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]

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

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 23, 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 mixtures of two liquids is expected to form a solution?

a) A mixture of two polar liquids
b) A mixture of two nonpolar liquids
D c) A mixture of a polar liquid and a nonpolar liquid
d) Both a and b
e) Both a and b and c

2) Consider a solution containing 40.0 g of ethylene glycol ($C_2H_6O_2$, MW = 62.07 g/mol), a nonvolatile solute, dissolved in 500.0 g of methyl alcohol (CH_3OH, MW = 32.04 g/mol), a volatile solvent. Which of the following will be true?

a) The boiling point of the solution will be lower than the boiling point of pure methyl alcohol
b) The freezing point of the solution will be higher than the freezing point of pure methyl alcohol
C c) The freezing point of the solution will be lower than the freezing point of pure methyl alcohol
d) both a and b
e) both a and c

3) Which of the following is a state function?

a) Enthalpy (H)
b) Entropy (S)
E c) Free energy (G)
d) Both a and b
e) Both a and b and c

4) A particular process is found to be spontaneous. It is also known that for the process $\Delta S_{syst} < 0$. Which of the following is possible for ΔS_{surr}?

a) $\Delta S_{surr} > 0$
b) $\Delta S_{surr} = 0$
A c) $\Delta S_{surr} < 0$
d) both a and b
e) both a and b and c

5) Which of the following statements about the free energy of formation is correct (at T = 25. °C)?

a) $\Delta G°_f(N(g)) = 0.0$ kJ/mol
b) $\Delta G°_f(N_2(g)) = 0.0$ kJ/mol
B c) $\Delta G°_f(NO_2(g)) = 0.0$ kJ/mol
d) both a and b
e) none of the above

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

Part 2. Short answer.

1) Define the following term: colligative property [5 points]

A property of a liquid solution of a nonvolatile solute and a volatile solvent, that at most depends on the concentration of solute particles and the physical properties of the solvent.

2) What is the molarity of a solution formed by dissolving 27.34 g of pentamethylbenzene ($C_{11}H_{16}$, MW = 148.25 g/mol) in benzene (C_6H_6, MW = 78.11 g/mol), to form a solution with final volume V = 400.0 mL? [10 points]

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

$$\text{moles } C_{11}H_{16} = 27.34 \text{ g} \times \frac{1 \text{ mol}}{148.25 \text{ g}} = 0.1844 \text{ mol } C_{11}H_{16}$$

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

$$\text{So molarity} = \frac{0.1844 \text{ mol}}{0.4000 \text{ L}} = 0.4610 \text{ mol/L}$$

Version 1: 0.4296 M **Version 2: 0.3314 M** **Version 3: 0.5934 M**

3) Give the correctly balanced formation reaction for silver carbonate ($Ag_2CO_3(s)$). [5 points]

$$2\ Ag(s) + C(s) + {}^3/_2\ O_2(g) \rightarrow Ag_2CO_3(s)$$

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

a) The pure chemical substance expected to have the largest value for S° (molar entropy) at T = 25. °C?

$CH_3CH_2CH_2OH(g)$ $CH_3CH_2CH_2OH(\ell)$ $CH_3CH_2CH_2OH(s)$ $CH_3CH_2OH(s)$

b) The values for $\Delta H°_{rxn}$ and $\Delta S°_{rxn}$ for a chemical reaction that is never spontaneous for standard conditions?

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

c) The van't Hoff factor for $AgNO_3$ (silver nitrate) dissolved in water?

i = 1 **i = 2** i = 3 i = 4

5) The Henry's law constant for nitrogen (N_2, MW = 28.01 g/mol) dissolved inwater (H_2O, MW = 18.02 g/mol) is k = 6.2 x 10^{-4} mol/L·atm at T = 25. °C. What is the concentration of dissolved nitrogen at sea level for air in equilibrium with water at T = 25. °C? Note that the partial pressure of nitrogen at sea level is p_{N2} =0.78 atm.
[6 points]

Henry's law says $[B] = k\, p_B$

Therefore $[N_2] = (6.2 \times 10^{-4}\ \text{mol/L·atm})\ (0.78\ \text{atm}) = 4.84 \times 10^{-4}\ \text{mol/L}$

Part 3. Problems.

