CHEM 1515.001 - 005
Exam I
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Name _____

TA's Name _____

Section _____

INSTRUCTIONS:

1. This examination consists of a total of 11 different pages. The last three pages include a periodic table, a table of vapor pressures for water, a solubility table and a table of thermodynamic values. 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 2 and 3.

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	Page 6	MC	TOTAL
SCORES	_____	_____	_____	_____	_____	_____	_____
	(22)	(16)	(20)	(18)	(9)	(18)	(100)

(12) 1. Identify the intermolecular attractive force(s) present in the liquids of the following substances. If more than one interparticle force, indicate which is the most important.

a) SiH_4	b) HNO_3
c) CH_3NH_2	In the space below draw several HNO_3 molecules and label the intermolecular attraction that occurs between adjacent molecules.

(10) 2. Diethyl ether has a normal boiling point of 34.6 ˚C. At -20.0 ˚C the vapor pressure of diethyl ether is 85 mmHg, calculate the ΔH°_{vap} for diethyl ether.

(30) 3. For the reaction below, the thermodynamic parameters are given at 25 ˚C.

$$N_2O_3(g) \rightarrow NO(g) + NO_2(g)$$

For this reaction, $\Delta H° = +39.75$ kJ mol^{-1}

	$\Delta H_f°$ (kJ mol^{-1})	$\Delta G_f°$ (kJ mol^{-1})	S° (J mol^{-1} K^{-1})
NO(g)	90.25	87	+210.7
NO_2(g)	33.20	52	+239.9
N_2O_3(g)	83.7		+312.2

a) Calculate $\Delta S°$ for the reaction above at 25 °C. (6 points)

b) Calculate $\Delta G°$ for the reaction at 25 °C. (6 points)

c) Calculate $\Delta G_f°$ for N_2O_3(g) at 25 °C. (4 points)

d) How does ΔG°, for this reaction, change with an increase in temperature. Show your work to support your answer. (6 points)

e) Using data from this problem and data from the table of Thermodynamic Values at the end of this examination calculate ΔS° for the formation of $N_2O_3(g)$ at 25 $^{\circ}C$. (8 points)

(6) 4.)

(8) 5. CH_3CH_2OH boils at 78 °C and CH_3OCH_3 boils at - 24 °C. Explain the why ethyl alcohol has the higher boiling point. (NOTE: Be sure to address both substances in your explanation.)

(10)6a.

b)

Short Answer:

(9) 7. For each of the following changes indicate the sign (positive, negative or zero) for the enthalpy (ΔH), the entropy (ΔS) and the free energy (ΔG) for the system described. (3 points each)

a) $Br_2(l) \rightarrow Br_2(g)$ at a temperature above the boiling point of bromine;

ΔH is _____ ΔS is _____ ΔG is _____

b) An ideal gas expands into another container through a small hole at constant temperature;

ΔH is _____ ΔS is _____ ΔG is _____

c) $CH_3OH(l) \rightarrow CH_3OH(s)$ at a temperature below the freezing point of methanol;

ΔH is _____ ΔS is _____ ΔG is _____

Multiple Choice: (18 points)

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

8. _____ 9. _____ 10. _____ 11. _____

12. _____ 13. _____

ONLY THE ANSWERS IN THE AREA ABOVE WILL BE GRADED. Select the most correct answer for each question. Each question is worth 3 points.

8. Which of the following reactions is a formation reaction?

(A) $H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g)$
(B) $Cl_2(g) + 1/2\ O_2(g) \rightarrow Cl_2O(g)$
(C) $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
(D) $2\ NH_4Cl(s) \rightarrow N_2(g) + 4\ H_2(g) + Cl_2(g)$
(E) $Cl_2(g) \rightarrow 2\ Cl(g)$

9. Which of the following reactions has the largest **positive** value of ΔS?

(A) $H_2(g) \rightarrow 2\ H(g)$
(B) $Na_2S(g) + 2HCl(g) \rightarrow 2NaCl\ (aq) + H_2S(g)$
(C) $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$
(D) $Cu_2O(s) + H_2(g) \rightarrow 2\ Cu(s) + H_2O(g)$
(E) $NH_4NO_3(s) \rightarrow N_2(g) + O_2(g) + 2\ H_2O(g)$

10. The reaction

$$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$$

is thermodynamically spontaneous at 298 K, but becomes nonspontaneous at higher temperatures. Which of the following is true at 298 K?

