GENERAL CHEMISTRY 2
FIRST HOUR EXAM
MAY 24, 2017

Name ____________Solutions ________________________________

Panthersoft ID ____

Signature ____

Part 1 __________________ **(24 points)**

Part 2 __________________ **(46 points)**

Part 3 __________________ **(50 points)**

TOTAL __________________ **(120 points)**

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Do all of the following problems. <u>Show your work.</u>

FORMULA SHEET (tear off)

1A	2A											3A	4A	5A	6A	7A	8A
1 H 1.01																	2 He 4.00
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
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	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 65.41	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
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
55 Cs 132.9	56 Ba 137.3	71 Lu 175.0	72 Hf 178.5	73 Ta 181.0	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]
87 Fr [223]	88 Ra [226]	103 Lr [262]	104 Rf [261]	105 Db [262]	106 Sg [266]												

57 La 138.9	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
89 Ac [227]	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np [237]	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]

$N_A = 6.022 \times 10^{23}$

$1 \text{ amu} = 1.661 \times 10^{-27}$ kg

1 atm = 760 torr = 760 mm Hg

R = 0.08206 L•atm/mol•K

R = 8.314 J/mol•K

$°C = (^5/_9)\,(°F - 32)$

°C = K - 273.15

1 atm = 1.013 bar

1 L•atm = 101.3 J

$1 \text{ J} = 1 \text{ kg}\cdot\text{m}^2/\text{s}^2$

$°F = (^9/_5)(°C) + 32$

K = °C + 273.15

pV = nRT

$p_A = X_A\, p_A°$

$\Delta T_b = K_b\, m_B$

$[B] = k\, p_B$

$\Delta T_f = K_f\, m_B$

$\Delta p_A = X_B p_A°$

$\Pi = [B]RT$

$K_p = K_C\,(RT)^{\Delta n}$

H = E + pV

$\Delta G_{rxn} = \Delta G°_{rxn} + RT \ln Q$

G = H - TS

$\ln K = -\,\Delta G°_{rxn}/RT$

If $ax^2 + bx + c = 0$, then $x = \left(\dfrac{-b \pm [b^2 - 4ac]^{1/2}}{2a}\right)$

Part 1. Multiple choice. Circle the letter corresponding to the correct answer. There is one and only one correct answer per problem. [4 points each]

1) Which of the following pairs of liquids are likely to be <u>immiscible</u>?

a) A polar liquid and a nonpolar liquid
b) Two polar liquids
A c) Two nonpolar liquids
d) Both a and b
e) Both b and c

2) A solution forms from a volatile solvent and a nonvolatile solute. Which of the following statements about the solution is correct?

a) The vapor pressure of the solution is higher than the vapor pressure of the pure solvent
b) The boiling point of the solution is higher than the boiling point of the pure solvent
B c) The freezing point of the solution is higher than the freezing point of the pure solvent
d) Both b and c
e) Both a and b and c

3) The Second Law of Thermodynamics says which of the following must be true for a process to occur?

a) $\Delta S_{syst} > 0$
b) $\Delta S_{surr} > 0$
C c) $\Delta S_{univ} > 0$
d) Both b and c
e) Both a and b and c

4) For a chemical reaction to be spontaneous for standard conditions, which of the following must be true?

a) $\Delta H^\circ_{rxn} < 0$
b) $\Delta G^\circ_{rxn} < 0$
B c) $\Delta S^\circ_{rxn} < 0$
d) $\Delta S^\circ_{rxn} > 0$
e) Both b and d

5) For which of the following reactions can an expression be written for both K_C and K_p?

a) $2\ H_2(g) + C_2H_2(g) \leftrightarrows C_2H_6(g)$
b) $MgCO_3(s) \leftrightarrows MgO(s) + CO_2(g)$
D c) $HNO_2(aq) + H_2O(\ell) \leftrightarrows H_3O^+(aq) + NO_2^-(aq)$
d) Both a and b
e) Both a and b and c

6) Consider the following chemical reaction at T =25. °C.

$N_2O_4(g) \leftrightarrows 2\ NO_2(g)$

The equilibrium constant for this reaction at this temperature is $K_C = 0.0046$

For a closed system with an initial value for reaction quotient $Q_C = 1.00$ at T = 25. °C, which of the following will occur as the system approaches equilibrium?

a) Moles of N_2O_4 will increase
b) Moles of NO_2 will decrease
D c) Moles of NO_2 will increase
d) Both a and b
e) Both a and c

Part 2. Short answer.

