FORMULA SHEET (tear off)

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

$N_A = 6.022 \times 10^{23}$ $\quad$ $°C = (5/9)(°F - 32)$ $\quad$ $°F = (9/5)(°C) + 32$

1 amu = 1.661×10^{-27} kg $\quad$ $°C = K - 273.15$ $\quad$ $K = °C + 273.15$

1 atm = 760 torr = 760 mm Hg $\quad$ 1 atm = 1.013 bar $\quad$ $pV = nRT$

$R = 0.08206$ L·atm/mol·K $\quad$ 1 L·atm = 101.3 J

$R = 8.314$ J/mol·K $\quad$ 1 J= 1 kg·m^2/s^2

$$\ln(p) = -\frac{\Delta H°_{vap}}{T} + C \qquad \ln(p_2/p_1) = -(\Delta H°_{vap}/R)\{(1/T_2) - (1/T_1)\}$$

$p_A = X_A\, p_A°$ $\quad$ $[B] = k\, p_B$ $\quad$ $\Delta p_A = X_B p_A°$

$\Delta T_b = K_b\, m_B$ $\quad$ $\Delta T_f = K_f\, m_B$ $\quad$ $\Pi = [B]RT$

$H = U + pV$ $\quad$ $G = H - TS$

GENERAL CHEMISTRY 2
FIRST EXAM
October 6, 2017

Name **_____KEY_Version 1_____**

Panthersoft ID **_____**

Signature **_____**

Part 1 **_____** **(24 points)**

Part 2 **_____** **(34 points)**

Part 3 **_____** **(42 points)**

TOTAL_____ **(100 points)**

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

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 states of matter is classified as a condensed phase?

a) solid
b) liquid
D c) gas
d) Both a and b
e) Both a and b and c

2) A solid compound is added to a liquid. Which of the following will favor formation of a solution from the solid and liquid?

a) If randomness increases when the solution forms
b) If randomness decreases when the solution forms
A c) If energy increases when the solution forms
d) Both a and c
e) Both b and c

3) Which of the following solutions is unstable?

a) An unsaturated solution
b) A saturated solution
C c) A supersaturated solution
d) Both a and b
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) $\Delta H°_{rxn} > 0$
b) $\Delta S°_{rxn} > 0$
E c) $\Delta G°_{rxn} > 0$
d) Both b and c
e) None of the above

5) For which of the following pure chemical substances (in the form of a perfect crystal) will $S° = 0.00$ J/mol•K at absolute zero?

a) Cu
b) O_2
E c) CuO_2
d) Both a and b
e) Both a and b and c

6) For which of the following pure chemical substances (at T = 25.0 °C) will $\Delta G°_f$, the free energy of formation, be equal to 0.00 kJ/mol?

a) $O_2(g)$
b) $O_3(g)$
A c) $SO_2(g)$
d) Both a and b
e) Both a and b and c

Version 2: D B A E E C
Version 3: D B C E E B
Version 4: D A A E E B

Part 2. Short answer.

1) Define the following [4 points each]

a) Second Law of Thermodynamics

The Second Law states that for a process to occur $\Delta S_{univ} \geq 0$

b) triple point

The pressure and temperature at which all three phases of a pure chemical substance can exist at equilibrium.

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

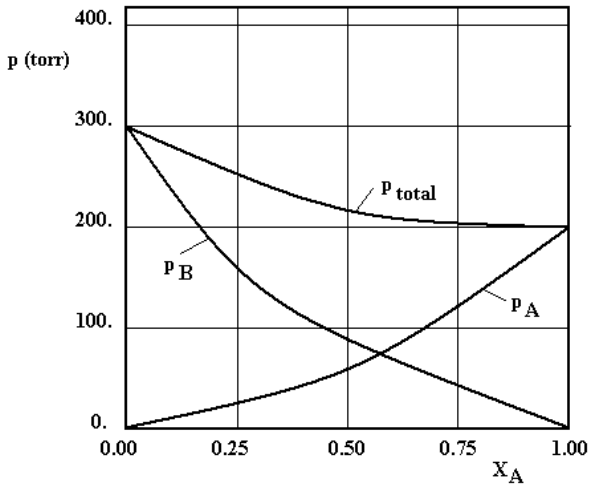
a) The substance expected to have the highest normal boiling point

$CH_3CH_2CH_2CH_3$ **$\underline{CH_3CH_2CH_2OH}$** Cl_2 CO_2

b) The substance with the largest value for entropy (at T = 25.0 °C and p = 1.00 atm).

$CH_3CH_2CN(\ell)$ $CH_3CN(\ell)$ **$\underline{CH_3CH_2CN(g)}$** $CH_3CN(g)$

3) A and B are volatile miscible liquids. The partial pressures of A and B and the total pressure above a solution of A and B are given in the diagram below as a function of X_A, the mole fraction of A, and at a temperature T = 40.0 °C. Based on the diagram answer the following questions. [5 points each]



a) Do A and B form an ideal liquid solution (yes or no, and a brief justification for your answer)?

