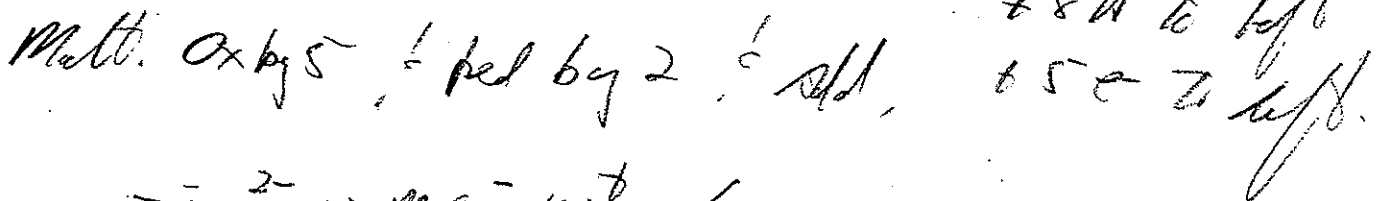**The Gas Constant is:** R = 8.31 J/mol-K = 8.31x10⁻³ kJ/mol-K
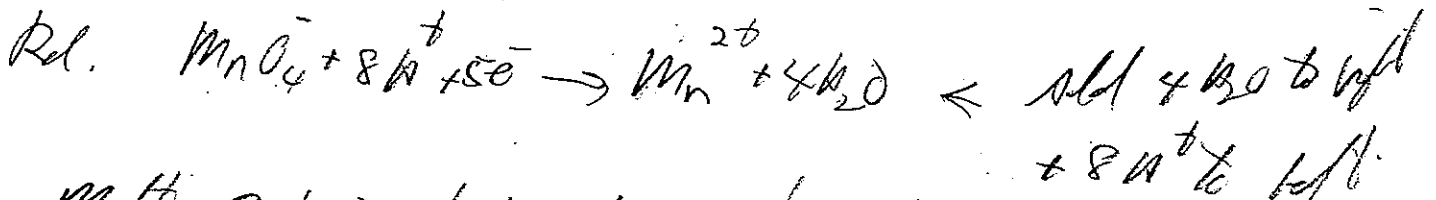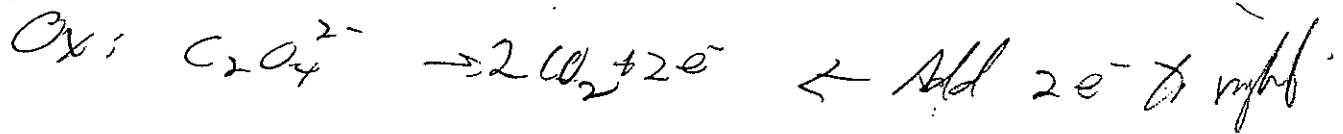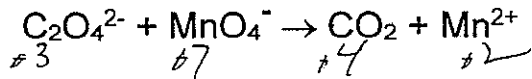
(5) 1. Write a balanced half reaction in **aqueous Acid** solution for the reaction of I_2 to form the IO_3^- ion.

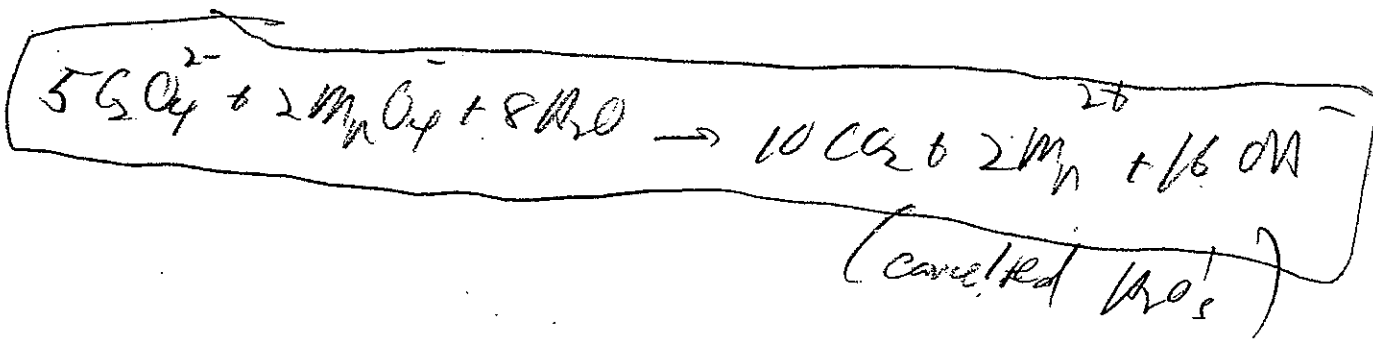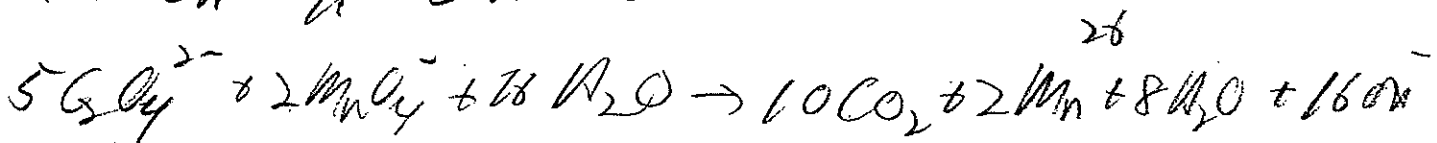$$I_2 \rightarrow 2\ IO_3^- \qquad \text{Mult. right by 2}$$

