CHEM 1515.001
Exam III
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April 12, 2001

Name ________________________

TA's Name ________________________

Lab Section _______

INSTRUCTIONS:

1. This examination consists of a total of 7 different pages. The last two pages include a periodic table, some useful mathematical equations and a solubility table. All work should be done in this booklet.
2. PRINT your name, TA's name and your lab section number now in the space at the top of this sheet. DO NOT SEPARATE THESE PAGES.
3. Answer all questions that you can and whenever called for show your work clearly. Your method of solving problems should pattern the approach used in lecture. You do not have to show your work for the multiple choice or short answer questions.
4. No credit will be awarded if your work is not shown in problems 4a, 4c, 4d, 5, 7 and 8.
5. Point values are shown next to the problem number.
6. Budget your time for each of the questions. Some problems may have a low point value yet be very challenging. If you do not recognize the solution to a question quickly, skip it, and return to the question after completing the easier problems.
7. Look through the exam before beginning; plan your work; then begin.
8. Relax and do well.

	Page 2	Page 3	Page 4	Page 5	TOTAL
SCORES	____ (29)	____ (27)	____ (18)	____ (26)	____ (100)

(9) 1. Write the chemical formula(s) of the product(s) and balance the following reactions. Identify all products phases as either (g)as, (l)iquid, (s)olid or (aq)ueous. Soluble ionic compounds should be written in the form of their component ions.

a) $H_2SO_4(aq)$ + **2**$KOH(aq)$ → $\mathbf{2H_2O}$***(l)*** + $\mathbf{2K^+}$***(aq)*** + $\mathbf{SO_4^{2-}}$***(aq)***

b) **3**$Na_2S(aq)$ + **2**$Al(NO_3)_3(aq)$ → $\mathbf{Al_2S_3}$***(s)*** + $\mathbf{6Na^+}$***(aq)*** + $\mathbf{6NO_3^-}$***(aq)***

c) $Fe(NO_3)_3(aq)$ + $KSCN(aq)$ → $\mathbf{FeSCN^{2+}}$***(aq)*** + $\mathbf{3NO_3^-}$***(aq)*** + $\mathbf{K^+}$***(aq)***

(4) 2. Write the ionic and net ionic chemical equations for 1a).

1a)

Ionic equation:

$\mathbf{2H^+}$***(aq)*** + $\mathbf{SO_4^{2-}}$***(aq)*** + $\mathbf{2K^+}$***(aq)*** + $\mathbf{2OH^-}$***(aq)*** → $\mathbf{2H_2O}$***(l)*** + $\mathbf{2K^+}$***(aq)*** + $\mathbf{2SO_4^{2-}}$***(aq)***

Net Ionic equation:

$\mathbf{2H^+}$***(aq)*** + $\cancel{\mathbf{SO_4^{2-}}(aq)}$ + $\cancel{\mathbf{2K^+}(aq)}$ + $\mathbf{2OH^-}$***(aq)*** → $\mathbf{2H_2O}$***(l)*** + $\cancel{\mathbf{2K^+}(aq)}$ + $\cancel{\mathbf{SO_4^{2-}}(aq)}$

$\mathbf{2H^+}$***(aq)*** + $\mathbf{2OH^-}$***(aq)*** → $\mathbf{2H_2O}$***(l)***

(16) 3. For the reaction

$$2N_2O(g) \rightarrow 2N_2(g) + O_2(g)$$

The following data was collected;

$[N_2O]$	Time (s)
0.250 M	0
0.218 M	60
0.204 M	90
0.190 M	120
0.166 M	180

Briefly, explain how you would determine whether the reaction is first or second order with respect to N_2O. Also explain how to determine the rate constant for the reaction. (Note: Just explain what to do, calculations are not required.)

Plot the data ln[N_2O] versus time. If the plot is a straight line with a negative slope the reaction is first order. The slope of the line is equal to –k (rate constant for the reaction).

Plot the data $[N_2O]^{-1}$ versus time. If the plot is a straight line with a positive slope the reaction is second order. The slope of the line is equal to k (rate constant for the reaction).

(33) 4. The following data was collected at a specific temperature for the reaction

$$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g);$$

Experiment	[NO]	[Cl_2]	Initial Rate (M s^{-1})
1	0.115 M	0.263 M	6.74×10^{-2}
2	0.200 M	0.264 M	1.17×10^{-1}
3	0.065 M	0.389 M	5.63×10^{-2}

a) Determine the order of the reaction with respect to NO and Cl_2. (Show your work clearly) (8)

