

CHEM 1515.001 – 1515.006
Exam I
John I. Gelder
February 8, 2001

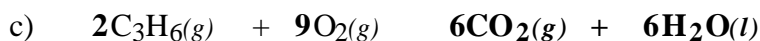
Name _____
TA's Name _____
Lab Section _____

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, 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 problems 4c and 7.
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	TOTAL
SCORES	<u>(24)</u>	<u>(16)</u>	<u>(24)</u>	<u>(18)</u>	<u>(18)</u>	<u>(100)</u>

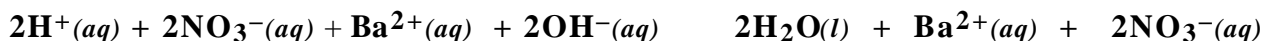
- (9) 1. Write the chemical formula(s) of the product(s) and balance the following reactions. Identify all products phases as either (g)as, (l)iquid, (s)olid or (aq)ueous. Soluble ionic compounds should be written in the form of their component ions.



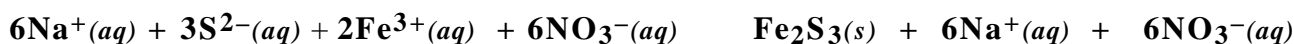
- (4) 2. Write the ionic and net ionic chemical equations for 1a) or 1b).

1a)

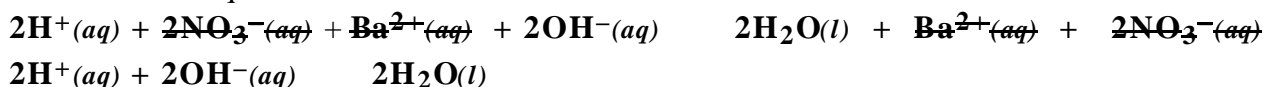
Ionic equation:



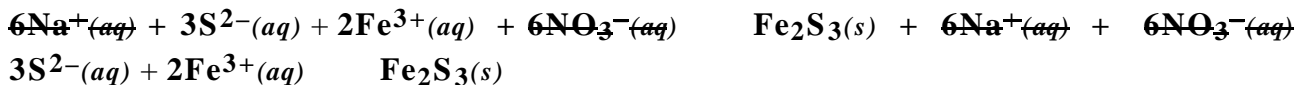
or



Net Ionic equation:



or



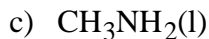
- (11) 3. Identify the intermolecular attractive force(s) present in the following substances. If more than one intermolecular force, indicate which is the most important.



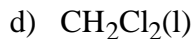
N_2 is a nonpolar element and London dispersion forces only



SO_2 is a polar compound and has dipole-dipole and London dispersion forces. Since S is in the third period the LDF is be more important.



CH_2NH_2 is a polar compound and has hydrogen-bonding and London dispersion forces. Hydrogen-bonding is be more important.



CH_2Cl_2 is a polar compound and has dipole-dipole and London dispersion forces. Since Cl is present LDF is be more important.

(16)4a. Define the term equilibrium vapor pressure.

Equilibrium vapor pressure is the pressure due to the vapor above a liquid at a given temperature.

Equilibrium is achieved when the rate of evaporation equals the rate of condensation.

b) What is the equilibrium vapor pressure for water at 90 °C?

Looking up in the table on the Useful Information sheet the equilibrium vapor pressure for water at 90 °C is 525.8 mmHg.

c) A 1.80 g sample of pure water is injected into a 4.00 L evacuated vessel at 95.0 °C. Calculate the pressure exerted by the sample of water assuming it is completely vaporized.

To do this problem we assume ALL of the water is in vapor phase.

$$1.80 \text{ g} \frac{1 \text{ mol}}{18.0 \text{ g}} = 0.100 \text{ mol}$$

$$PV = nRT \quad P = \frac{nRT}{V} = \frac{0.100 \text{ mol} \cdot 0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}} \cdot 368}{4.00 \text{ L}} = 0.755 \text{ atm}$$

$$0.755 \text{ atm} \frac{760 \text{ mmHg}}{1 \text{ atm}} = 574 \text{ mmHg}$$

d) Is the assumption the sample water is completely vaporized at 95.0 °C in this 4.00 L vessel reasonable? Explain.

Yes, it is reasonable. The equilibrium vapor pressure of water at 95 °C is 634 mmHg. The calculated pressure assuming all the water is in the vapor phase was 574 mmHg, which is less than the equilibrium vapor pressure. So all of the water is in the vapor phase at 95 °C.

e) If the sample in the vessel is cooled to 90.0 °C, indicate the phase(s) present and the pressure exerted by water in the vapor phase.