(A) ΔG, ΔH, and ΔS are all positive.
(B) ΔG, ΔH, and ΔS are all negative.
(C) ΔG and ΔH are negative, but ΔS is positive.
(D) ΔG and ΔS are negative, but ΔH is positive.
(E) ΔG and ΔH are positive, but ΔS is negative.

11. A sample of water placed in an evacuated container exerts a pressure of 485 mmHg at 90.0 ˚C. The container is cooled to 80.0 ˚C. Which of the following is true at 80 ˚C;

(A) liquid and vapor exist and the vapor pressure is 472 mmHg
(B) vapor only and the pressure is 355 mmHg.
(C) vapor only and the pressure is 472 mmHg.
(D) liquid and vapor exist and the vapor pressure is 355 mmHg
(E) liquid and vapor exist and the vapor pressure is 431 mmHg

12. Which of the following is the correct order from lowest to highest melting point

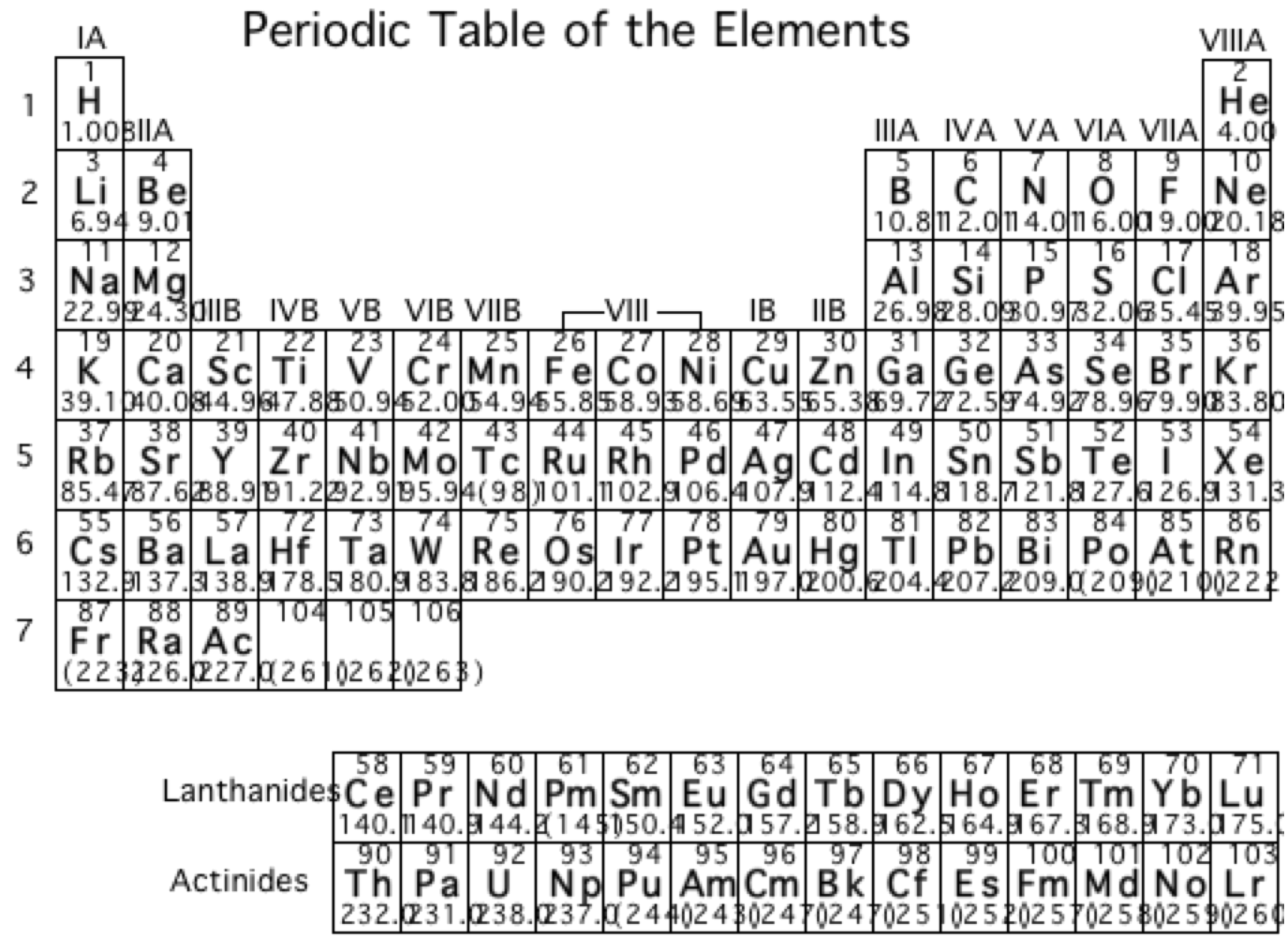
(A) HCl < HBr < HF < NaCl
(B) HF < HBr < NaCl < HCl
(C) NaCl < HCl < HBr < HF
(D) HBr < NaCl < HF < HCl
(E) HF < HCl < NaCl < HBr