Experiments 1 and 2:

$$\frac{rate_2}{rate_1} = \frac{k_2[NO]_2^m[Cl_2]_2^n}{k_1[NO]_1^m[Cl_2]_1^n}$$

$$\frac{1.17 \times 10^{-1}}{6.74 \times 10^{-2}} = \frac{\cancel{k_2}[NO]_2^m\cancel{[Cl_2]_2^n}}{\cancel{k_1}[NO]_1^m\cancel{[Cl_2]_1^n}} = \left(\frac{0.200\ M}{0.115\ M}\right)^m$$

$$1.73 = (1.73)^m$$

$$m = 1$$

Experiments 2 and 3:

$$\frac{rate_2}{rate_3} = \frac{k_2[NO]_2^1\ [Cl_2]_2^n}{k_3[NO]_3^1\ [Cl_2]_3^n}$$

$$\frac{1.17 \times 10^{-1}}{5.63 \times 10^{-2}} = \frac{\cancel{k_2}[NO]_2^1\ [Cl_2]_2^n}{\cancel{k_3}[NO]_2^1\ [Cl_2]_3^n}) = \left(\frac{0.200\ M}{0.065\ M}\right)^1\left(\frac{0.264\ M}{0.389\ M}\right)^n$$

$$2.08 = 3.08^1\ (0.679)^n$$

$$0.675 = (0.679)^n$$

$$n = 1$$

b) Write the differential rate law for this reaction. (4)

$$rate = k[NO]^1[Cl_2]^1$$

c) What is the magnitude and the units of the rate constant? (6)

$$6.74 \times 10^{-2}\ M\ s^{-1} = k[0.115\ M]^1[0.263\ M]^1$$

$$k = \frac{6.74 \times 10^{-2}\ M\ s^{-1}}{[0.115\ M]^1[0.263\ M]^1} = 2.23\ M^{-1}\cdot s^{-1}$$

d) The initial rate listed in the table is in terms of the disappearance of Cl_2. For Experiment 1 calculate the initial rate of appearance of NOCl. (3)

$$Rate = \frac{-\Delta[Cl_2]}{\Delta t} = \frac{1}{2}\frac{\Delta[NOCl]}{\Delta t}$$

$$6.74 \times 10^{-2}\ M\ s^{-1} = \frac{-\Delta[Cl_2]}{\Delta t} = \frac{1}{2}\frac{\Delta[NOCl]}{\Delta t}$$

$$6.74 \times 10^{-2}\ M\ s^{-1} = \frac{1}{2}\frac{\Delta[NOCl]}{\Delta t}$$

$$1.35 \times 10^{-1}\ M\ s^{-1} = \frac{\Delta[NOCl]}{\Delta t}$$ **(rate of the reaction with respect to NOCl)**

e) Suggest a 2-step mechanism that is supported by the rate law you determined. (6)

slow	**Step 1**	$NO(g) + Cl_2(g) \rightarrow NOCl(g) + Cl(g)$
fast	**Step 2**	$NO(g) + Cl(g) \rightarrow NOCl(g)$

4. (CONTINUED)

f) List two factors that are important for collisions between reactant molecules to be effective. Briefly, explain why all collisions between reactant molecules do not lead to a chemical reaction. (6)

Effective collisions depend on the proper orientation of the colliding molecules and on the energy of the colliding molecules. If the orientation is not optimal, or the colliding molecules do not have sufficient energy (energy that exceeds the activation energy, E_a) the collision will not be effective.

(12) 5. The following reaction,

$$3H_2(g) \quad + \quad N_2(g) \quad ä \quad 2NH_3(g)$$

occurs at 700 K. Initially 0.30 mol of H_2 and 0.50 mol of N_2 are added to 1.00 L container, at equilibrium the concentration of H_2 was found to be 0.21 M. Calculate K_c for the reaction.

	$3H_2(g)$	+	$N_2(g)$	ä	$2NH_3(g)$
Initial	**0.30 M**		**0.50 M**		**0**
Change	**–3x**		**–x**		**+2x**
Equilibrium	**.30 – 3x**		**.50 – x**		**+2x**

$$K_c = \frac{[NH_3]^2}{[H_2]^3[N_2]^1}$$

At equilibrium

$[H_2]_{eq}$ = 0.21 M = 0.30 – 3x   x = 0.030 M

$[N_2]_{eq}$ =0.50 – x = 0.05 – 0.030 = 0.47 M

$[NH_3]_{eq}$ =2x = 2(0.030) = 0.060 M

$$K_c = \frac{[NH_3]^2}{[H_2]^3[N_2]^1} = \frac{[0.060]^2}{[0.21]^3[0.47]^1} = 0.827$$

(8) 6. For the following equation

$$2NO(g) \quad + \quad Br_2(g) \quad \text{ä} \quad 2NOBr(g)$$

K_c at 25 ˚C is 5.25 and $\Delta H^\circ = -160$ kJ. If the reaction is at equilibrium in a 10.0 L container and subjected to each of the following changes, predict whether the concentration of NOBr will increase, decrease or remain the same.

