CHEM 1515
Exam V
John V. Gelder

Name _____

TA's Name _____

Section _____

INSTRUCTIONS:

1. This examination consists of a total of 11 different pages. The last three pages include a periodic table, a table of vapor pressures for water, a solubility table and a table of thermodynamic values. 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 2c and 2e.
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	MC	TOTAL
SCORES	_____	_____	_____	_____	_____	_____
	(24)	(20)	(12)	(11)	(33)	(100)

(44) 1. Consider the following experimental data for the three compounds provided.

Compound	Boiling Point (°C)	Polarity
$CH_3NH_{2(l)}$	-6.6	
$CH_3OH_{(l)}$	64.7	
$CH_3CH_{3(l)}$	-88.5	

a) Complete the table above by indicating the polarity of each compound. (3 pts)

b) Identify the intermolecular attractive forces that are present in liquid CH_3OH and liquid CH_3CH_3. Also in each compound identify the most important intermolecular attractive force. (6 pts)

c) Using complete Lewis structures, draw at least two molecules of CH_3OH in the box below. Clearly show (with a dashed line) and label the most important intermolecular attractive force that occurs in the liquid phase of CH_3OH. (6 pts)

d) Which compound has stronger intermolecular attractive forces: CH_3NH_2 or CH_3OH? What evidence do you have to support your prediction? (2 pts)

e) Based on the types of intermolecular attractive forces present in each compound, explain your prediction in 1d. (7 pts)

1. Continued

f) Write a chemical equation that would represent the phase change from liquid to gas for CH_3CH_3. (2 pts)

i. What is the sign of ΔH° for this phase change? (2 pts)

ii. What is the sign of ΔS° for this phase change? (2 pts)

iii. Is this phase change favored at high temperature or low temperature? Explain. (4 pts)

g) If liquid CH_3CH_3 is mixed with liquid CH_3OH, is the result going to be a homogeneous mixture or a heterogeneous mixture? Explain. (NOTE: Your explanation must be in terms of the solution process and include the thermodynamic quantities that are involved.) (10 pts)

(23) 2. When methylamine, CH_3NH_2 is mixed with water a reaction occurs. A student obtains a 50.0 mL sample of an aqueous solution of methylamine and determines the pH of the solution to be 11.77. ($K_b(CH_3NH_2) = 6.4 \times 10^{-4}$)

a) Write the balanced chemical equation that describes what happens when methylamine is added to water. (3)

b) Calculate the $[OH^-]$ in the 50.0 mL sample of methylamine. (3)

c) Calculate the initial concentration of the CH_3NH_2 in the solution before it reacted with water and equilibrium was established. (6)

In another experiment 6.75 grams of CH_3NH_3Cl, the salt of a weak base and a strong acid, is added to enough water to prepare 100.0 mL of solution.

d) Write the balanced chemical equation(s) that describes what happens when CH_3NH_3Cl is added to water. (3)

e) Calculate the pH of this solution. (8)

(23) 4a. Calculate the pH of a 500. mL sample of a solution that is 0.325 M $HC_3H_5O_2$ and 0.300 M $NaC_3H_5O_2$. (10 pts)

b) Calculate the pH of the solution in Question 4a following the addition of 0.025 mol of $HCl_{(g)}$. (12 pts)

c) Considering an original 500 mL sample of the solution in part 3a, how many moles of a strong acid would have to be added to destroy the buffer? Justify your claim with a calculation. (5)

Multiple Choice: (33 points)

Print the letter (A, B, C, D, E) which corresponds to the answer selected.

3. _____ 4. _____ 5. _____ 6. _____

7. _____ 8. _____ 9. _____ 10. _____

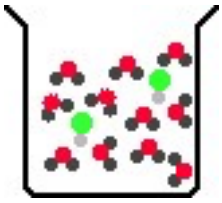
11. _____ 12. _____ 13. _____

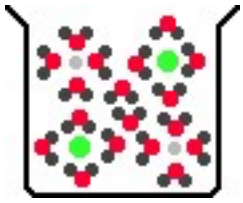
ONLY THE ANSWERS IN THE AREA ABOVE WILL BE GRADED. Select the most correct answer for each question. Each question is worth 3 points.