1) Consider a solution of 4-bromobenzaldehyde (C_7H_5BrO, MW = 185.03 g/mol), a nonvolatile solute, in ethyl alcohol (C_2H_5OH, MW = 46.07 g/mol), a volatile solvent. The mole fraction of C_7H_5BrO in the solution is X_B = 0.072 (where B = 4-bromobenzaldehyde).

a) What are the percent by mass and molality of 4-bromobenzaldehyde in the solution, including correct units? [12 points]

$$\% \text{ by mass B} = \frac{\text{mass B}}{\text{mass B + mass E}} \times 100\% \qquad m_B = \frac{\text{moles B}}{\text{kg E}}$$

where B = 4-bromobenzaldehyde and E = ethyl alcohol

Assume we have 1.000 mol of solution

Then mol B = 0.072 mol mol E = 1.000 – 0.072 = 0.928 mol E

$$\text{mass B} = 0.072 \text{ mol} \times \frac{185.03 \text{ g}}{1 \text{ mol}} = 13.32 \text{ g B}$$

$$\text{mass E} = 0.928 \text{ mol} \times \frac{46.07 \text{ g}}{1 \text{ mol}} = 42.75 \text{ g E} = 0.04275 \text{ kg E}$$

And so $\% \text{ by mass B} = \frac{13.32 \text{ g}}{13.32 \text{ g} + 42.75 \text{ g}} \times 100\% = 23.8 \text{ \% B}$ $m_B = \frac{0.072 \text{ mol}}{0.04275 \text{ kg}} = 1.68 \text{ mol/kg}$

Version 1: m_B = 1.34 mol/kg %B = 19.8 %
Version 2: m_B = 2.77 mol/kg %B = 33.9 %
Version 3: m_B = 2.28 mol/kg %B = 29.7 %

b) The vapor pressure of pure ethyl alcohol at T = 40.0 °C is $p_{vap}°$ = 134.1 torr. What is the partial pressure of ethyl alcohol above the solution of 4-bromobenzaldehyde + ethyl alcohol with X_B = 0.072, measured at T = 40.0 °C? Give your final answer in units of torr. [12 points]

The formula for vapor pressure lowering is

$\Delta p_E = X_B \, p_E°$ where X_B is the mol fraction of solute particles. X_B = 0.072
E = ethyl alcohol

Δp_E = (0.072) (134.1 torr) = 9.7 torr

The vapor pressure of the solution is lower than that of the pure liquid (hence vapor pressure lowering) and so

$p_E = p_E° - \Delta p_E$ = (134.1 torr) – (9.7 torr) = 124.4 torr

Version 1: p_E = 126.3 torr Version 2: p_E = 118.9 torr Version 3: p_E = 121.4 torr

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

substance	$\Delta H°_f$ (kJ/mol)	$\Delta G°_f$ (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
$NaBH_4(s)$	– 188.6	– 123.9	101.3

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

$$3\ NaBF_4(s) + 2\ B_2H_6(g) \rightarrow 4\ BF_3(g) + 3\ NaBH_4(s) \qquad (2.1)$$

a) Find $\Delta S°_{rxn}$ and $\Delta G°_{rxn}$ for the above reaction (including correct units). [12 points]

$\Delta S°_{rxn} = [\ 4\ S°(BF_3(g)) + 3\ S°(NaBH_4(s))\ ] – [\ 3\ S°(NaBF_4(s)) + 2\ S°(B_2H_6(g))\ ]$

$= [\ 4\ (254.4) + 3\ (101.3)\ ] – [\ 3\ (145.3) + 2\ (232.1)\ ]$

$= [\ 1321.5\ ] – [\ 900.1\ ] = 421.4$ J/mol·K

$\Delta G°_{rxn} = [\ 4\ \Delta G°_f(BF_3(g)) + 3\ \Delta G°_f(NaBH_4(s))\ ] – [\ 3\ \Delta G°_f(NaBF_4(s)) + 2\ \Delta G°_f(B_2H_6(g))\ ]$

$= [\ 4\ (-1119.4) + 2\ (-123.9)\ ] – [\ 3\ (-1750.1) + 2\ (87.6)\ ]$

$= [\ -4725.4\ ] – [\ -5075.1\ ] = 349.7$ 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]

No, since $\Delta G°_{rxn} > 0$ the reaction is not spontaneous for standard conditions at T = 25. °C.