13. At a given temperature the vapor pressure of acetone, methanol and carbon tetrachloride increase in the order

carbon tetrachloride < methanol < acetone

Identify the substance with the

	Highest boiling point	weakest intermolecular attractive forces	largest ΔH°_{vap}
(A)	acetone	acetone	carbon tetrachloride
(B)	methanol	acetone	carbon tetrachloride
(C)	carbon tetrachloride	acetone	carbon tetrachloride
(D)	carbon tetrachloride	methanol	acetone
(E)	acetone	carbon tetrachloride	methanol



Useful Information

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

$\ln\left(\frac{vp_2}{vp_1}\right) = -\frac{\Delta H^\circ_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$ $\qquad$ density of $H_2O = 1.00 \frac{g}{cm^3}$

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

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

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

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

Equilibrium Vapor Pressure for Water

Temperature (°C)	Vapor Pressure(mmHg)	Temperature (°C)	Vapor Pressure(mmHg)
-5	3.2	50	92.5
0	4.6	55	118.0
5	6.52	60	149.4
10	9.20	65	187.5
15	12.8	70	233.7
20	17.5	75	289.1
25	23.8	80	355.1
30	31.8	85	433.6
35	42.1	90	525.8
40	55.3	95	633.9
45	71.9	100	760

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

Thermodynamic Values (25 °C)

Substance and State	ΔH^o_f $\left(\frac{kJ}{mol}\right)$	ΔG^o_f $\left(\frac{kJ}{mol}\right)$	S^o $\left(\frac{J}{K \cdot mol}\right)$
Carbon			
C(*s*) (graphite)	0	0	6
C(*s*) (diamond)	2	3	2
CO(*g*)	-110.5	-137	198
CO_2(*g*)	-393.5	-394	214
CH_4(*g*)	?	-51	186
CH_3OH(*g*)	-201	-163	240
CH_3OH(*l*)	-239	-166	127
CH_3Cl(*g*)	-80.8	-57.4	234
$CHCl_3$(*g*)	-100.8		
$CHCl_3$(*l*)	-131.8		
H_2CO(*g*)	-116	-110	219
HCOOH(*g*)	-363	-351	249
HCN(*g*)	135.1	125	202
C_2H_2(*g*)	227	209	201
C_2H_4(*g*)	52	68	219
CH_3CHO(*g*)	-166	-129	250
C_2H_5OH(*l*)	-278	-175	161
C_2H_6(*g*)	-84.7	-32.9	229.5
C_3H_6(*g*)	20.9	62.7	266.9
C_3H_8(*g*)	-104	-24	270
Bromine			
Br_2(*l*)	0	0	152.
BrCl(*g*)	14.64	-0.96	240
Chlorine			
Cl_2(*g*)	0	0	223
Cl_2(*aq*)	-23	7	121
Cl^-(*aq*)	-167	-131	57
HCl(*g*)	-92	-95	187
Fluorine			
F_2(*g*)	0	0	203
F^-(*aq*)	-333	-279	-14
HF(*g*)	-271	-273	174
Hydrogen			
H_2(*g*)	0	0	131
H(*g*) 217	203	115	
H^+(*aq*)	0	0	0
OH^-(*aq*)	-230	-157	-11
H_2O(*l*)			
H_2O(*g*)	-242	-229	189
Magnesium			
Mg(s)	0	0	33
Mg(aq)	-492	-456	-118
MgO(s)	-601	-569	26.9