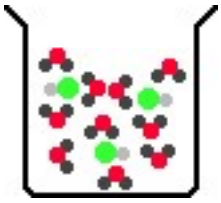
3. All of the following species can function as Bronsted-Lowry acids in solution EXCEPT

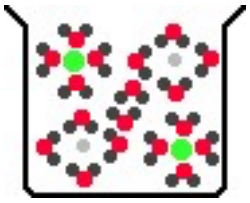
A. H_2O
B. CCl_3COOH
C. $CH_3NH_3^+$
D. HCO_3^-
E. S^{2-}

4. Which of the images below best represents an ionic compound like NaCl dissolved in water?

A. 

B. 

C. 

D. 

5. From the following list of aqueous solutions and water, select the one with the lowest ideal freezing point.

A. 0.50 *m* NaCl
B. 0.25 *m* Na_2SO_4
C. 0.35 *m* $NaClO_3$
D. 0.75 *m* $C_6H_{12}O_6$ (glucose)
E. 0.50 *m* CH_3COOH

6. Select the strongest electrolyte from the following set.

A. C_2H_5COOH (propionic acid)
B. $(NH_2)_2CO$, urea
C. $C_6H_{12}O_6$, fructose
D. CH_3NH_2 (methylamine)
E. $NaHSO_4$ (sodium bisulfate)

7. Determine the concentration of ammonium ions, NH_4^+, that are present when 50.0 mL of 3.00 M $(NH_4)_2CO_3$ are mixed with 100. mL of 2.00 M NH_4NO_3?

A. 1.33 M
B. 2.33 M
C. 3.33 M
D. 4.33 M
E. 6.33 M

8. Which of the following statements describes the correct method of preparation of 1.00 kg of solution that is also a 5.0 molal sodium chloride solution? MM sodium chloride = 58.5 g mol^{-1}

A. Dissolve 292 g of sodium chloride in 0.708 kg of distilled water
B. Dissolve 708 g of sodium chloride in 292 g of distilled water.
C. Dissolve 292 g of sodium chloride in 1.00 kg of distilled water.
D. Dissolve 226 g of sodium chloride in 774 g of distilled water.

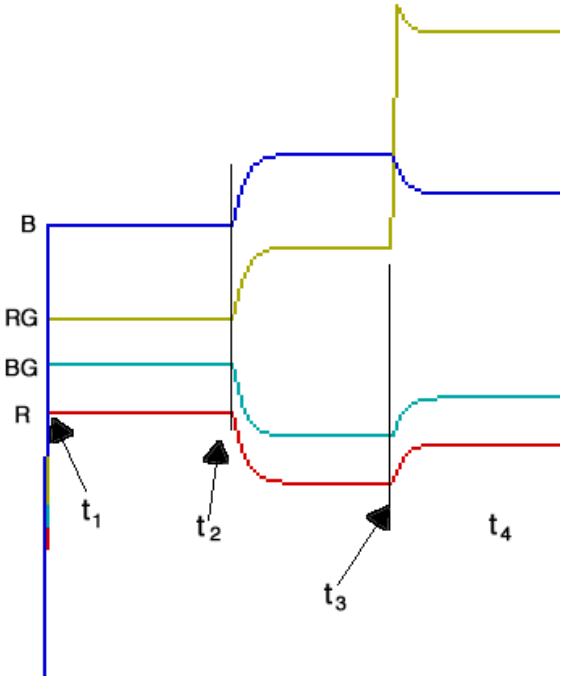
9. A sample of water placed in an evacuated container exerts a pressure of 485 mmHg at 90.0 ˚C. The container is cooled to 80.0 ˚C. Which of the following is true at 80 ˚C;

A. liquid and vapor exist and the vapor pressure is 472 mmHg
B. vapor only and the pressure is 355 mmHg.
C. vapor only and the pressure is 472 mmHg.
D. liquid and vapor exist and the vapor pressure is 355 mmHg

10. Which of the following solutions will have the lowest pH?

A. 0.100 M H_2SO_4
B. 0.100 M NaOH
C. 0.100 M $HC_2H_3O_2$
D. 0.100 M $HC_2H_3O_2$ and 0.100 M $NaC_2H_3O_2$

Answer Questions 11 - 13 based on the chart recording below.



