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

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

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

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

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

GENERAL CHEMISTRY 2
FIRST EXAM (Sample)

Name **_____KEY _____**

Panthersoft ID **_____**

Signature **_____**

Part 1 **_____** **(20 points)**

Part 2 **_____** **(48 points)**

Part 3 **_____** **(32 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) Consider the following three pure chemical substances: hydrogen (H_2), chlorine (Cl_2), and methyl alcohol (CH_3OH). Of these three substances, we would expect

a) H_2 has the highest normal boiling point and Cl_2 has the lowest normal boiling point
b) H_2 has the highest normal boiling point and CH_3OH has the lowest normal boiling point
C c) CH_3OH has the highest normal boiling point and H_2 has the lowest normal boiling point
d) CH_3OH has the highest normal boiling point and Cl_2 has the lowest normal boiling point
e) Cl_2 has the highest normal boiling point and H_2 has the lowest normal boiling point

2) 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

3) 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

4) 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

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

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

Part 2. Short answer.

1) What is the difference (if any) between an amorphous solid and a crystalline solid? [6 points]

A crystalline solid has a regular arrangement of the particles making up the solid (a crystal structure). In an amorphous solid there is not a regular arrangement of the particles making up the solid.

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

a) The substance where hydrogen bonding between molecules can occur

$CH_3CH_2CH_3$ H_2 HCN **NH_3**

b) 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

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

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

d) 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 $\Delta S°_{rxn} < 0$

3) 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? [6 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

$\Delta T_b = K_b m_B = (2.53\ kg\ •°C/mol)(0.225\ mol/kg) = 0.57\ °C$

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

4) State the Third Law of Thermodynamics. [4 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).

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

$C(s) + {}^5/_2\ H_2(g) + {}^1/_2\ N_2(g) \rightarrow CH_3NH_2(\ell)$

6) 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? [12 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

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]

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

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

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

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

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

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

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

a) What are $\Delta G°_{rxn}$ and $\Delta S°_{rxn}$ for the following reaction, at T = 25. °C [12 points]

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

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

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

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

$= [\ 2\ (246.4) + (223.07)\ ] - [\ 2\ (234.6) + (245.46)\ ] = 1.2$ J/mol·K

b) Is the above reaction spontaneous for standard conditions and T = 25. °C (yes or no)? Justify your answer. [4 points]

For a chemical reaction to be spontaneous for standard conditions we require that $\Delta G°_{rxn} < 0$. Since $\Delta G°_{rxn} > 0$ for the above reaction, the reaction is not spontaneous for standard conditions.