CHEM 1515.001 - 006
Exam I
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February 5, 2002

Name ______________________

TA's Name ______________________

Section _______

INSTRUCTIONS:

1. This examination consists of a total of 8 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 4a, 4d and 8.

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	TOTAL
SCORES	____ (23)	____ (35)	____ (18)	____ (24)	____ (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. Soluble ionic compounds should be written in the form of their component ions.

a) **2**$K(s)$ + **2**$H_2O(l)$ $\rightarrow$ **$2K^+(aq)$ + $2OH^-(aq)$ + $H_2(g)$**

b) $Na_2CO_3(aq)$ + $Ca(NO_3)_2(aq)$ $\rightarrow$ **$2Na^+(aq)$ + $2NO_3^-(aq)$ + $CaCO_3(s)$**

c) $Ba(OH)_2 \cdot 8H_2O(s)$ + **2**$NH_4SCN(s)$ $\rightarrow$ **$Ba^{2+}(aq)$ + $10H_2O(l)$ + $2NH_3(aq)$ + $2SCN^-(aq)$**

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

Ionic equation

$2Na^+(aq)$ + $CO_3^{2-}(aq)$ + $Ca^{2+}(aq)$ + $2NO_3^-(aq)$ $\rightarrow$ $2Na^+(aq)$ + $2NO_3^-(aq)$ + $CaCO_3(s)$

Net Ionic equation

$CO_3^{2-}(aq)$ + $Ca^{2+}(aq)$ $\rightarrow$ $CaCO_3(s)$

(10) 3. Predict whether the entropy change in the system is positive or negative for each of the following processes.

a) $CH_3OH(l)$ + $O_2(g)$ $\rightarrow$ $HCO_2H(l)$ + $H_2O(l)$

The phases are both liquid, while the reactants are a liquid and a gas. There are equal numbers of moles, and the liquid phase is more ordered compared to the gas phase, so the products are more ordered compared to the reactants and ΔS is –.

b) $2SO_3(g)$ $\rightarrow$ $2SO_2(g)$ + $O_2(g)$

The reactants and products are all in the same phase, but there are more moles of products compared to reactants. So there are more possible arrangements in the products compared to the reactants and ΔS is +.

4. Methanol, CH_3OH, can be synthesized by reacting hydrogen gas with carbon monoxide, according to the chemical equation,

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$$

(18) a) Calculate ΔH°_{rxn}, ΔS°_{rxn} and ΔG°_{rxn}.

	$CO(g)$	+	$2H_2(g)$	→	$CH_3OH(l)$
$\Delta H^\circ_f \left(\frac{kJ}{mol}\right)$	**-110.5**		**-0**		**–239**
$S^\circ \left(\frac{J}{K\cdot mol}\right)$	**198**		**131**		**127**
$\Delta G^\circ_f \left(\frac{kJ}{mol}\right)$	**-137**		**-0**		**–166**

$$\Delta H^\circ_{rxn} = \Sigma\Delta H^\circ_f \text{ (products)} - \Sigma\Delta H^\circ_f \text{ (reactants)}$$

$$= [\Delta H^\circ_f (CH_3OH(l))] - [\Delta H^\circ_f (CO(g)) + 2\Delta H^\circ_f (H_2(g))]$$

$$= (-239 \text{ kJ}) - [(-110.5 \text{ kJ}) + 2(0 \text{ kJ})] = -128 \text{ kJ}$$

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

$$= [S^\circ(CH_3OH(l))] - [S^\circ(CO(g)) + 2S^\circ(H_2(g))]$$

$$= [(127 \tfrac{J}{K})] - [(198 \tfrac{J}{K}) + 2(131 \tfrac{J}{K})] = -333 \text{ J/K}$$

$$\Delta G^\circ_{rxn} = \Sigma\Delta G^\circ_f \text{ (products)} - \Sigma\Delta G^\circ_f \text{ (reactants)}$$

$$= [\Delta G^\circ_f (CH_3OH(l))] - [\Delta G^\circ_f (CO(g)) + 2\Delta G^\circ_f (H_2(g))]$$

$$= (-166 \text{ kJ}) - [(-137 \text{ kJ}) + 2(0 \text{ kJ})] = -29 \text{ kJ}$$

(4) b) Which factor, the change in enthalpy, ΔH°, or the change in entropy, ΔS°, provides the principal driving force for the reaction at 298 K? Explain.

ΔH is the principal driving force, because the sign of ΔH in the reaction is negative. A –ΔH favors spontaneity. ΔS is also negative. –ΔS does not favor spontaneity.