11. Above is a chart recording depicting the reaction

$$R + BG \rightleftharpoons RG + B$$

At t_1 some amounts of R, BG, RG and B have been added to the reaction vessel. At t_2 the reaction as described in the chemical equation above occurs.

Based on the chart recording, which of the following statement is true?

A) The reaction is at equilibrium at some time from t_1 to t_2.
B) The reaction is at equilibrium at some time from t_2 to t_3
C) The temperature of the products was increased at t_2.
D) At t_2 some amounts of reactants were added and some amounts of products were removed from the container.

12. Based on the chart recording, which of the following statement is true?

A) At t_3 some additional RG was added to the container.
B) At t_3 a catalyst was added to the container.
C) At t_3 the temperature of the reaction container was increased.
D) At t_3 R and BG was added to the container and B was removed from the container.

13. Based on the chart recording, which of the following statement is true?

A) During t_4 the temperature of the container is increased again.
B) During t_4 the reaction is proceeding from right to left to establish equilibrium.
C) During t_4 the reaction proceeds from left to right to establishes equilibrium, but it will require more time before equilibrium is established.
D) During t_4 the reaction is slowing down.

Periodic Table of the Elements

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	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 (261)	105 (262)	106 (263)												

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

$PV = nRT$ $\quad R = 0.0821 \frac{L \cdot atm}{mol \cdot K} = 8.314 \frac{J}{mol \cdot K}$ $\quad$ density of $H_2O = 1.00 \frac{g}{cm^3}$

$$\ln\left(\frac{vp_2}{vp_1}\right) = -\frac{\Delta H^\circ_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$\Delta H^\circ_{rxn} = \sum m(\Delta H_f^\circ(\text{products})) - \sum n(\Delta H_f^\circ(\text{reactants}))$

$\Delta S^\circ_{rxn} = \sum m(S^\circ(\text{products})) - \sum n(S^\circ(\text{reactants}))$

$\Delta G^\circ_{rxn} = \sum m(\Delta G_f^\circ(\text{products})) - \sum n(\Delta G_f^\circ(\text{reactants}))$

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\quad \Delta G^\circ = -RT \ln K$

$P_{solution} = \chi_{solvent} P^\circ_{solvent}$ $\quad \Delta T = ikm$ $\quad k_f(H_2O) = 1.86 \frac{^\circ C}{m}$ $\quad k_b(H_2O) = 0.52 \frac{^\circ C}{m}$

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

$K_w = 1.00 \times 10^{-14}$ $\quad K_p = K_c(RT)^{\Delta n}$

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

Equilibrium Vapor Pressure for Water

Temperature (°C)	Vapor Pressure(mmHg)	Temperature (°C)	Vapor Pressure(mmHg)
-5	3.2	50	92.5
0	4.6	55	118.0
5	6.52	60	149.4
10	9.20	65	187.5
15	12.8	70	233.7
20	17.5	75	289.1
25	23.8	80	355.1
30	31.8	85	433.6
35	42.1	90	525.8
40	55.3	95	633.9
45	71.9	100	760

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

Thermodynamic Values (25 °C)

