

**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)**

Do all of the following problems. Show your work.

FORMULA SHEET (tear off)

1A																	8A														
1 H 1.01	2A										3A					4A	5A	6A	7A	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	[98]	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]

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

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

$$1 \text{ atm} = 760 \text{ torr} = 760 \text{ mm Hg}$$

$$R = 0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K}$$

$$R = 8.314 \text{ J}/\text{mol}\cdot\text{K}$$

$$^\circ\text{C} = (5/9) (^\circ\text{F} - 32)$$

$$^\circ\text{C} = \text{K} - 273.15$$

$$1 \text{ atm} = 1.013 \text{ bar}$$

$$1 \text{ L}\cdot\text{atm} = 101.3 \text{ J}$$

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

$$^\circ\text{F} = (9/5)(^\circ\text{C}) + 32$$

$$\text{K} = ^\circ\text{C} + 273.15$$

$$pV = nRT$$

$$p_A = X_A p_A^\circ$$

$$\Delta T_b = K_b m_B$$

$$[B] = k p_B$$

$$\Delta T_f = K_f m_B$$

$$\Delta p_A = X_B p_A^\circ$$

$$\Pi = [B]RT$$

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

$$H = E + pV$$

$$\Delta G_{\text{rxn}} = \Delta G^\circ_{\text{rxn}} + RT \ln Q$$

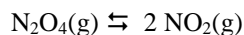
$$G = H - TS$$

$$\ln K = -\Delta G^\circ_{\text{rxn}}/RT$$

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

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 immiscible?
- 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) $\Delta S_{\text{syst}} > 0$
 - b) $\Delta S_{\text{surr}} > 0$
 - C** c) $\Delta S_{\text{univ}} > 0$
 - 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) $\Delta H^{\circ}_{\text{rxn}} < 0$
 - b) $\Delta G^{\circ}_{\text{rxn}} < 0$
 - B** c) $\Delta S^{\circ}_{\text{rxn}} < 0$
 - d) $\Delta S^{\circ}_{\text{rxn}} > 0$
 - 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) $2 \text{H}_2(\text{g}) + \text{C}_2\text{H}_2(\text{g}) \rightleftharpoons \text{C}_2\text{H}_6(\text{g})$
 - b) $\text{MgCO}_3(\text{s}) \rightleftharpoons \text{MgO}(\text{s}) + \text{CO}_2(\text{g})$
 - D** c) $\text{HNO}_2(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{NO}_2^-(\text{aq})$
 - d) Both a and b
 - e) Both a and b and c
- 6) Consider the following chemical reaction at $T = 25. \text{ }^{\circ}\text{C}$.



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 $T = 25. \text{ }^{\circ}\text{C}$, 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 CaCl₂
solution

0.050 M Fe(NO₃)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)

CH₃COOH(l)

CH₃COOH(g)

CH₃CH₂CH₂COOH(l)

CH₃CH₂CH₂COOH(g)

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

$\Delta H^\circ_{\text{rxn}} > 0$ and
 $\Delta S^\circ_{\text{rxn}} > 0$

$\Delta H^\circ_{\text{rxn}} > 0$ and
 $\Delta S^\circ_{\text{rxn}} < 0$

$\Delta H^\circ_{\text{rxn}} < 0$ and
 $\Delta S^\circ_{\text{rxn}} > 0$

$\Delta H^\circ_{\text{rxn}} < 0$ and
 $\Delta S^\circ_{\text{rxn}} < 0$

2) Information about benzene (C₆H₆, 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 (C₁₀H₈, 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]

$$\Delta T_f = K_f m_B \quad \text{so } m_B = \Delta T_f / K_f = (1.15 \text{ }^\circ\text{C}) / (5.12 \text{ kg } \cdot^\circ\text{C/mol}) = 0.225 \text{ mol/kg}$$

$$\Delta T_b = K_b m_B = (2.53 \text{ kg } \cdot^\circ\text{C/mol})(0.225 \text{ mol/kg}) = 0.57 \text{ }^\circ\text{C}$$

Boiling point is an elevation, and so the boiling point of the solution is $T = 80.08 \text{ }^\circ\text{C} + 0.57 \text{ }^\circ\text{C} = 80.65 \text{ }^\circ\text{C}$

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 ($\text{CH}_3\text{NH}_2(\ell)$). [4 points]