Since ΔG = ΔH – TΔS a spontaneous reaction has a negative ΔG. In this equation spontaneity is favored by a –ΔH and a +ΔS. In the reaction in part a only the sign of ΔH favors spontaneity.

(5) c) For the reaction, how is the value of the standard free energy change, ΔG°, affected by an increase in temperature? Explain.

Using the equation ΔG = ΔH – TΔS, since ΔH is negative and ΔS is negative as the temperature increases the TΔS term is becoming more negative, and –TΔS is more positive, making ΔG˚ more positive and less spontaneous.

(8) d) Calculate the ΔS°_f for $CH_3OH(l)$.

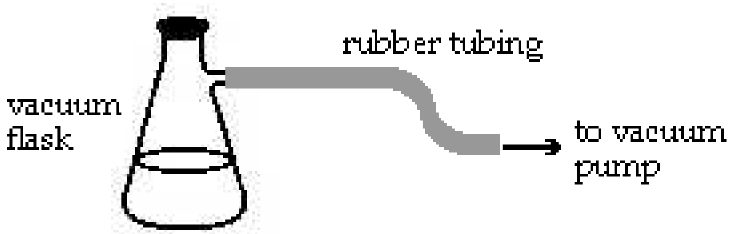
	$C(s)$ +	$2H_2(g)$	+	$\frac{1}{2}O_2(g)$	→	$CH_3OH(l)$
$S^\circ \left(\frac{J}{K\cdot mol}\right)$	**6**	**131**		**205**		**127**

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

$$= [S^\circ(CH_3OH(l))] - [S^\circ(C(s)) + 2S^\circ(H_2(g)) + \tfrac{1}{2} S^\circ(O_2(g))]$$

$$= [(127 \tfrac{J}{K})] - [(6 \tfrac{J}{K}) + 2(131 \tfrac{J}{K}) + \tfrac{1}{2}(205 \tfrac{J}{K})] = -243 \text{ J/K}$$

(12) 5. A sample of water is in the vacuum flask shown below.



The vacuum flask side arm has vacuum rubber tubing with one end attached to the flask and the other end attached to a vacuum pump (can not see in this diagram). When the vacuum pump is on any gas/vapor in the flask is removed.

In an experiment the water placed into the flask initially is at room temperature. The rubber tubing is attached to the flask and the vacuum pump, and the pump is turned on. After the pump has been on for several minutes the following two observations are made:

1. the volume of water in the flask has decreased;
2. what water remains has turned to ice.

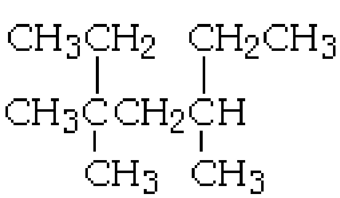
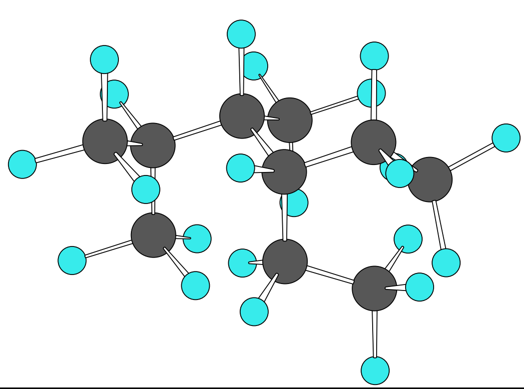
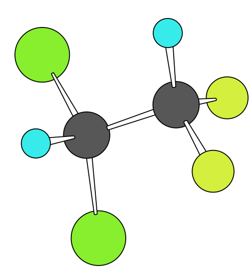
Explain both of these observations.

The volume of liquid water decreases because as the vacuum pump removes vapor from above the liquid, particles escape the liquid phase to maintain the equilibrium vapor pressure. Since particles are evaporating and few particles are condensing, the volume of the liquid will decrease.