Substance and State	ΔH^o_f $\left(\frac{kJ}{mol}\right)$	ΔG^o_f $\left(\frac{kJ}{mol}\right)$	S^o $\left(\frac{J}{K \cdot mol}\right)$
Carbon			
C(*s*) (graphite)	0	0	6
CO(*g*)	-110.5	-137	198
CO_2(*g*)	-393.5	?	214
CH_4(*g*)	-75	-51	186
CH_3OH(*l*)	-239	?	127
CH_3Cl(*g*)	-80.8	-57.4	234
$CHCl_3$(*l*)	-131.8	-71.5	203
CCl_4(*l*)	-139	-68.6	214.4
H_2CO(*g*)	-116	-110	219
HCOOH(*g*)	-363	-351	249
HCN(*g*)	135.1	125	202
C_2H_2(*g*)	227	209	201
C_2H_4(*g*)	52	68	219
CH_3CHO(*g*)	-166	-129	250
C_2H_5OH(*l*)	-278	-175	161
C_2H_6(*g*)	-84.7	-32.9	229.5
C_4H_{10}(*g*)	-125	-16.7	310
$C_6H_{12}O_6$(*s*)	-1273		212
Bromine			
Br_2(*l*)	0	0	152.
Br_2(*g*)	30.91	3.13	245.
BrCl(*g*)	14.64	-0.96	240
Chlorine			
Cl_2(*g*)	0	0	223
Cl_2(*aq*)	-23	7	121
Cl^-(*aq*)	-167	-131	57
HCl(*g*)	-92	-95	187
Fluorine			
F_2(*g*)	0	0	203
F^-(*aq*)	-333	-279	-14
HF(*g*)	-271	-273	174
Hydrogen			
H_2(*g*)	0	0	131
H(*g*)	217	203	115
H^+(*aq*)	0	0	0
OH^-(*aq*)	-230	-157	-11
H_2O(*l*)	–286	?	70
H_2O(*g*)	–242	–229	189
Magnesium			
Mg(s)	0	0	33
Mg^{2+}(aq)	-492	-456	-118
MgO(s)	-601	-569	26.9

Substance and State	ΔH^o_f $\left(\frac{kJ}{mol}\right)$	ΔG^o_f $\left(\frac{kJ}{mol}\right)$	S^o $\left(\frac{J}{K \cdot mol}\right)$
Oxygen			
O_2(*g*)	0	0	205
O(*g*)	249	232	161
O_3(*g*)	143	163	239
Nitrogen			
N_2(*g*)	0	0	192
NCl_3(*g*)	230	271	-137
NF_3(*g*)	-125	-83.6	-139
NH_3(*g*)	-46.2	-17	193
NH_3(*aq*)	?	-27	111
CH_3NH_2(l)	-47.3	?	150
NO(*g*)	90	87	211
NO_2(*g*)	32	52	?
N_2O(*g*)	82	104	?
N_2O_4(*g*)	10	98	?
N_2O_5(*g*)	-42	134	?
HNO_3(*aq*)	-207	-111	146
HNO_3(*l*)	-174	-81	156
NH_4Cl(s)	-314	-201	95
NH_4ClO_4(*s*)	-295	-89	186
Silver			
Ag(*s*)	0	0	42.6
Ag^+(*aq*)	105.6	77.1	72.7
$Ag(S_2O_3)^{3-}$(*aq*)	-1285.7	--	--
AgBr(s)	-100.4	-96.9	107.1
AgCl(s)	-127.1	-109.8	96.2
Sulfur			
S(rhombic)	0	0	31.8
SO_2(g)	-296.8	-300.2	248.8
SO_3(g)	-395.7	-371.1	256.3
H_2S(g)	-20.17	-33.0	205.6
Phosphorus			
P_4(*s*)	0	0	41.1
PCl_5(*g*)	-375	-305	---
PCl_3(*g*)	-287	-272	---
Aluminum			
$AlCl_3$(*s*)	-526	-505	?
Barium			
$BaCl_2$(*aq*)	-872	-823	123
$Ba(OH)_2 \cdot 8H_2O$(*s*)	-3342	-2793	427
Iodine			
I_2(*s*)	0	0	116.7
HI(*g*)	25.94	1.30	206.3

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}	Pyridine	C_5H_5N	1.7×10^{-9}
Ethylamine	$C_2H_5NH_2$	6.4×10^{-4}			
Hydrazine	H_2NNH_2	1.3×10^{-6}			

(29) 1. For the reaction,

$$C_6H_{12}O_6(s) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$$

a) Calculate the ΔH°_{rxn}, ΔS°_{rxn}, and ΔG°_{rxn} at 25 ˚C. (20)

b) Does the thermodynamic favorability of this reaction depend on temperature? Explain. (6)

c) Is the decomposition of $C_6H_{12}O_6(s)$ thermodynamically favored (spontaneous) at 25 ˚C? Explain. (3)