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	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 amu = 1.661×10^{-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 J= 1 kg•m^2/s^2

°F = ($^9/_5$)(°C) + 32

K = °C + 273.15

pV = nRT

$p_A = X_A\, p_A°$

$\Delta T_b = K_b\, m_B$

$[B] = k\, p_B$

$\Delta T_f = K_f\, m_B$

$\Delta p_A = X_B p_A°$

$\Pi = M_B RT$

H = U + pV

G = H - TS

GENERAL CHEMISTRY 2
FIRST HOUR EXAM
SEPTEMBER 22, 2022

Name _______Solutions, Version 4_______________________

Panthersoft ID ____

Signature ____

Part 1 ________________ **(20 points)**

Part 2 ________________ **(38 points)**

Part 3 ________________ **(42 points)**

TOTAL ________________ **(100 points)**

Unless otherwise stated, you may assume T = 25.0 °C in all of the problems below.

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 favors two liquids mixing to form a solution?
a) A decrease in energy
b) A decrease in randomness
E c) An increase in randomness
d) Both a and b
e) Both a and c

2) Which of the following ways of indicating solution concentration has units?
a) molarity
b) molality
D c) mole fraction
d) both a and b
e) both a and b and c

3) Which of the following statements concerning solubility is correct?
a) The solubility of a gas in a liquid usually increases when temperature increases
b) The solubility of a solid in a liquid usually increases when temperature increases
B c) The solubility of a solid in a liquid usually decreases when temperature increases
d) Both a and b
e) Both a and c

4) Consider the following three chemical reactions, carried out for standard conditions and T = 25. °C.

i. $C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(\ell)$
ii. $2\ C_6H_6(\ell) + Br_2(\ell) \rightarrow 2\ C_6H_5Br(\ell) + H_2(g)$
iii. $2\ HF(g) + Cl_2(g) \rightarrow 2\ HCl(g) + F_2(g)$

For which of the above reactions, carried out at standard conditions and T = 25. °C, would you expect $\Delta S°_{rxn}$ to be large and positive?
a) Reaction i. only
b) Reaction ii. only
B c) Reaction iii. only
d) Both reaction i. and reaction ii.
e) Both reaction i. and reaction ii. and reaction iii.

5) A particular chemical reaction is found to always be spontaneous for standard conditions. If we assume $\Delta H°_{rxn}$ and $\Delta S°_{rxn}$ are independent of temperature, which of the following will be true?
a) $\Delta H°_{rxn} > 0$ and $\Delta S°_{rxn} > 0$
b) $\Delta H°_{rxn} > 0$ and $\Delta S°_{rxn} < 0$
C c) $\Delta H°_{rxn} < 0$ and $\Delta S°_{rxn} > 0$
d) $\Delta H°_{rxn} < 0$ and $\Delta S°_{rxn} < 0$
e) Cannot tell from the information given

Version 1: C, D, E, A, A **Version 2: D, D, C, A, B** **Version 3: B, D, A, C, B**

Part 2. Short answer.

1) Define the following term: normal boiling point [5 points]

The temperature at which a liquid boils when the pressure is exactly 1.00 atm.

2) What is the molarity of a solution formed by dissolving 34.83 g of dichloromethane (CH_2Cl_2, MW = 84.93 g/mol) in toluene (C_7H_8, MW = 92.14 g/mol), to form a solution with final volume V = 400.0 mL? [10 points]

$$M = \frac{\text{moles solute}}{\text{L soln}}$$

$$\text{moles } CH_2Cl_2 = 34.83 \text{ g} \; \frac{1 \text{ mol}}{84.93 \text{ g}} = 0.4101 \text{ mol } CH_2Cl_2$$

$$\text{L solution} = 400.0 \text{ ml} \; \frac{1 \text{ L}}{1000.0 \text{ mL}} = 0.4000 \text{ L}$$

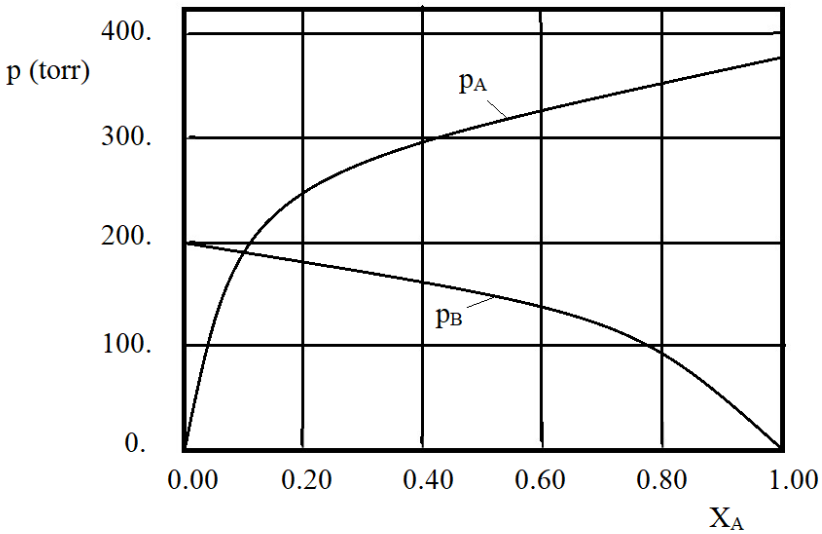
$$\text{So molarity} = \frac{0.4101 \text{ mol}}{0.4000 \text{ L}} = 1.025 \text{ mol/L}$$