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

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

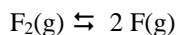
For a process carried out at constant pressure, $q = \Delta H$, and so $\Delta H^\circ_{\text{vap}} = 31400. \text{ J/mol} = 31.4 \text{ kJ/mol}$

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

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

Since $\Delta G^\circ_{\text{vap}} = 0.$, it follows that $\Delta S^\circ_{\text{vap}} = \Delta H^\circ_{\text{vap}}/T = (31400. \text{ J/mol})/(341.6 \text{ K}) = 91.9 \text{ J/mol}\cdot\text{K}$

6) The equilibrium constant for the reaction



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

A system initially contains 0.0840 mol/L of $\text{F}_2(\text{g})$ at $T = 25.^\circ\text{C}$. No $\text{F}(\text{g})$ is initially present in the system. What will the concentration of $\text{F}(\text{g})$ be in the system when equilibrium is reached? [10 points]

$K_C = \frac{[\text{F}]^2}{[\text{F}_2]}$		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 $x \ll 0.084$, then

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

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

Therefore, at equilibrium $[\text{F}] = 8.2 \times 10^{-13} \text{ mol/L}$

Part 3. Problems.

1) A solution is prepared by dissolving 25.628 g of hexamethylbenzene (HMB = C₁₂H₁₈, MW = 162.3 g/mol) in carbon tetrachloride (CCl₄, 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]

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

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

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

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

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

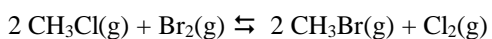
$$\text{So mass(solvent)} = \text{mass(total)} - \text{mass(HMB)} = 311.2 \text{ g} - 25.628 \text{ g} = 285.6 \text{ g} = 0.2856 \text{ kg}$$

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	ΔH°_f (kJ/mol)	ΔG°_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 ₃ Br(g)	- 35.4	- 26.3	246.4
CH ₃ Cl(g)	- 81.9	- 58.4	234.6

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



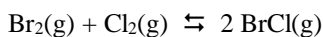
$$\begin{aligned} \Delta G^\circ_{\text{rxn}} &= [2 \Delta G^\circ_f(\text{CH}_3\text{Br}(\text{g})) + \Delta G^\circ_f(\text{Cl}_2(\text{g}))] - [2 \Delta G^\circ_f(\text{CH}_3\text{Cl}(\text{g})) + \Delta G^\circ_f(\text{Br}_2(\text{g}))] \\ &= [2 (- 26.3) + (0.0)] - [2 (- 58.4) + (3.110)] = 61.1 \text{ kJ/mol} \end{aligned}$$

$$\begin{aligned} \Delta S^\circ_{\text{rxn}} &= [2 S^\circ(\text{CH}_3\text{Br}(\text{g})) + S^\circ(\text{Cl}_2(\text{g}))] - [2 S^\circ(\text{CH}_3\text{Cl}(\text{g})) + S^\circ(\text{Br}_2(\text{g}))] \\ &= [2 (246.4) + (223.07)] - [2 (234.6) + (245.46)] = 1.2 \text{ J/mol}\cdot\text{K} \end{aligned}$$

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

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

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



at $T = 25.^\circ\text{C}$ is $K_C = 7.90$

a) What is the numerical value for K_p for the above reaction at $T = 25.^\circ\text{C}$? [4 points]

Since $\Delta n = \text{change in moles of gas per mole reaction} = 0$, then $K_p = K_C = 7.9$

b) A system at $T = 25.^\circ\text{C}$ initially has $0.100 \text{ mol/L Cl}_2(\text{g})$ and $0.360 \text{ mol/L BrCl}(\text{g})$. No $\text{Br}_2(\text{g})$ 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]

$K_C = \frac{[\text{BrCl}]^2}{[\text{Br}_2][\text{Cl}_2]}$	Initial	Change	Equilibrium
	Br_2	0	x
	Cl_2	0.100	x
	BrCl	0.360	$- 2x$
			x
			$0.100 + x$
			$0.360 - 2x$

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

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

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

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

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

$$3.9x^2 + 2.23x - 0.1296 = 0$$

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

$$x = \underline{0.053}, -0.625$$

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

So $[\text{Br}_2] = 0.053 \text{ mol/L}$ $[\text{Cl}_2] = 1.53 \text{ mol/L}$ $[\text{BrCl}] = 0.254 \text{ mol/L}$