CHEM 1515.001
Exam III
John III. Gelder
November 7, 2001

Name ____________________

TA's Name ____________________

Lab Section _______

INSTRUCTIONS:

1. This examination consists of a total of 9 different pages. The last three pages include a periodic table, some useful mathematical equations, a solubility table and a table of equilibrium constants. 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 3, 5, 6b and 7.

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	Page 6	TOTAL
SCORES	______ (23)	______ (20)	______ (30)	______ (9)	______ (16)	______ (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) $HI(aq) + RbOH(aq) \rightarrow$ $\mathbf{H_2O(l) + Rb^+(aq) + I^-(aq)}$

b) $\mathbf{3}Na_2S(aq) + \mathbf{2}Fe(NO_3)_3(aq) \rightarrow$ $\mathbf{Fe_2S_3(s) + 6Na^+(aq) + 6NO_3^-(aq)}$

c) $C_6H_5NH_2(aq) + HCN(aq) \rightarrow$ $\mathbf{C_6H_5NH_3^+(aq) + CN^-(aq)}$

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

1a)

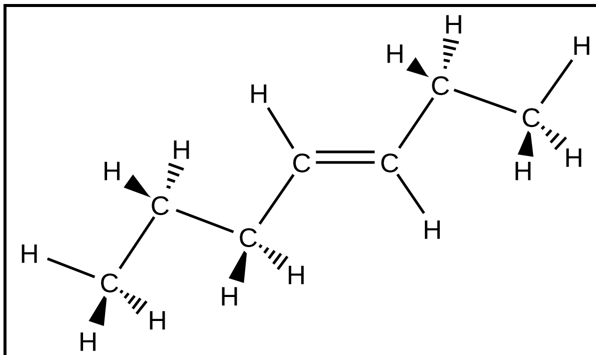
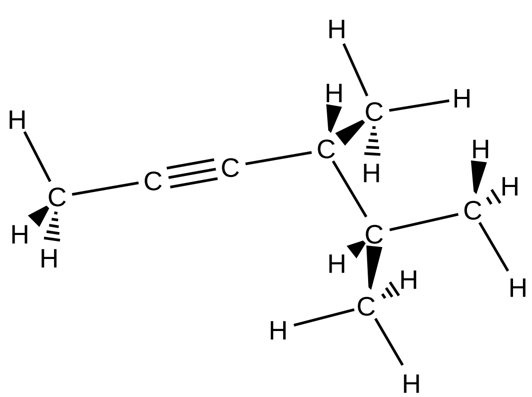
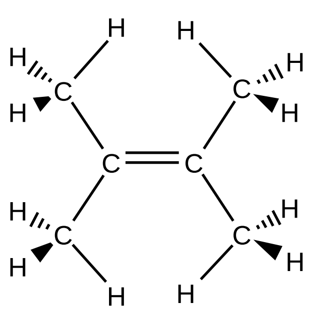
Ionic equation:

$\mathbf{H^+(aq) + I^-(aq) + Rb^+(aq) + OH^-(aq) \rightarrow H_2O(l) + Rb^+(aq) + I^-(aq)}$

Net Ionic equation:

$\mathbf{H^+(aq) + OH^-(aq) \rightarrow H_2O(l)}$

(6) 3. Give the name or draw the Lewis structure for each of the following compounds.

 **trans-3-heptene**	4,5-dimethyl-2-hexyne 
2,3-dimethyl-2-butene 	

(20) 4. When $H_2(g)$ is mixed with $CO_2(g)$ at 2000 K, the equilibrium is achieved according to the equation below,

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

In one experiment, the following equilibrium concentrations were measured;

$$[H_2] = 0.150\ M$$
$$[CO_2] = 0.400\ M$$
$$[H_2O] = [CO] = 0.550\ M$$

a) Calculate the value of K_c, the equilibrium constant for the reaction.

$$\mathbf{K_c = \frac{[H_2O][CO]}{[H_2][CO_2]} = \frac{[0.550][0.550]}{[0.150][0.400]} = 5.04}$$

b) In a different experiment, 0.75 mol $H_2(g)$ is mixed with 0.75 mol of $CO_2(g)$ in a 3.00 liter reaction vessel at 2000 K. Calculate the equilibrium concentrations, in moles per liter of all species at this temperature.