Substance and State	ΔH^o_f $\left(\frac{kJ}{mol}\right)$	ΔG^o_f $\left(\frac{kJ}{mol}\right)$	S^o $\left(\frac{J}{K \cdot mol}\right)$
Oxygen			
O_2(*g*)	0	0	205
O(*g*) 249	232	161	
O_3(*g*)	143	163	239
Nitrogen			
N_2(*g*)	0	0	192
NCl_3(*g*)	230	271	-137
NF_3(*g*)	-125	-83.6	-139
NH_3(*g*)	?	-17	193
NH_3(*aq*)	?	-27	111
NH_2CONH_2(aq)	?	?	174
NO(*g*)	90	87	211
NO_2(*g*)	32	52	240
N_2O(*g*)	82	104	220
N_2O_4(*g*)	10	98	304
N_2O_5(*g*)	-42	134	178
HNO_3(*aq*)	-207	-111	146
HNO_3(*l*)	-174	-81	156
NH_4Cl(s)	-314	-201	95
NH_4ClO_4(*s*)	-295	-89	186
Silver			
Ag(*s*)	0	0	42.6
Ag^+(*aq*)	105.6	77.1	72.7
$Ag(S_2O_3)^{3-}$(*aq*)	-1285.7	--	--
AgBr(s)	-100.4	-96.9	107.1
AgCl(s)	-127.1	-109.8	96.2
Sulfur			
S(rhombic)	0	0	31.8
SO_2(g)	-296.8	-300.2	248.8
SO_3(g)	-395.7	-371.1	256.3
H_2S(g)	-20.17	-33.0	205.6
Phosphorus			
P_4(*s*)	0	0	41.1
PCl_5(*g*)	-375	-305	365
Aluminum			
$AlCl_3$(*s*)	-526	-505	184
Barium			
$BaCl_2$(*aq*)	-872	-823	123
$Ba(OH)_2 \cdot 8H_2O$(*s*)	-3342	-2793	427
Iodine			
I_2(*s*)	0	0	116.7
HI(*g*)	25.94	1.30	206.3

Activity Series

Metal	Half-Reaction Reaction
Gold	$Au^{3+} + 3e^- \rightarrow Au$
Platinum	$Pt^{2+} + 2e^- \rightarrow Pt$
Mercury	$Hg^{2+} + 2e^- \rightarrow Hg$
Silver	$Ag^{+} + e^- \rightarrow Ag$
Copper	$Cu^{2+} + 2e^- \rightarrow Cu$
Hydrogen	$2H^{+} + 2e^- \rightarrow H_2$
Lead	$Pb^{2+} + 2e^- \rightarrow Pb$
Tin	$Sn^{2+} + 2e^- \rightarrow Sn$
Nickel	$Ni^{2+} + 2e^- \rightarrow Ni$
Cobalt	$Co^{2+} + 2e^- \rightarrow Co$
Iron	$Fe^{2+} + 2e^- \rightarrow Fe$
Chromium	$Cr^{3+} + 3e^- \rightarrow Cr$
Zinc	$Zn^{2+} + 2e^- \rightarrow Zn$
Manganese	$Mn^{2+} + 2e^- \rightarrow Mn$
Aluminum	$Al^{3+} + 3e^- \rightarrow Al$
Magnesium	$Mg^{2+} + 2e^- \rightarrow Mg$
Sodium	$Na^{+} + e^- \rightarrow Na$
Calcium	$Ca^{2+} + 2e^- \rightarrow Ca$
Barium	$Ba^{2+} + 2e^- \rightarrow Ba$
Potassium	$K^{+} + e^- \rightarrow K$
Lithium	$Li^{+} + e^- \rightarrow Li$

$\xrightarrow[]{H_2O}$

(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. **Soluble ionic compounds should be written in the form of their component ions.**

a) $Na_3PO_{4(aq)} + Mg(NO_3)_{2(aq)} \rightarrow$

b) $Na_2CO_{3(aq)} + HCl_{(aq)} \rightarrow$

c) $C_8H_{16(l)} + O_{2(g)} \rightarrow$

(4) 2a. Write the ionic and net ionic chemical equation for 1a) or 1b).

Ionic equation

Net Ionic equation