No. For an ideal solution Raoult's law is obeyed, and the plots of pressure vs mol fraction A would be linear. Since this is not observed, the solution is not ideal.

b) What is $p_B°$, the vapor pressure of pure B, at T = 40.0 °C? $p_B° = 300.$ torr

4) Complete the table below by filling in the missing information. Note that T = 25.0 °C. [4 points each]

	$\Delta H°_{rxn}$ (kJ/mol)	$\Delta G°_{rxn}$ (kJ/mol)	$\Delta S°_{rxn}$ (J/mol·K)	Is the reaction spontaneous?
Reaction 1	- 196.4	- 208.5	___**+ 40.6**_____	yes
Reaction 2	+ 52.7	+ 45.0	+ 25.8	_____**no**_____

$\Delta G°_{rxn} = \Delta H°_{rxn} - T\Delta S°_{rxn}$, and so $\Delta S°_{rxn} = \frac{\Delta H°_{rxn} - \Delta G°_{rxn}}{T} = -\frac{196.4 \text{ kJ/mol} - (-208.5 \text{ kJ/mol})}{298. \text{ K}}$

$= + 0.0406 \text{ kJ/mol·K} = + 40.6 \text{ J/mol·K}$

Version 2: + 52.0 J/mol·K no
Version 3: + 62.4 J/mol·K no
Version 4: + 72.5 J/mol·K no

Part 3. Problems.

1) A solution is prepared by mixing together cyclohexane (C_6H_{12}, MW = 84.16 g/mol) and p-xylene ($C_6H_4(CH_3)_2$), MW = 106.17 g/mol). The mole fraction of p-xylene in the solution is $X_p = 0.1664$. What are the molality and the percent by mass p-xylene in the solution? [12 points]

Assume 1.00 mole of solution. Then $n_P = 0.1664$ mol, and $n_C = 1.0000 - 0.1664 = 0.8336$ mol

The grams of each substance are then

mass P = $0.1664 \text{ mol} \frac{106.17 \text{ g}}{\text{mol}} = 17.67 \text{ g P}$ mass C = $0.8336 \text{ mol} \frac{84.16 \text{ g}}{\text{mol}} = 70.16 \text{ g C}$

The percent by mass p-xylene is then

$$\% \text{ P (by mass)} = \frac{17.67 \text{ g}}{(17.67 \text{ g} + 70.16 \text{ g})} \times 100\% = 20.1 \% \text{ P by mass}$$

The molality of p-xylene is

$$m_P = \frac{0.1664 \text{ mol}}{0.07016 \text{ kg}} = 2.37 \text{ mol/kg}$$

Version 2: % P (by mass) = 15.3 % m_P = 1.70 mol/kg
Version 3: % P (by mass) = 13.3 % m_P = 1.44 mol/kg
Version 4: % P (by mass) = 18.0% m_P = 2.06 mol/kg

2) 2.09 g of copper II nitrate ($Cu(NO_3)_2$, MW = 187.56 g/mol) is dissolved in water, to form a solution with final volume V = 250.0 mL. What is the osmotic pressure of the solution relative to pure water? Assume T = 25.0 °C in your calculations, and give your final answer in units of atm. [12 points]

moles $Cu(NO_3)_2$ = 2.09 g $\frac{1 \text{ mol}}{187.56 \text{ g}}$ = 0.01114 mol $Cu(NO_3)_2$

moles particles = 0.01114 mol $Cu(NO_3)_2$ $\frac{3 \text{ mol particles}}{1 \text{ mol } Cu(NO_3)_2}$ = 0.03343 mol particles

When $Cu(NO_3)_2$ is added to water, it dissolves by the process

$Cu(NO_3)_2(s) \rightarrow Cu^{2+}(aq) + 2\ NO_3^-(aq)$, so there are 3 particles formed per formula unit

The molarity of particles in the solution is then $M = \frac{0.03343 \text{ mol particles}}{0.2500 \text{ L soln}} = 0.1337$ mol/L

So $\Pi = [B]RT = (0.1337 \text{ mol/L})(0.08206 \text{ L·atm/mol·K})(298. \text{ K}) = 3.27$ atm

Version 2: Π = 3.22 atm
Version 3: Π = 2.80 atm
Version 4: Π = 2.77 atm

3) 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)
$H_2O(\ell)$	- 285.83	- 237.13	69.91
$H_3PO_4(s)$	- 1279.0	- 1118.8	110.50
$P_4O_{10}(s)$	- 2984.0	- 2697.0	228.86

Phosphoric acid (H_3PO_4) may be prepared by adding tetraphosphorus decaoxide (P_4O_{10}) to water (H_2O), by the process

$$P_4O_{10}(s) + 6\ H_2O(\ell) \rightarrow 4\ H_3PO_4(s)$$

a) What are $\Delta S°_{rxn}$ and $\Delta G°_{rxn}$ for the above reaction, at T = 25.0 °C? [12 points]

$\Delta S°_{rxn} = [\ 4\ S°(H_3PO_4(s))\ ] - [\ S°(P_4O_{10}(s)) + 6\ S°(H_2O(\ell))\ ]$

$= [\ 4\ (110.50)\ ] - [\ 228.86 + 6\ (69.91)\ ] = -\ 206.32$ J/mol·K

$\Delta G°_{rxn} = [\ 4\ \Delta G°_f(H_3PO_4(s))\ ] - [\ \Delta G°_f(P_4O_{10}(s)) + 6\ \Delta G°_f(H_2O(\ell))\ ]$

$= [\ 4\ (-\ 1118.8)\ ] - [\ (-\ 2697.0 + 6\ (-\ 237.13)\ ] = -\ 355.4$ kJ/mol

b) Give the correctly balanced formation reaction for $H_3PO_4(s)$. [6 points]

$^3/_2\ H_2(g) + P(s) + 2\ O_2(g) \rightarrow H_3PO_4(s)$