$$\mathbf{\frac{0.75\ mol}{3.0\ L} = 0.25\ M}$$

	CO_2	+	H_2	⇄	H_2O	+	CO	
initial	**0.25 M**		**0.25 M**		**0**		**0**	**x = $[H_2O]_{(reacting)}$**
change	**-x**		**-x**		**+x**		**+x**	
final	**0.25 - x**		**0.25 - x**		**0 + x**		**0 + x**	

$$\mathbf{K_c = \frac{[H_2O][CO]}{[H_2][CO_2]} = 5.04}$$

$$\mathbf{5.04 = \frac{x^2}{(0.25 - x)^2}}$$

taking the square root of both sides

$$\mathbf{2.24 = \frac{x}{0.25 - x}}$$

solving for x

$$\mathbf{x = 0.173\ M}$$

($[H_2O] = [CO] = x = 0.173$ M

$[H_2] = [CO_2] = 0.25 - 0.173$ M $= 0.077$ M

(30) 5. Calculate the pH for each of the following solution;

a) 0.00360 M $Ba(OH)_2$

	$Ba(OH)_2$	$\rightarrow$	Ba^{2+}	+	$2OH^-$
I	0.0036		0		~0
F	0		.0036		.0072

NaOH is a strong base and completely dissociates in water. Therefore,

$[OH^-]$ = 0.0072 M and pOH = 2.14, pH = 11.86

b) 0.750 M $HC_3H_5O_2$ (propionic acid)

	$HC_3H_5O_2$	$\rightleftarrows$	H^+	+	$C_3H_5O_2^-$	
I	.750		~0		0	
C	-x		+x		+x	$x = [H\ C_3H_5O_2]_D$
E	.750 – x		x		x	

$$K_a = \frac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]} = 1.3 \times 10^{-5}$$

$$1.3 \times 10^{-5} = \frac{(x)(x)}{(0.750 - x)}$$

Assume 0.750 – x = 0.750

$$1.3 \times 10^{-5} = \frac{x^2}{0.750} =$$

$$1.3 \times 10^{-5} = \frac{x^2}{0.750} =$$

x = 0.0031 M = $[H^+]$: pH = 2.51

c) 0.218 M $(CH_3)_3N$

	$(CH_3)_3N$	+	H_2O	$\rightleftarrows$	$(CH_3)_3NH^+(aq)$	+	$OH^-(aq)$	
I	0.218 M		-		0		0	
C	-x		-		+x		+x	let $x = [(CH_3)_3N]_R$
E	0.218 – x		-		x		x	

$$K_b = \frac{[(CH_3)_3NH^+][OH-]}{[(CH_3)_3N]}$$

$$6.4 \times 10^{-5} = \frac{(x)\ (x)}{0.218 - x}$$ **assume x << 0.218**

$$6.4 \times 10^{-5} = \frac{x^2}{.218}$$

3.7×10^{-3} M = x = $[OH^-]$

pOH = 2.43

pH = 11.57

Short Answer: Parts a – d are worth 4 points, part e is worth 6 points and part f is worth 9 points.

(20) 6a. Identify the acid, base, conjugate acid and conjugate base in the following chemical equation,

$$HPO_4^{2-}(aq) + HC_2H_3O_2(aq) \rightarrow H_2PO_4^-(aq) + C_2H_3O_2^-(aq)$$

base **acid** **conjugate acid** **conjugate base**

b) K for the reaction in 6a above has a value of 290. Identify the stronger acid and base in the reaction.

acid **$HC_2H_3O_2$** base **HPO_4^{2-}**

c) The pH of a 5.50×10^{-4} M $HClO_3$ solution is about 3.30. Is $HClO_3$ a strong acid or a weak acid? Explain.

For a pH of 3.30 the [H^+] = 5.01×10^{-4}. The concentration of [H^+] is nearly the same as the initial concentration of $HClO_3$. The percent ionization is;

$$\frac{5.01 \times 10^{-4}}{5.50 \times 10^{-4}} \times 100 = 91\%$$

So nearly all of the has $HClO_3$ dissociated, so $HClO_3$ is a strong acid.

d) Identify the chemical specie(s) in the highest concentration in 6c. (Note: excluding water.)

[H^+] and [ClO_3^-] are at the largest concentrations in the solution.

e) Identify each of the following substances as an acid or a base and write a chemical equation that describes the acid or base character.

i) $(CH_3)_2NH_2^+(aq)$

$$(CH_3)_2NH_2^+(aq) \rightleftarrows H^+(aq) + (CH_3)_2NH(aq)$$

acid

ii) $C_4H_7O_2^-(aq)$

$$C_4H_7O_2^-(aq) + H_2O(aq) \rightleftarrows HC_4H_7O_2(aq) + OH^-(aq)$$

base

f) K_p is 2.00 at a certain temperature for the reaction below

$$2NO(g) + O_2(g) \rightleftarrows 2NO_2(g)$$

The reaction mixture initially contains 1 atm of each compound in the equation, and then is allowed to proceed towards equilibrium.

i) Will the total pressure of the reaction system increase, decrease or stay the same? Explain.

$$\mathbf{Q = \frac{P^2_{NO_2}}{P^2_{NO} \cdot P_{O_2}} = \frac{1^2}{1^2 \cdot 1} = 1}$$

Q = 1, therefore the reaction must go from left to right to establish equilibrium. Since there are fewer moles of product the total pressure will decrease.

ii) Will $P_{NO} = P_{O_2}$ when equilibrium is established? Explain.