a) remove NO? **NOBr will decrease**

b) change the volume of the container to 5.0 L? **NOBr will increase**

c) change the temperature from 25 ˚C to 50 ˚C? **NOBr will decrease**

d) add a catalyst? **NOBr will not change**

(6) 7. K_p for the reaction

$$PCl_5(g) \quad \text{ä} \quad PCl_3(g) + Cl_2(g)$$

is 1.42 at a certain temperature. A mixture is prepared by adding 0.345 mol of PCl_5, 1.04 mol of PCl_3 and 0.453 mol of Cl_2 to a 5.00 L container. Which direction will the reaction proceed to establish equilibrium? Show your work.

$$\mathbf{Q = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{[0.208][0.0906]}{[0.069]} = 0.273}$$

$Q < K_c$ To get $Q = K_c$ the numerator must be increased and the denominator must be decreased. This translates to increasing the products and decreasing the reactant. The reaction must go from left to right to move Q towards K_c.

(12) 8. NO is produced in the internal combustion engine from the following reaction;

$$N_2(g) \quad + \quad O_2(g) \quad \text{ä} \quad 2NO(g)$$

$K_c = 1.7 \times 10^{-3}$ at 2300 K. If the initial concentration of N_2 and O_2 are the same and equal to 1.10 M, calculate the equilibrium concentration of all species.

	$N_2(g)$	**+**	**$O_2(g)$**	**ä**	**$2NO(g)$**
Initial	**1.10 M**		**1.10 M**		**0**
Change	**–x**		**–x**		**+2x**
Equilibrium	**1.1 – x**		**1.1 – x**		**+2x**

$$\mathbf{K_c = 1.7 \times 10^{-3} = \frac{[NO]^2}{[N_2]^1[O_2]^1} = \frac{[2x]^2}{[1.1 - x]^1[1.1 - x]^1} = \frac{[2x]^2}{[1.1 - x]^2}}$$

Now take the square root of both sides,

$$\mathbf{4.12 \times 10^{-2} = \frac{[2x]}{[1.1 - x]}}$$

$$\mathbf{4.12 \times 10^{-2} - 4.12 \times 10^{-2}x = 2x}$$

$$\mathbf{4.12 \times 10^{-2} = 2.041x}$$

$$\mathbf{2.22 \times 10^{-2}\ M = x}$$

$$\mathbf{[N_2]_{eq} = [N_2]_{eq} = 1.10\ M - x = 1.10\ M - 0.0222\ M = 1.08\ M}$$

$$\mathbf{[NO]_{eq} = 2x = 2(0.0222\ M) = 0.044\ M}$$

Periodic Table of the Elements

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1 **H** 1.008																	2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
6	55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.8	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** 226.0	89 **Ac** 227.0	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)									

Lanthanides	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.2	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
Actinides	90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237.0	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Useful Information

$$\ln\left(\frac{k_1}{k_2}\right) = \frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \qquad R = 8.314\ \frac{J}{K\cdot mol}$$

$$\ln\left(\frac{[A]_t}{[A]_o}\right) = -kt \qquad \frac{1}{[A]_t} - \frac{1}{[A]_o} = kt$$

$$K_p = K_c(RT)^{\Delta n} \qquad R = 0.0821\ \frac{L\cdot atm}{mole\cdot K}$$

$$\ln\left(\frac{K_1}{K_2}\right) = \frac{\Delta H^\circ_{rxn}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$x_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad \text{for } ax^2 + bx + c = 0$$

6.023×10^{23}

Solubility Table

Ion	Solubility	Exceptions
NO_3^-	soluble	none
ClO_4^-	soluble	none
Cl^-	soluble	except Ag^+, Hg_2^{2+}, *Pb^{2+}
I^-	soluble	except Ag^+, Hg_2^{2+}, Pb^{2+}
SO_4^{2-}	soluble	except Ca^{2+}, Ba^{2+}, Sr^{2+}, Hg^{2+}, Pb^{2+}, Ag^+
CO_3^{2-}	insoluble	except Group IA and NH_4^+
PO_4^{3-}	insoluble	except Group IA and NH_4^+
^-OH	insoluble	except Group IA, *Ca^{2+}, Ba^{2+}, Sr^{2+}
S^{2-}	insoluble	except Group IA, IIA and NH_4^+
Na^+	soluble	none
NH_4^+	soluble	none
K^+	soluble	none

*slightly soluble

(14) 5. Molecules of butadiene, C_4H_6, are known to "dimerize" according to the equation

$$2C_4H_6(g) \rightarrow C_8H_{12}(g)$$

This dimerization reaction is second order and the rate constant has a value of 0.0140 $M^{-1}\cdot s^{-1}$ at 500 ˚C.

a) Calculate the concentration of C_4H_6 after 45.0 seconds if the initial concentration of C_4H_6 is 0.0250 M.

b) Calculate the half-life for the reaction when the initial concentration of C_4H_6 is 0.0250 M.