1) For each of the following circle the correct answer. There is one and only one correct answer per problem. [4 points each]

a) The aqueous solution with the largest value for osmotic pressure (relative to pure water)

0.050 M $CaCl_2$ solution	**0.050 M $Fe(NO_3)_3$ solution**	0.050 M glucose solution	0.050 M NaBr solution

b) The substance with the highest value for S° (at T = 25. °C)

$CH_3COOH(\ell)$	$CH_3COOH(g)$	$CH_3CH_2CH_2COOH(\ell)$	**$CH_3CH_2CH_2COOH(g)$**

c) A reaction that is never expected to be spontaneous for standard conditions (assuming the values for both $\Delta H°_{rxn}$ and $\Delta S°_{rxn}$ are independent of temperature)

$\Delta H°_{rxn} > 0$ and $\Delta S°_{rxn} > 0$	**$\Delta H°_{rxn} > 0$ and $\Delta S°_{rxn} < 0$**	$\Delta H°_{rxn} < 0$ and $\Delta S°_{rxn} > 0$	$\Delta H°_{rxn} < 0$ and $\Delta S°_{rxn} < 0$

2) Information about benzene (C_6H_6, MW = 78.11 g/mol) is given below

Freezing point depression constant (K_f) = 5.12 kg •°C/mol

Boiling point elevation constant (K_b) = 2.53 kg •°C/mol

Normal boiling point for benzene (T_b) = 80.08 °C

A solution is formed by dissolving an unknown amount of naphthalene ($C_{10}H_8$, MW = 128.2 g/mol), a nonvolatile solute, in benzene. The normal freezing point of the solution is found to be 1.15 °C lower than the normal freezing point of pure benzene. What will be the value for the normal boiling point of the solution? [5 points]

$\Delta T_f = K_f\, m_B$ so $m_B = \Delta T_f/K_f$ = (1.15 °C)/(5.12 kg •°C/mol) = 0.225 mol/kg

$\Delta T_f = K_f\, m_B$ = (2.53 kg •°C/mol)(0.225 mol/kg = 0.57 °C

Boiling point is an elevation, and so the boiling point of the solution is T = 80.08 °C + 0.57 °C = 80.65 °C

3) State the Third Law of Thermodynamics. [5 points]

The absolute entropy of any pure substance in the form of a perfect crystal is 0.00 J/mol•K at T = 0. K (absolute zero).

4) Give the correctly balanced formation reaction for methylamine ($CH_3NH_2(\ell)$). [4 points]

$$C(s) + {}^{5}/_{2}\ H_2(g) + {}^{1}/_{2}\ N_2(g) \rightarrow CH_3NH_2(\ell)$$

5) It takes 31400. J of heat to convert 1.000 moles of a particular unknown liquid into vapor at its normal boiling point, $T°_{vap}$ = 68.5 °C. What are $\Delta G°_{vap}$, $\Delta H°_{vap}$, and $\Delta S°_{vap}$ for the substance at this temperature? [10 points]

At the normal boiling point the liquid and vapor are at equilibrium, and so $\Delta G°_{vap}$ = 0.0 kJ/mol

For a process carried out at constant pressure, q = ΔH, and so $\Delta H°_{vap}$ = 31400. J/mol = 31.4 kJ/mol

Since G = H - TS, then for a process at constant temperature and pressure

$$\Delta G = \Delta H - T\ \Delta S$$

Since $\Delta G°_{vap}$ = 0., it follows that $\Delta S°_{vap} = \Delta H°_{vap}/T$ = (31400. J/mol)/(341.6 K) = 91.9 J/mol•K

6) The equilibrium constant for the reaction

$$F_2(g) \leftrightarrows 2\ F(g)$$

is $K_C = 8.1 \times 10^{-24}$ at T = 25. °C.

A system initially contains 0.0840 mol/L of $F_2(g)$ at T = 25. °C. No F(g) is initially present in the system. What will the concentration of F(g) be in the system when equilibrium is reached? [10 points]

$$K_C = \frac{[F]^2}{[F^2]}$$

	Initial	Change	Equilibrium
F	0.0	x	x
F_2	0.084	- x/2	0.084 - x/2

Substituting, we get $\frac{(x)^2}{(0.084 - x/2)} = 8.1 \times 10^{-24}$ If we assume x << 0.084, then

$$\frac{(x)^2}{(0.084)} = 8.1 \times 10^{-24} \qquad x^2 = (0.084)(8.1 \times 10^{-24}) = 6.8 \times 10^{-25}$$

$$x = (6.8 \times 10^{-25})^{1/2} = 8.2 \times 10^{-13}$$

Therefore, at equilibrium [F] = 8.2×10^{-13} mol/L

Part 3. Problems.