No, twice as much NO reacts as O_2 so the $P_{NO} < P_{O_2}$ at equilibrium.

iii) The reaction between NO(g) and O_2(g) is exothermic. What will happen to the magnitude of K if the temperature of the reaction is increased? Explain

K will decrease. The reaction will shift from right to left to relieve the stress of adding heat. So the amount of reactants increase and the amount of products decrease and K gets smaller.

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

$K_w = 1.0 \times 10^{-14}$ $K_p = K_c(RT)^{\Delta n}$

$pH = -\log[H^+]$ $pH + pOH = 14$

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

6.023×10^{23}

$$R = 0.0821 \frac{L\cdot atm}{mol\cdot K} = 8.314 \frac{J}{mol\cdot K}$$

E.1 DISSOCIATION CONSTANTS FOR ACIDS AT 25 ˚C

Name	Formula	K_{a1}	K_{a2}	K_{a3}
Acetic	$HC_2H_3O_2$	1.8×10^{-5}		
Ascorbic	$HC_6H_7O_6$	8.0×10^{-3}		
Arsenic	H_3AsO_4	5.6×10^{-3}	1.0×10^{-7}	3.0×10^{-12}
Arsenous	H_3AsO_3	6.0×10^{-10}		
Benzoic	$HC_7H_5O_2$	6.5×10^{-5}		
Boric	H_3BO_3	5.8×10^{-10}		
Butyric acid	$HC_4H_7O_2$	1.5×10^{-5}		
Carbonic	H_2CO_3	4.3×10^{-7}	5.6×10^{-11}	
Cyanic	HCNO	3.5×10^{-4}		
Citric	$H_3C_6H_5O_7$	7.4×10^{-4}	1.7×10^{-5}	4.0×10^{-7}
Formic	$HCHO_2$	1.8×10^{-4}		
Hydroazoic	HN_3	1.9×10^{-5}		
Hydrocyanic	HCN	4.9×10^{-10}		
Hydrofluoric	HF	7.2×10^{-4}		
Hydrogen chromate ion	$HCrO_4^-$	3.0×10^{-7}		
Hydrogen peroxide	H_2O_2	2.4×10^{-12}		
Hydrogen selenate ion	$HSeO_4^-$	2.2×10^{-2}		
Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}		
Hydrogen sulfide	H_2S	5.7×10^{-8}	1.3×10^{-13}	
Hypobromous	HBrO	2.0×10^{-9}		
Hypochlorous	HClO	3.0×10^{-8}		
Hypoiodus	HIO	2.0×10^{-11}		
Iodic	HIO_3	1.7×10^{-1}		
Lactic	$HC_3H_5O_3$	1.4×10^{-4}		
Malonic	$H_2C_3H_2O_4$	1.5×10^{-3}	2.0×10^{-6}	
Oxalic	$H_2C_2O_4$	5.9×10^{-2}	6.4×10^{-5}	
Nitrous	HNO_2	4.5×10^{-4}		
Phenol	HC_6H_5O	1.3×10^{-10}		
Phosphoric	H_3PO_4	7.5×10^{-3}	6.2×10^{-8}	4.2×10^{-13}
Paraperiodic	H_5IO_6	2.8×10^{-2}	5.3×10^{-9}	
Propionic	$HC_3H_5O_2$	1.3×10^{-5}		
Pyrophosphoric	H_4P_2O	3.0×10^{-2}	4.4×10^{-3}	
Selenous	H_2SeO_3	2.3×10^{-3}	5.3×10^{-9}	
Sulfuric	H_2SO_4	strong acid	1.2×10^{-2}	
Sulfurous	H_2SO_3	1.7×10^{-2}	6.4×10^{-8}	
Tartaric	$H_2C_4H_4O_6$	1.0×10^{-3}	4.6×10^{-5}	

E.2 DISSOCIATION CONSTANTS FOR BASES AT 25˚C

Name	Formula	K_b	Name	Formula	K_b
Ammonia	NH_3	1.8×10^{-5}	Hydroxylamine	$HONH_2$	1.1×10^{-8}
Aniline	$C_6H_5NH_2$	4.3×10^{-10}	Methylamine	CH_3NH_2	4.4×10^{-4}
Dimethylamine	$(CH_3)_2NH$	5.4×10^{-4}			
Ethylamine	$C_2H_5NH_2$	6.4×10^{-4}	Trimethylamine	$(CH_3)_3N$	6.4×10^{-5}
Hydrazine	H_2NNH_2	1.3×10^{-6}			

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