CHEM 142 - Exam 2 Version A

!!! DO NOT OPEN THIS EXAM BOOK UNTIL TOLD TO DO SO BY THE INSTRUCTOR !!!

Instructor: Dr. Kari Pederson

Date: Friday, August 5

Time: 9:40-10:40am

Location: BAG 154

NO GRAPHING CALCULATORS ALLOWED

ONLY CALCULATORS MAY BE USED AS CALCULATORS
(you may not use your *cellular phone* as a calculator)

NO HEADPHONES ALLOWED (EARPLUGS ARE OK)

NO HATS WITH BRIMS ALLOWED

!!! PLEASE READ THIS !!!

Indicate *all* of the following on your scantron form or ***five points*** will be deducted from your exam score:

First Name, Last Name, Student Number, Section, Exam Version

YOUR FULL NAME: ____________________ ____________________
first name *last name*

YOUR SECTION/SEAT: ____________________ ____________________
discussion section *seat number*

Question	Points Possible	Score
1-8	24	
9-16	40	
17-24	16	
25	20	
Scantron Info?	-5	
TOTAL	**100**	

MULTIPLE CHOICE: CONCEPTS. 8 @ 3 pts each → **24 POINTS TOTAL**
Please mark the *one* correct answer for each of the following questions on your scantron.

1. Which of the following statements is(are) false?
   Oxidation and reduction
   I. accompany all chemical changes.
   II. result in a change in the oxidation states of the species involved.
   III. describe the loss and gain of electron(s), respectively.
   IV. cannot occur independently of each other.

   A) I only
   B) II only
   C) III only
   D) IV only
   E) II, III, and IV

2. In which of the following compounds does nitrogen have the most positive oxidation state?
   A) NH_4Cl **N: -3**
   B) HNO_3 **N: +5**
   C) N_2O **N: +1**
   D) $NaNO_2$ **N: +3**
   E) NO_2 **N: +4**

3. A rigid container contains 10.0 g of chlorine gas. With the temperature kept constant, 10.0 g of oxygen gas is added. What happens?
   A) The pressure in the container doubles.
   B) The pressure in the container increases by less than a factor of 2.
   C) The pressure in the container increases by more than a factor of 2.
   D) The pressure stays the same size, but the volume increases.
   E) The pressure decreases by a factor of 2.

$P \propto n$ → **10.0g O_2 more moles than 10.0g Cl_2 means total number of moles will increase by more than a factor of two, therefore total pressure will increase by more than a factor of two.**

4. Under which of the following conditions does a gas behave most ideally?
   A) STP
   B) P = 0.50 atm, T = 0.0°C
   C) P = 0.50 atm, T = 100.0°C
   D) P = 1.0 atm, T = 100.0°C
   E) P = 2.0 atm, T = -100.0°C

5. Consider three 1 L flasks at the same temperature and pressure. Flask A contains CO gas, flask B contains N_2 gas, and flask C contains O_2 gas. In which flask do the molecules have the greatest kinetic energy?
   A) flask A
   B) flask B
   C) flask C
   D) The molecules in two of the flasks have the same kinetic energy.
   E) The molecules in all of the flasks have the same kinetic energy.

6. Four identical 1.0 L flasks contain the gases Ne, CH_4, N_2, and F_2, each at 0°C and 1 atm pressure. For which gas do the molecules have the lowest root mean square velocity (u_{rms})?
   A) Ne
   B) CH_4
   C) N_2
   D) F_2
   E) The molecules of all the gases have the same root mean square velocity.

$u_{rms} \propto \frac{1}{MM}$ → **Highest MM corresponds to lowest u_{rms}**

7. Consider the reaction C (*s*) + H_2O (*g*) $\rightleftharpoons$ CO (*g*) + H_2 (*g*) at T = 900 K, where it is exothermic with equilibrium constant K = 0.64. With the system at equilibrium, more H_2(*g*) is added. This will result in ___________.
   A) an increase in K_p.
   B) a decrease in K_p.
   C) a shift in the equilibrium position to the right (products).
   D) a shift in the equilibrium position to the left (reactants).
   E) none of these

8. The K for the reaction, NH_4^+ (*aq*) + H_2O (*l*) $\rightleftharpoons$ H_3O^+ (*aq*) + NH_3 (*aq*), is called
   A) K_b for NH_4^+
   B) K_b for NH_3
   C) K_a for NH_4^+
   D) K_a for NH_3
   E) none of the above

MULTIPLE CHOICE: SHORT CALCULATIONS. 8 @ 5 pts each → **40 TOTAL POINTS**
Please mark the *one* correct answer for each of the following questions on your scantron.