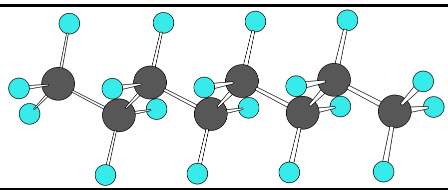
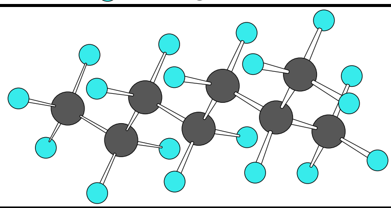
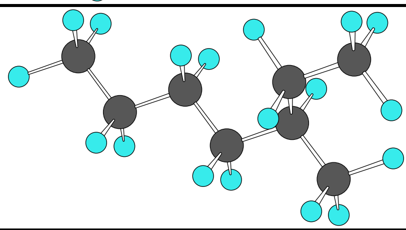
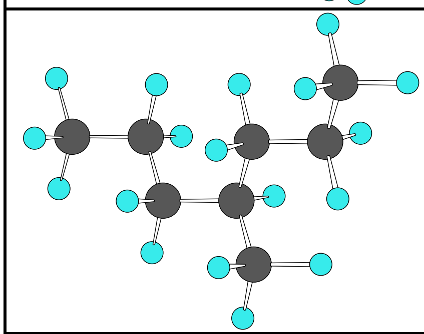
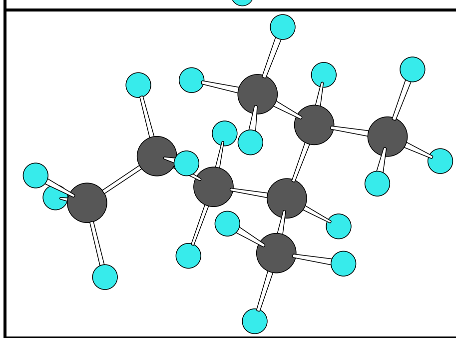
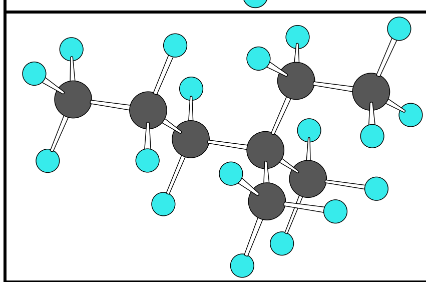
The reason the liquid eventually turns to solid is because evaporation is an endothermic process, and heat is removed from the system (the liquid water). When enough heat is removed the liquid freezes.

Evaporation is endothermic because the conversion of water in the liquid phase to water in the vapor phase requires breaking hydrogen-bonding forces. Breaking bonds is always an endothermic process.

(6) 6. Give the name or draw the complete Lewis structure (showing all C-H(X) bonds) for each of the following compounds.

 **3, 3, 5–trimethylheptane**	4-ethyl-2,3-dimethylhexane 	1,1-dichloro-2,2-difluoroethane 

(12) 7. Draw and name six different structural isomers for C_8H_{18}. (NOTE: You may use condensed formulas when representing the different structural isomers.)

	***n*–octane**
	**2-methylheptane**
	**3-methylheptane**
	**4-methylheptane**
	**2,3-dimethylhexane**
	**3,3-dimethylhexane**

(12) 8. CH_3I has a vapor pressure of 400 mm Hg at 25.3 ˚C. Calculate the temperature that CH_3I has a vapor pressure of 40.0 mm Hg. ΔH°_{vap} for CH_3I is 29.2 kJ mol^{-1}.

$$\ln \frac{P_1}{P_2} = \frac{-\Delta H}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\ln \frac{400}{40} = \frac{-29200 \frac{J}{mol}}{8.314 \frac{J}{mol \cdot K}}\left(\frac{1}{298.3\ K} - \frac{1}{T_1}\right)$$

$$\ln (10) = -3512\ K\left(3.35 \times 10^{-3} - \frac{1}{T_1}\right)$$

$$2.303 = -3512\ K\left(3.35 \times 10^{-3} - \frac{1}{T_1}\right)$$

$$-6.56 \times 10^{-4} = 3.35 \times 10^{-3} - \frac{1}{T_1}$$

$$\frac{1}{T_1} = 4.00 \times 10^{-3} \qquad T_1 = 250\ K$$

Periodic Table of the Elements

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1 **H** 1.008																	2 **He** 4.00
2	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
3	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
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	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** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
5	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
6	55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	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)
7	87 **Fr** (223)	88 **Ra** 226.0	89 **Ac** 227.0	104 (261)	105 (262)	106 (263)												

Lanthanides	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	71 **Lu** 175.0
Actinides	90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237.0	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** (260)

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

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

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

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

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

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

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
Titanium			
$TiCl_4$(*g*)	-763	-727	355
TiO_2(*s*)	-945	-890	50
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

$\overset{H_2O}{\rightarrow}$