CHEM 1515 Sections 20511 & 20516
Exam I
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Name ____________________

TA's Name ____________________

Section _______

INSTRUCTIONS:

1. This examination consists of a total of 9 different pages. The last two pages include a periodic table, useful mathematical equations, and a solubility table. All work should be done in this booklet.
2. PRINT your name, TA's name and your lab section number now in the space at the top of this sheet. DO NOT SEPARATE THESE PAGES.
3. Answer all questions that you can and whenever called for, show your work clearly. Your method of solving problems should pattern the approach used in lecture. You do not have to show your work for the multiple choice or short answer questions.
4. No credit will be awarded if your work is not shown in 5a.
5. Point values are shown next to the problem number.
6. Budget your time for each of the questions. Some problems may have a low point value yet be very challenging. If you do not recognize the solution to a question quickly, skip it, and return to the question after completing the easier problems.
7. Look through the exam before beginning; plan your work; then begin.
8. Relax and do well.

	Page 2	Page 3	Page 4	Page 5	MC	TOTAL
SCORES	____	____	____	____	____	____
	(27)	(12)	(22)	(23)	(16)	(100)

(9) 1. Write the chemical formula(s) of the product(s) and balance the following reactions. Identify all products phases as either (g)as, (l)iquid, (s)olid or (aq)ueous.

a) $H_2SO_4(aq)$ + $2NaOH(aq)$ → **$Na_2SO_4(aq)$ + $2H_2O(l)$**

b) $C_7H_{16}(l)$ + $11O_2(g)$ → **$7CO_2(g)$ + $8H_2O(l)$**

c) $HC_2H_3O_2(aq)$ + $NaHCO_3(s)$ → **$NaC_2C_3O_2(aq)$ + $CO_2(g)$ + $8H_2O(l)$**

(4) 2. Write the ionic and net ionic chemical equations for reaction 1a.

1a) Ionic equation:

$2H^+(aq)$ + $SO_4^{2-}(aq)$ + $2Na^+(aq)$ + $2OH^-(aq)$ → $2Na^+(aq)$ + $SO_4^{2-}(aq)$ + $2H_2O(l)$

1a) Net Ionic equation:

$2H^+(aq)$ + $2OH^-(aq)$ → $2H_2O(l)$
$H^+(aq)$ + $OH^-(aq)$ → $H_2O(l)$

(26) 3. The element iodine, $I_2(g)$, a diatomic molecule, undergoes deposition according to the chemical equation below,

$$I_2(g) \rightarrow I_2(s)$$

(i) Which phase of iodine has the greater absolute entropy? (2) Explain. (5)

Gas phase I_2 – molecules of I_2 in the gas phase can occupy any position in the container and the energy of system is distributed between translational, rotational and vibrational modes.

(ii) Which phase of iodine has the lower absolute entropy? (2) Explain. (5)

Solid phase I_2 – molecules of I_2 in the solid phase are in fixed positions in the container and the energy of system is only in the vibrational modes.

3. (Continued) The element iodine, $I_{2(g)}$, a diatomic molecule, undergoes deposition according to the chemical equation below,

$$I_{2(g)} \rightarrow I_{2(s)}$$

(iii) Is ΔH° for the deposition of iodine positive or negative? (3)

Negative (exothermic)

(iv) Is ΔS° for the deposition of iodine positive or negative? (3)

Negative (becoming less dispersed)

(v) Based on parts (iii) and (iv), is the phase change described above thermodynamically favored at high temperature or a low temperature? Explain. (6)

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$
$$\Delta H^\circ \; -$$
$$\Delta S^\circ \; -$$
$$\Delta G^\circ = - \; - \; + \cdot -$$

When T is small ΔG° will be more negative, so low temperatures.

$$\frac{1}{2} Br_{2}(l) + \frac{1}{2} Cl_{2}(g) \rightarrow BrCl(g)$$

(22) 4a. Is the above reaction a formation reaction? **Yes** or No? (Circle your choice) (2)
Explain. (3)

Reactants are elements in their standard state forming one mol of compound.

(b) Predict the sign of ΔS° for the above reaction between $Br_2(l)$ and $Cl_2(g)$. (3)
_____positive___________
Describe the evidence used to support your claim. (5)

One-half a mole of liquid and one-half mol of gas form one mol of gas, so the ΔS° should be positive.

(c) The boiling point of Br_2 is 332K, whereas the boiling point of BrCl is 278 K. Explain this difference in boiling point in terms of the polarity of each substance and all of the intermolecular attractive forces present between molecules of each substance. (9)

Br_2 **Nonpolar** **LDF only**	**BrCl** **Polar** **LDF** **Dipole dipole**

Br_2 has two bromine atoms while BrCl only has one Br atom. The valence electrons in Br are in the 4^{th} level, far from the nucleus. These valence electrons are polarizable. So Br_2 has more electrons that are polarizable compared to BrCl, so the instantaneous dipoles in Br_2 are stronger compared to the instantaneous dipoles in BrCl. So Br_2 has the higher boiling point.