9. A student weighs out 0.568 g of KHP (molar mass = 204 g/mol) and titrates to the equivalence point with 36.78 mL of a stock NaOH solution. What is the concentration of the stock NaOH solution? KHP is an acid with one acidic proton.
   A) 0.100 M
   B) 3.15 M
   C) 0.115 M
   D) 0.0757 M
   E) none of these

$$0.568g\ KHP \times \frac{1mol\ KHP}{204g\ KHP} = 2.78 \times 10^{-3} mol\ KHP$$

$$2.78 \times 10^{-3} mol\ KHP \times \frac{1mol\ NaOH}{1mol\ KHP} = 2.78 \times 10^{-3} mol\ NaOH$$

$$\frac{2.78 \times 10^{-3} mol\ NaOH}{0.03678L} = 0.0757M\ NaOH$$

10. A balloon is inflated with helium to a volume of 4.5 L at 37°C. If you take the balloon outside on a cold day and the volume decreases to 4.0 L, what is the temperature outside?
   A) 276 K
   B) 306 K
   C) 283 K
   D) 349 K
   E) none of the above

$$\frac{T_1}{V_1} = \frac{T_2}{V_2} \rightarrow T_2 = \frac{T_1}{V_1} \times V_2 = \frac{310K}{4.5L} \times 4.0L = 276K$$

11. A piece of sodium metal undergoes complete reaction with water as follows:

$$2Na\ (s) + 2H_2O\ (l) \rightarrow 2NaOH\ (aq) + H_2\ (g)$$

The hydrogen gas generated is collected over water at 25°C. The volume of gas is 216 mL measured at 1.00 atm. How many grams of sodium reacted? (The vapor pressure of water at 25°C is 0.0313 atm.)

A) 0.393 g
B) 0.197 g
C) 0.203 g
D) 0.406 g
E) 3.96 g

$$P_{H_2} = P_{total} - P_{H_2O} = 1.00atm - 0.0313atm = 0.9687atm$$

$$PV = nRT \rightarrow n = \frac{PV}{RT} = \frac{0.9687atm \cdot 0.216L}{0.08206\frac{L \cdot atm}{mol \cdot K} \cdot 298K} = 8.56 \times 10^{-3} mol\ H_2$$

$$8.56 \times 10^{-3} mol\ H_2 \times \frac{2mol\ Na}{1mol\ H_2} = 1.71 \times 10^{-2} mol\ Na$$

$$1.71 \times 10^{-2} mol\ Na \times \frac{22.98977g\ Na}{1mol\ Na} = 0.393g\ Na$$

12. The diffusion rate of H_2 gas is 4.47 times as great as that of a certain noble gas (both gases are at the same temperature). What is the noble gas?

A) He
B) Ne
C) Ar
D) Kr
E) Xe

$$\frac{rate_1}{rate_2} = \frac{\sqrt{MM_2}}{\sqrt{MM_1}} \rightarrow MM_2 = \left(\frac{rate_1}{rate_2} \times \sqrt{MM_1}\right)^2 = \left(4.47 \times \sqrt{2}\right)^2 = 39.9\,g/mol \rightarrow Ar$$

13. What is the molar mass of a gas that has a density of 5.75 g/L at STP?

A) 3.90 g/mol
B) 129 g/mol
C) 176 g/mol
D) 1.91 x 10^4 g/mol
E) none of the above

$$PV = \frac{m}{MM}RT \rightarrow MM = \frac{m}{V} \times \frac{RT}{P} = \left(5.75\,g/L\right)\frac{\left(0.08206\frac{L \cdot atm}{mol \cdot K}\right)273K}{1atm} = 129\,g/mol$$

14. The equilibrium constant for $2SO_2\ (g) + O_2\ (g) \rightleftharpoons 2SO_3\ (g)$ is 0.76 at 900 K. What is the equilibrium constant for the reaction $SO_3\ (g) \rightleftharpoons SO_2\ (g) + \frac{1}{2}\ O_2\ (g)$ at the same temperature?
    A) -0.76
    B) 2.6
    C) -0.38
    D) 1.1
    E) -0.87