$$I_2 + 6H_2O \rightarrow 2 IO_3^- + 12 H^+ + 10 e^-$$

Add 6H₂O to left,
+ 12 H⁺ to right,
+ 10 e⁻ to right

(10) 2. Balance the following oxidation-reduction reaction in **aqueous Basic** solution.

$$C_2O_4^{2-} + MnO_4^- \rightarrow CO_2 + Mn^{2+}$$

Ox: $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ ← Add $2e^-$ to rght.

Red. $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ ← Add $4H_2O$ to rght

$+ 8H^+$ to left.

$+ 5e^-$ to left.

Mult. Ox by 5 ; Red by 2 ; Add,

$5C_2O_4^{2-} + 2MnO_4^- + 16H^+ + 10e^- \rightarrow 10CO_2 + 10e^- + 2Mn^{2+} + 8H_2O$

Add $16OH^-$ to each side

$5C_2O_4^{2-} + 2MnO_4^- + 16H_2O \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O + 16OH^-$

$5C_2O_4^{2-} + 2MnO_4^- + 8H_2O \rightarrow 10CO_2 + 2Mn^{2+} + 16OH^-$

(cancelled H_2O's)
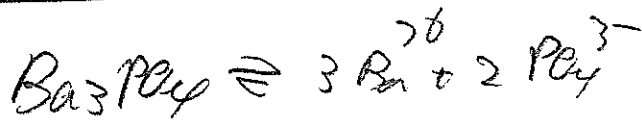
(08) 3. Barium Phosphate, $Ba_3(PO_4)_2(s)$, is a sparingly soluble salt with $K_{sp} = 3.0 \times 10^{-23}$.

6.0 L of 2.5×10^{-4} M $Ba(NO_3)_2(aq)$ is mixed with 4.0 L of 1.00×10^{-5} M $Na_3PO_4(aq)$.

Use this data to **calculate whether or not** any $Ba_3(PO_4)_2(s)$ will precipitate when the two solutions are mixed.

You **MUST** show your calculation to receive credit.

Use $C_{F_n} = C_{init} \times \dfrac{V_{init}}{V_{F_n}}$

$$[Ba^{2+}] = 2.5 \times 10^{-4}\,m \times \frac{6}{6+4} = 1.5 \times 10^{-4}\,m$$

$$[PO_4^{3-}] = 1.0 \times 10^{-5}\,m \times \frac{4}{6+4} = 4.0 \times 10^{-6}\,m$$

$$Ba_3PO_4 \rightleftharpoons 3\,Ba^{2+} + 2\,PO_4^{3-}$$

$$Q = [Ba^{2+}]^2 [PO_4^{3-}]^3$$

$$= (1.5 \times 10^{-4})^3 (4.0 \times 10^{-6})^2$$

$$Q = 5.4 \times 10^{-23} > K_{sp} \left(= 3 \times 10^{-23}\right)$$

Some **will** precipitate

Since $Q > K_{sp}$

(14) 4. Consider the gas phase equilibrium, 2 PBr_3(g) + O_2(g) $\rightleftharpoons$ 2 $POBr_3$(g). The equilibrium constant for this reaction is K = 0.04 at 200 °C.

(10) (a) If the pressures of O_2(g) and $POBr_3$(g) are both 0.65 bar, what is the pressure of PBr_3(g) if the Gibbs Free Energy change is ΔG = 7.00 kJ at 200 °C?

$$\Delta G^{\circ} = -RT \ln K = -(0.0083)(473) \ln (4.04) = 12.65 \, kJ$$

$$\Delta G = \Delta G^{\circ} + RT \ln Q \rightarrow \ln Q = \frac{\Delta G - \Delta G^{\circ}}{RT} = \frac{7.00 - 12.65}{(0.0083)(473)}$$

$$= -1.437 \rightarrow Q = e^{-1.437} = 0.237$$

$$Q = 0.237 = \frac{P^2_{POBr_3}}{P^2_{PBr_3} P_{O_2}} = \frac{(0.65)^2}{P^2_{PBr_3}(0.65)} = \frac{0.65}{P^2_{PBr_3}}$$

$$P^2_{PBr_3} = \frac{0.65}{0.237} = 2.74$$

$$P_{PBr_3} = \sqrt{2.74} = \boxed{1.66 \, bar}$$

(4) (b) What is the value of K for the related reaction, $POBr_3$(g) $\rightleftharpoons$ PBr_3(g) + ½ O_2g)

We have reversed & halved the reaction

so $K' = \frac{1}{K^{\frac{1}{2}}} = \frac{1}{(0.04)^{\frac{1}{2}}} = \boxed{5.0}$