(23) 5. One of many possible reactions between ammonia and oxygen is show below.

$$2\ NH_3(g) + 2\ O_2(g) \rightarrow N_2O(g) + 2\ H_2O(g)$$

Compound	ΔH_f° (kJ mol^{-1})	S°(J mol^{-1} K^{-1})	ΔG_f°(kJ mol^{-1})
$NH_3(g)$	-46	?	-16.5
$O_2(g)$	0	205	0
$N_2O(g)$	+82.1	220	104
$H_2O(g)$	-242	189	-229

a) Calculate ΔH°_{rxn}, ΔS°_{rxn}, and ΔG°_{rxn} for the reaction above at 298 K. (20)

$\Delta H^\circ_{rxn} = \sum m\Delta H_f^\circ(\text{products}) - \sum n\Delta H_f^\circ(\text{reactants})$

$= m\Delta H_f^\circ(N_2O(g)) + 2\cdot\Delta H_f^\circ(H_2O(g)) - 2\cdot\Delta H_f^\circ(NH_3(g)) + 2\cdot\Delta H_f^\circ(O_2(g))$

$= (+82.1\text{ kJ mol}^{-1}) + 2\cdot(-242\text{ kJ mol}^{-1}) - 2\cdot(-46\text{ kJ mol}^{-1}) + 2\cdot(0\text{ kJ mol}^{-1})$

$= -309.9\text{ kJ mol}^{-1}$

$\Delta S^\circ_{rxn} = \sum mS^\circ(\text{products}) - \sum nS^\circ(\text{reactants})$ not enough information to use this mathematical equation

$\Delta G^\circ_{rxn} = \sum m\Delta G_f^\circ(\text{products}) - \sum n\Delta G_f^\circ(\text{reactants})$

$= m\Delta G_f^\circ(N_2O(g)) + 2\cdot\Delta G_f^\circ(H_2O(g)) - 2\cdot\Delta G_f^\circ(NH_3(g)) + 2\cdot\Delta G_f^\circ(O_2(g))$

$= (+104\text{ kJ mol}^{-1}) + 2\cdot(-229\text{ kJ mol}^{-1}) - 2\cdot(-16.5\text{ kJ mol}^{-1}) + 2\cdot(0\text{ kJ mol}^{-1})$

$= -321\text{ kJ mol}^{-1}$

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

$$\Delta S^\circ = \frac{\Delta G^\circ - \Delta H^\circ}{T}$$

$$= \frac{-321\text{ kJ mol}^{-1} - (-309.9\text{ kJ mol}^{-1})}{298\text{ K}} = \frac{-11.1\text{ kJ mol}^{-1}}{298\text{ K}} = -3.72 \times 10^{-2}\ \frac{\text{kJ mol}^{-1}}{\text{K}}$$

$$= -3.72 \times 10^{-2}\ \frac{\text{kJ mol}^{-1}}{\text{K}}\left(\frac{1000\text{ J}}{1\text{ kJ}}\right) = -37.2\ \frac{\text{J mol}^{-1}}{\text{K}}$$

However, it was discovered during the exam the chemical equation was not balanced properly.

$$2\ NH_3(g) + 2\ O_2(g) \rightarrow N_2O(g) + 3\ H_2O(g)$$

$\Delta H^\circ_{rxn} = \sum m\Delta H_f^\circ(\text{products}) - \sum n\Delta H_f^\circ(\text{reactants})$

$= m\Delta H_f^\circ(N_2O(g)) + 3\cdot\Delta H_f^\circ(H_2O(g)) - 2\cdot\Delta H_f^\circ(NH_3(g)) + 2\cdot\Delta H_f^\circ(O_2(g))$

$= (+82.1\text{ kJ mol}^{-1}) + 3\cdot(-242\text{ kJ mol}^{-1}) - 2\cdot(-46\text{ kJ mol}^{-1}) + 2\cdot(0\text{ kJ mol}^{-1})$

$= -551.9\text{ kJ mol}^{-1}$

$\Delta G^\circ_{rxn} = \sum m\Delta G_f^\circ(\text{products}) - \sum n\Delta G_f^\circ(\text{reactants})$

$= m\Delta G_f^\circ(N_2O(g)) + 3\cdot\Delta G_f^\circ(H_2O(g)) - 2\cdot\Delta G_f^\circ(NH_3(g)) + 2\cdot\Delta G_f^\circ(O_2(g))$

$= (+104\text{ kJ mol}^{-1}) + 3\cdot(-229\text{ kJ mol}^{-1}) - 2\cdot(-16.5\text{ kJ mol}^{-1}) + 2\cdot(0\text{ kJ mol}^{-1})$