$K' = K^{-1/2} = (0.76)^{-1/2} = 1.1$

15. For the reaction $2SO_2\ (g) + O_2\ (g) \rightleftharpoons 2SO_3\ (g)$, $K_c = 0.25$ at 25°C. An equilibrium mixture is found to contain $[SO_2]=[SO_3]=0.20$ M. What is the concentration of $O_2\ (g)$ in the flask?
    A) 4.00 M
    B) 1.25 M
    C) 2.00 M
    D) 0.25 M
    E) none of the above

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} \rightarrow [O_2] = \frac{[SO_3]^2}{[SO_2]^2 K_c} = \frac{0.2^2}{0.2^2 \cdot 0.25} = 4.00M$$

16. A sample of HNO_3 is found to have a pH of 4.40. This solution is __________.
    A) acidic with $[HNO_3]=4.0 \times 10^{-5}$ M and pOH=9.60
    B) acidic with $[HNO_3]=2.5 \times 10^{-4}$ M and pOH=4.40
    C) basic with $[HNO_3]=4.0 \times 10^{-5}$ M and pOH=9.60
    D) basic with $[HNO_3]=2.5 \times 10^{-4}$ M and pOH=4.40
    E) acidic with $[HNO_3]=2.5 \times 10^{-4}$ M and pOH=9.60

pH < 7 → acidic

$pOH = 14.00 - 4.40 = 9.60$

$[H^+] = 10^{-4.40} = 4.0 \times 10^{-5} M\ H^+$

$$4.0 \times 10^{-5} M\ H^+ \times \frac{1 mol\ HNO_3}{1 mol\ H^+} = 4.0 \times 10^{-5} M\ HNO_3$$

MATCHING. 8 @ 2 pts each → **16 POINTS TOTAL**
Please indicate the letter of the *one* best answer for each of the following questions in the blank. Each answer is used no more than *once*.

17. Chemical equilibrium is microscopically_____A_______.

18. The following reaction represents a _____C_________ equilibria.
    $CaCO_3\ (s) \rightleftharpoons CaO\ (s) + CO_2\ (g)$

19. The following is an example of a ________S__________ reaction.
    $Pb(NO_3)_2\ (aq) + Na_2SO_4\ (aq) \rightleftharpoons PbSO_4\ (s) + 2\ NaNO_3\ (aq)$

20. Heating magnesium hydroxide produces magnesium oxide and water.
    $Mg(OH)_2\ (s) \rightleftharpoons MgO\ (s) + H_2O\ (l)$
    This would be classified as a ________K________ reaction.

21. For the following reaction, K_c is _____I______ K_p.
    $N_2\ (g) + O_2\ (g) \rightleftharpoons 2\ NO\ (g)$

22. For a certain reaction at 25.0°C, the value of *K* is 1.2×10^{-3}. At 50.0°C the value of *K* is 3.4×10^{-1}. This means that the reaction is _____B______.

23. $HClO_4$ is best classified as a ______M________.

24. $H_2PO_4^-$ is the ______Q_________ of HPO_4^{2-}.

A) dynamic	B) endothermic	C) heterogeneous	D) greater than
E) static	F) exothermic	G) homogeneous	H) less than
I) equal to	J) combination	K) decompostion	L) neutralization
M) strong acid	N) weak acid	O) strong base	P) weak base
Q) conjugate acid	R) conjugate base	S) double replacement	
T) single replacement	U) combustion		

LONG ANSWER. 20 POINTS TOTAL

25. The following reaction occurs in acidic solution:

$$VO_2^+ (aq) + Fe^{2+} (aq) \rightleftharpoons VO^{2+} (aq) + Fe^{3+} (aq)$$

A) What is the balanced equation for this reaction? **(6 pts)**

oxidation: $Fe^{2+} (aq) \rightleftharpoons Fe^{3+} (aq)$
reduction: $VO_2^+ (aq) \rightleftharpoons VO^{2+} (aq)$

balance everything but O and H
oxidation: $Fe^{2+} (aq) \rightleftharpoons Fe^{3+} (aq)$
reduction: $VO_2^+ (aq) \rightleftharpoons VO^{2+} (aq)$
balance O with H_2O
oxidation: $Fe^{2+} (aq) \rightleftharpoons Fe^{3+} (aq)$
reduction: $VO_2^+ (aq) \rightleftharpoons VO^{2+} (aq) + H_2O (l)$
balance H with H^+
oxidation: $Fe^{2+} (aq) \rightleftharpoons Fe^{3+} (aq)$
reduction: $VO_2^+ (aq) + \mathbf{2}H^+ (aq) \rightleftharpoons VO^{2+} (aq) + H_2O (l)$
balance charges with e^-
oxidation: $Fe^{2+} (aq) \rightleftharpoons Fe^{3+} (aq) + e^-$
reduction: $VO_2^+ (aq) + \mathbf{2}H^+ (aq) + e^- \rightleftharpoons VO^{2+} (aq) + H_2O (l)$