Version 1: 1.212 M **Version 2: 0.9247 M** **Version 3: 0.7720 M**

3) Give the correctly balanced formation reaction for copper I nitrate ($CuNO_3(s)$). [5 points]

$$Cu(s) + \tfrac{1}{2} N_2(g) + {}^{3}/_{2}\, O_2(g) \rightarrow CuNO_3(s)$$

4) Consider a solution of two volatile liquids A and B at T = 30. °C. A figure indicating partial pressure of A and partial pressure of B vs mole fraction A in the solution is given below and may be useful in answering the following questions. [4 points each]



a) What is $p_A°$, the vapor pressure of pure A? _____375 torr_____________

b) What is $p_B°$, the vapor pressure of pure B? _____200 torr_____________

c) For what value of X_B is p_B = 100. torr? _____0.28_______________

5) For each of the following processes indicate whether the process is spontaneous (yes / no / cannot tell). [3 points each]

ΔS_{syst}	ΔS_{surr}	Process is spontaneous? (yes / no / cannot tell)
positive	negative	____cannot tell_______
negative	negative	_______no___________

Version 1: cannot tell; yes **Version 2: no; cannot tell** **Version 3: yes; cannot tell**

Part 3. Problems.

1) Consider a solution of hexamethylbenzene ($C_{12}H_{18}$, MW = 162.28 g/mol), a nonvolatile solute, in carbon tetrachloride (CCl_4, MW = 153.82 g/mol), a volatile solvent. The molality of hexamethylbenzene in the solution is m_H = 0.658 mol/kg (where H = hexamethylbenzene).

a) What are the mole fraction and percent by mass of hexamethylbenzene in the solution, including correct units. [12 points]

$$X_H = \frac{\text{moles H}}{\text{moles H + moles C}} \qquad \text{\% by mass H} = \frac{\text{mass H}}{\text{mass H + mass C}} \times 100\ \%$$

where H = hexamethylbenzene and C = carbon tetrachloride

Assume we have 1.000 kg = 1000.0 g of CCl_4, the solvent. So grams C = 1000.0 g

$$\text{moles C} = 1000.0\text{ g}\ \frac{1\text{ mol}}{153.82\text{ g}} = 6.501\text{ mol C}$$

$$\text{moles H} = \frac{0.658\text{ mol}}{\text{kg}}\ 1\text{ kg} = 0.658\text{ mol H}$$

$$\text{grams H} = 0.658\text{ mol}\ \frac{162.26\text{ g}}{\text{mol}} = 106.8\text{ g H}$$

And so $X_H = \dfrac{0.658\text{ mol}}{0.658\text{ mol} + 6.501\text{ mol}} = 0.0919$ % by mass H = $\dfrac{106.8\text{ g}}{106.8\text{ g} + 1000.0\text{ g}} \times 100\ \% = 9.65\ \%$

Version 1: X_H = 0.0991 **Version 2: X_H = 0.0749** **Version 3: X_H = 0.0664**
%H = 10.4 % **%H = 7.86 %** **%H = 6.98 %**

b) The normal freezing point of pure carbon tetrachloride is $T_f°$ = – 22.9 °C, and the freezing point depression constant for carbon tetrachloride is K_f = 29.8 kg•°C/mol. What is the normal freezing point of the solution of hexamethylbenzene + carbon tetrachloride with m_H = 0.658 mol/kg? Give your final answer in units of °C. [12 points]

The formula for freezing point depression is

$\Delta T_f = K_f\, m_B$ where m_B is the molality of solute particles. Since $m_B = m_H$ = 0.658 mol/kg

ΔT_f = (29.8 kg•°C/mol) (0.658 mol/kg) = 19.6 °C

The freezing point of the solution is lower than that of the pure liquid (hence freezing point depression) and so

$T_f = T_f° - \Delta T_f$ = (– 22.9 °C) – (19.6 °C) = – 42.5 °C

Version 1: T_f = – 44.2 °C **Version 2: T_f = – 38.6 °C** **Version 3: T_f = – 36.7 °C**

The data below is given at T = 25.0 °C, and may be of use in doing the following problem.

substance	ΔH°_f (kJ/mol)	ΔG°_f (kJ/mol)	S° (J/mol•K)
$BF_3(g)$	– 1136.0	– 1119.4	254.4
$B_2H_6(g)$	36.4	87.6	232.1
$NaBF_4(s)$	– 1844.7	– 1750.1	145.3
NaH(s)	– 56.3	– 33.5	40.0

2) H. C. Brown won the 1979 Nobel Prize in Chemistry for his work on boron compounds. One important reaction involving diborane (B_2H_6, MW = 27.67 g/mol) is given below

$$8\ BF_3(g) + 6\ NaH(s) \rightarrow 6\ NaBF_4(s) + B_2H_6(g) \qquad (2.1)$$

a) Find ΔS°_{rxn} and ΔG°_{rxn} for the above reaction (including correct units). [12 points]

ΔS°_{rxn} = [6 S°($NaBF_4$(s)) + S°(B_2H_6(g))] – [8 S°(BF_3(g)) + 6 S°(NaH(s))]

= [6 (145.3) + (232.1)] – [8 (254.4) + 6 (40.0)]

= [1103.9] – [2275.2] = – 1171.3 J/mol•K

ΔG°_{rxn} = [6 ΔG°_f($NaBF_4$(s)) + ΔG°_f(B_2H_6(g))] – [8 ΔG°_f(BF_3(g)) + 6 ΔG°_f(NaH(s))]

= [6 (– 1750.1) + (87.6)] – [8 (–1119.4) + 6 (– 33.5)]

= [– 10413.0] – [– 9156.2] = – 1256.8 kJ/mol

b) Is reaction 2.1 spontaneous for standard conditions and at T = 25.0 °C (yes or no, and a brief justification for your answer)? [6 points]

Yes, since $\Delta G^\circ_{rxn} < 0$ the reaction is spontaneous for standard conditions at T = 25. °C.