$= -550\text{ kJ mol}^{-1}$

$$\Delta S^\circ = \frac{\Delta G^\circ - \Delta H^\circ}{T} = \frac{-550\text{ kJ mol}^{-1} - (-551.9\text{ kJ mol}^{-1})}{298\text{ K}} = \frac{+1.9\text{ kJ mol}^{-1}}{298\text{ K}} = 6.38 \times 10^{-3}\ \frac{\text{kJ mol}^{-1}}{\text{K}}$$

$$= 6.38 \times 10^{-3}\ \frac{\text{kJ mol}^{-1}}{\text{K}}\left(\frac{1000\text{ J}}{1\text{ kJ}}\right) = 6.38\ \frac{\text{J mol}^{-1}}{\text{K}}$$

b) Is the reaction thermodynamically favored or not thermodynamically favored at 298 K? Explain. (3)

The reaction is thermodynamically favored because ΔG° is negative

Multiple Choice: (16 points)

Print the letter (A, B, C, D, E) which corresponds to the answer selected.

6. ___**B**__ 7. __**A**___ 8. __**C**___ 9. __**E**___

ONLY THE ANSWERS IN THE AREA ABOVE WILL BE GRADED. Select the most correct answer for each question. Each question is worth 4 points.

Questions 6 and 7. Use the table of equilibrium vapor pressures for ethanol, $CH_3CH_2OH(l)$

Temperature (˚C)	Vapor Pressure (mm Hg)
72	600
65	450
52	250
33	100

6. A sample of ethanol in a constant volume container at 75 ˚C exerts a pressure of 550 mm Hg. The sample is cooled to 52 ˚C.

A. the sample condenses and the pressure exerted by the vapor is 513 mm Hg
B. the sample condenses and the pressure exerted by the vapor is 250 mm Hg
C. the sample remains in the vapor phase and the pressure exerted by the vapor is 513 mm Hg
D. the sample remains in the vapor phase and the pressure exerted by the vapor is 381 mm Hg
E. the sample begins as vapor at 75 ˚C and remains as vapor with the new pressure exerted by the vapor less than 250 mm Hg

7. Calculate the enthalpy of vaporization for $CH_3CH_2OH(l)$

A. 40.4 kJ mol^{-1} B. 33.2 kJ mol^{-1} C. 78.0 kJ mol^{-1} D. -155 kJ mol^{-1} E. 26.5 kJ mol^{-1}

For Questions 8 and 9:

Consider the following attractive forces

I. London dispersion forces
II. Dipole dipole forces
III. Hydrogen bonding forces
IV. Covalent bonds
V. Ionic bonding

8. Which forces must be overcome when CH_2F_2 boils?

A. I only
B. II only
C. I and II
D. I and III
E. I, II and III

9. Which forces must be overcome when CH_3OH boils?
A. I only
B. II only
C. I and II
D. I and III
E. I, II and III

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.008																	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** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	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** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.97	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** 95.95	43 **Tc** (97)	44 **Ru** 101.1	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 ***La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **†Ac** (227)	104 **Rf** (267)	105 **Db** (270)	106 **Sg** (271)	107 **Bh** (270)	108 **Hs** (277)	109 **Mt** (276)	110 **Ds** (281)	111 **Rg** (282)	112 **Cn** (285)	113 **Uut** (285)	114 **Fl** (289)	115 **Uup** (288)	116 **Lv** (293)	117 **Uus** (294)	118 **Uuo** (294)

*Lanthanoid Series	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
†Actinoid Series	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	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)	103 **Lr** (262)

Useful Information

$PV = nRT$

$R = 0.0821 \frac{L\cdot atm}{mol\cdot K} = 8.314 \frac{J}{mol\cdot K}$

$\ln\left(\frac{vp_2}{vp_1}\right) = -\frac{\Delta H^\circ_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

density of $H_2O = 1.00 \frac{g}{cm^3}$

$\Delta H^\circ_{rxn} = \sum m\Delta H_f^\circ(\text{products}) - \sum n\Delta H_f^\circ(\text{reactants})$

$\Delta S^\circ_{rxn} = \sum mS^\circ(\text{products}) - \sum nS^\circ(\text{reactants})$

$\Delta G^\circ_{rxn} = \sum m\Delta G_f^\circ(\text{products}) - \sum n\Delta G_f^\circ(\text{reactants})$

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

Solubility Table

Ion	Solubility	Exceptions
NO_3^-	soluble	none
ClO_4^-	soluble	none
Cl^-	soluble	except Ag^+, Hg_2^{2+}, *Pb^{2+}
I^-	soluble	except Ag^+, Hg_2^{2+}, Pb^{2+}
SO_4^{2-}	soluble	except Ca^{2+}, Ba^{2+}, Sr^{2+}, Hg^{2+}, Pb^{2+}, Ag^+
CO_3^{2-}	insoluble	except Group IA and NH_4^+
PO_4^{3-}	insoluble	except Group IA and NH_4^+
^-OH	insoluble	except Group IA, *Ca^{2+}, Ba^{2+}, Sr^{2+}
S^{2-}	insoluble	except Group IA, IIA and NH_4^+
Na^+	soluble	none
NH_4^+	soluble	none
K^+	soluble	none

*slightly soluble