Equalize electron transfer
oxidation: $Fe^{2+} (aq) \rightleftharpoons Fe^{3+} (aq) + e^-$
reduction: $VO_2^+ (aq) + \mathbf{2}H^+ (aq) + e^- \rightleftharpoons VO^{2+} (aq) + H_2O (l)$

Balanced: $Fe^{2+} (aq) + VO_2^+ (aq) + \mathbf{2}H^+ (aq) \rightleftharpoons Fe^{3+} (aq) + VO^{2+} (aq) + H_2O (l)$

Please use your answer from part A for the calculations in parts B-C. If you are unable to write a balanced equation, use the following balanced chemical reaction for the remainder of the problem:

$MnO_2 (s) + \mathbf{2}Ag^+ (aq) + \mathbf{4}H^+ (aq) \rightarrow Mn^{2+} (aq) + \mathbf{2}Ag^{2+} (aq) + \mathbf{2}H_2O (l)$

B) What is the equilibrium constant expression, K_c, for your balanced reaction? **(2 pts)**

$$K_c = \frac{\left[Fe^{3+}\right]\left[VO^{2+}\right]}{\left[Fe^{2+}\right]\left[VO_2^+\right]\left[H^+\right]^2} \quad \textbf{OR} \quad K_c = \frac{\left[Ag^{2+}\right]^2\left[Mn^{2+}\right]}{\left[Ag^+\right]^2\left[H^+\right]^4}$$

C) A laboratory chemist mixes 1.0 mol of each aqueous and gaseous product or reactant in a rigid 2.0 L container. After the reaction reaches equilibrium, 1.25 mol of the Fe^{3+} (or Ag^{2+}) is observed.

i) When the system has reached equilibrium, what are the concentrations of all aqueous and gaseous reactants and products? **(10 pts)**

	$[Fe^{2+}]$	$[VO_2^+]$	$[H^+]$	$[Fe^{3+}]$	$[VO^{2+}]$
Initial	0.5	0.5	0.5	0.5	0.5
Change	-x	-x	-2x	+x	+x
Equilibrium	0.5-x	0.5-x	0.5-2x	0.5+x	0.5+x

At equilibrium, $\left[Fe^{3+}\right]=\dfrac{1.25mol}{2.0L}=0.625M$ $\quad 0.5+x=0.625\rightarrow x=0.125M$

$\left[Fe^{2+}\right]=0.375M$, $\left[VO_2^+\right]=0.375M$, $\left[H^+\right]=0.25M$, $\left[Fe^{3+}\right]=0.625M$, $\left[VO^{2+}\right]=0.625M$

OR

	$[Ag^+]$	$[H^+]$	$[Mn^{2+}]$	$[Ag^{2+}]$
Initial	0.5	0.5	0.5	0.5
Change	-2x	-4x	+x	+2x
Equilibrium	0.5-2x	0.5-4x	0.5+x	0.5+2x

At equilibrium, $\left[Ag^{2+}\right]=\dfrac{1.25mol}{2.0L}=0.625M$ $\quad 0.5+2x=0.625\rightarrow x=0.0625M$

$\left[Ag^+\right]=0.375M$, $\left[H^+\right]=0.25M$, $\left[Mn^{2+}\right]=0.5625M$, $\left[Ag^{2+}\right]=0.625M$

ii) What is the value of K_c? **(2 pts)**

$$K_c=\frac{\left[Fe^{3+}\right]^2\left[VO^{2+}\right]}{\left[Fe^{2+}\right]^2\left[VO_2^+\right]\left[H^+\right]^2}=\frac{(0.625M)(0.625M)}{(0.375M)(0.375M)(0.25M)^2}=44.4M^{-2}$$

OR

$$K_c=\frac{\left[Ag^{2+}\right]^2\left[Mn^{2+}\right]}{\left[Ag^+\right]^2\left[H^+\right]^4}=\frac{(0.625M)^2(0.5625M)}{(0.375M)^2(0.25M)^4}=400$$