1) A solution is prepared by dissolving 25.628 g of hexamethylbenzene (HMB = $C_{12}H_{18}$, MW = 162.3 g/mol) in carbon tetrachloride (CCl_4, MW = 153.8 g/mol). The density and final volume of the solution are D = 1.556 g/mL and V = 200.0 mL. What are the molarity, molality, and percent by mass HMB in the solution? [16 points]

$$\text{moles HMB} = 25.628 \text{ g} \; \frac{1 \text{ mol}}{162.3 \text{ g}} = 0.1579 \text{ mol HMB}$$

So molarity is $$M = \frac{0.1579 \text{ mol}}{0.2000 \text{ L}} = 0.790 \text{ mol/L}$$

The total mass of the solution is mass = (200.0 mL) (1.556 g/mL) = 311.2 g

Therefore, the percent by mass HMB is $$\%\text{ HMB (by mass)} = \frac{25.628 \text{ g}}{311.2 \text{ g}} \; 100.0\ \% = 8.2\ \%$$

The total mass of solution is mass(total) = mass(HMB) + mass(solvent)

So mass(solvent) = mass(total) - mass(HMB) = 311.2 g - 25.628 g = 285.6 g = 0.2856 kg

The molality of the solution is then $$m = \frac{0.1579 \text{ mol}}{0.2856 \text{ kg}} = 0.553 \text{ mol/kg}$$

2) Thermodynamic data are given below (at T = 25. °C) and may be of use in doing this problem.

Substance	$\Delta H°_f$ (kJ/mol)	$\Delta G°_f$ (kJ/mol)	S° (J/mol•K)
Br_2(g)	30.907	3.110	245.46
Cl_2(g)	0.00	0.00	223.07
CH_3Br(g)	- 35.4	- 26.3	246.4
CH_3Cl(g)	- 81.9	- 58.4	234.6

What are $\Delta G°_{rxn}$, $\Delta S°_{rxn}$, and K_{eq} for the following reaction, at T = 25. °C [16 points]

$$2\ CH_3Cl(g) + Br_2(g) \leftrightarrows 2\ CH_3Br(g) + Cl_2(g)$$

$$\Delta G°_{rxn} = [\ 2\ \Delta G°_f(CH_3Br(g)) + \Delta G°_f(Cl_2(g))\ ] - [\ 2\ \Delta G°_f(CH_3Cl(g)) + \Delta G°_f(Br_2(g))\ ]$$

$$= [\ 2\ (-26.3) + (0.0)\ ] - [\ 2\ (-58.4) + (3.110)\ ] = 61.1 \text{ kJ/mol}$$

$$\Delta S°_{rxn} = [\ 2\ S°(CH_3Br(g)) + S°(Cl_2(g))\ ] - [\ 2\ S°(CH_3Cl(g)) + S°(Br_2(g))\ ]$$

$$= [\ 2\ (246.4) + (223.07)\ ] - [\ 2\ (234.6) + (245.46)\ ] = 1.2 \text{ J/mol•K}$$

$$\ln K = -\frac{\Delta G°_{rxn}}{RT} = -\frac{(61100.\text{ J/mol})}{(8.314\text{ J/mol•K})(298.2\text{ K})} = -24.64$$

$$K = e^{-24.64} = 2.0 \times 10^{-11}$$

3) The numerical value for the equilibrium constant for the reaction

$Br_2(g) + Cl_2(g) \leftrightarrows 2\,BrCl(g)$

at T = 25. °C is $K_C = 7.90$

a) What is the numerical value for K_p for the above reaction at T = 25. °C? [4 points]

Since Δn = change in moles of gas per mole reaction = 0, then $K_p = K_C = 7.9$

b) A system at T = 25. °C initially has 0.100 mol/L $Cl_2(g)$ and 0.360 mol/L $BrCl(g)$. No $Br_2(g)$ is initially present in the system. What will be the concentrations of BrCl, Br_2, and Cl_2 when the system reaches equilibrium? [14 points]

$$K_C = \frac{[BrCl]^2}{[Br_2]\,[Cl_2]}$$

	Initial	Change	Equilibrium
Br_2	0	x	x
Cl_2	0.100	x	0.100 + x
BrCl	0.360	- 2x	0.360 - 2x

So $$\frac{(0.360 - 2x)^2}{(x)\,(0.100 + x)} = 7.9$$

If we assume x << 0.100, then $$\frac{(0.360)^2}{(x)\,(0.100)} = 7.9\ ; \qquad x = \frac{(0.360)^2}{(0.100)\,(7.9)} = 0.164$$

So the assumption that x << 0.100 is not valid. We therefore need to do the problem using a different approach.

$$(0.360 - 2x)^2 = (x)\,(0.100 + x)\,(7.9)$$

$$0.1296 - 1.44\,x + 4\,x^2 = 7.9\,x^2 + 0.79\,x$$

$$3.9\,x^2 + 2.23\,x - 0.1296 = 0 \qquad x = \frac{(-2.23) \pm [\,(2.23)^2 - 4\,(3.9)\,(-0.1296)]^{1/2}}{2\,(3.9)}$$

x = <u>0.053</u>, - 0.625

The underlined root is the only one that gives all positive final concentrations, and so is the correct answer.

So $[Br_2]$ = 0.053 mol/L $[Cl_2]$ = 1.53 mol/L [BrCl] = 0.254 mol/L