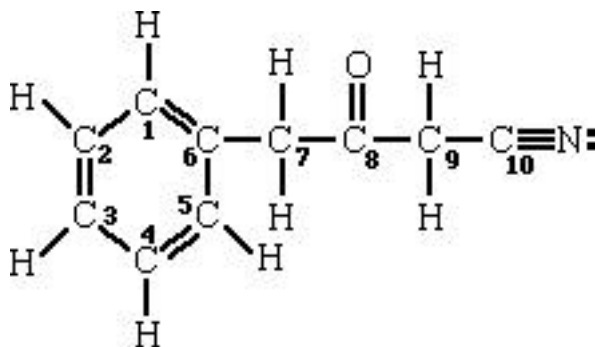
When the sample of water in the vapor phase at 95 °C is cooled to 90 °C the new pressure is;

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad \frac{574 \text{ mmHg}}{368 \text{ K}} = \frac{P_2}{363 \text{ K}}$$

$$P_2 = \frac{574 \text{ mmHg} \cdot 363 \text{ K}}{368 \text{ K}} = 566 \text{ mmHg}$$

So the calculated pressure due to water in the vapor phase at 90 °C is 566 mmHg. The equilibrium vapor pressure for water at 90 °C is 525.8 mmHg. The calculated value exceeds the equilibrium vapor pressure at the temperature. Since the equilibrium vapor pressure at a particular temperature is the maximum pressure possible, and the calculated is higher than that value, condensation must occur. The final pressure about the liquid at 90 °C is 525.8 mmHg.

(24)5a. What is the hybridization on each of the designated *central atoms* in the molecule shown below.



C ₁	sp²	C ₈	sp²
C ₂	sp²	C ₉	sp³
C ₃	sp²	C ₁₀	sp
C ₇	sp³		

b) What is the bond angle for each of the following combination of atoms?

C₁-C₆-C₇ **120°**

H-C₇-C₈ **109.5°**

C₉-C₁₀-N **180°**

C₉-C₈-O **120°**

f) Determine the number of sigma and pi-bonds in the structure.

21 sigma bonds and 6 pi bonds

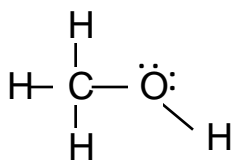
d) Clearly identify the portion(s) of the molecule where delocalized electrons are located.

The ring containing C₁-C₆ contains delocalized electrons. Each of those carbon atoms is sp² hybridized. So each of these carbon atoms has a single pure 'p' orbital that contains a single electron. Since all of the C atoms are bonded together the electrons are delocalized over all of those carbon atoms.

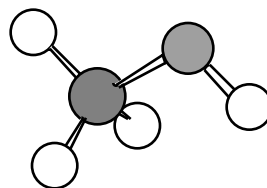
e) Identify the types of atomic or hybrid orbitals needed to explain the bonding in the CN functional group on this molecule and between C₆ and C₇.

The sigma bond between the carbon and the nitrogen atom uses an Sp hybrid orbital on the carbon overlapping with an sp hybrid orbital on the nitrogen. The two pi bond between the carbon and the nitrogen are formed from the remaining two 2p orbitals on carbon and the two 2p orbitals on nitrogen.

- (18)6a. Below is the Lewis structure and a ball-and-stick model of methyl alcohol. Indicate the molecular geometry about both the carbon and the oxygen atom.



Lewis structure



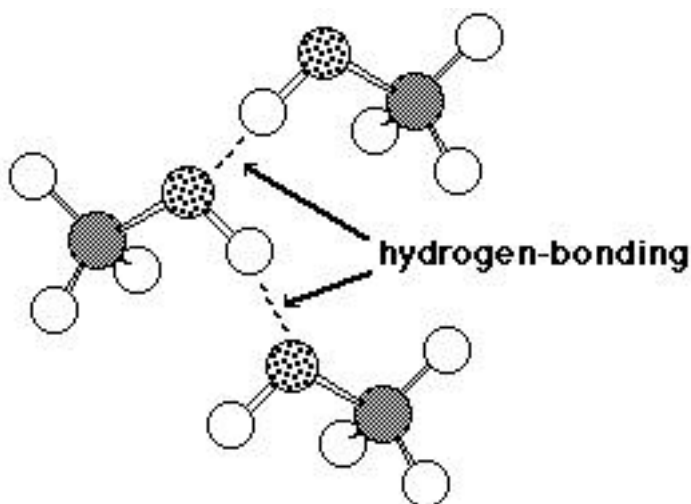
ball-and-stick model

The molecular geometry around the carbon atom is tetrahedral and around the oxygen atom is bent.

- b) What is the most important intermolecular attractive force that occurs in liquid methyl alcohol?

Hydrogen-bonding is the most important IMF.

- c) Draw several methyl alcohol molecules and clearly indicate how adjacent molecules interact. In your sketch label the most important intermolecular attractive force between adjacent methyl alcohol molecules.



- d) Methyl alcohol has a normal boiling point of $64.5\text{ }^{\circ}\text{C}$, Monofluoromethane, CH_3F , has a normal boiling point of $-78.4\text{ }^{\circ}\text{C}$. Both of these compounds have approximately the same molar mass, explain the large difference in boiling points.

Methyl alcohol has hydrogen-bonding. CH_3F is polar but does NOT have any hydrogen bonding in the pure substance. There are only dipole-dipole forces and dipole-dipole forces are weaker compared to hydrogen-bonding so CH_3F has a lower boiling point compared to methanol.

- (18)7a. Isopropyl alcohol, C_3H_8O , has a vapor pressure of 219.0 mmHg at 24.0 °C. If the $H^\circ_{\text{vaporization}}$ is $19.3 \frac{\text{kJ}}{\text{mol}}$, calculate the vapor pressure of isopropyl alcohol at 39.5 °C.

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

$$\ln \frac{P_1}{219 \text{ mmHg}} = \frac{-19300 \frac{\text{J}}{\text{mol}}}{8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}}} \left(\frac{1}{312.5 \text{ K}} - \frac{1}{297 \text{ K}} \right)$$

$$\ln \frac{P_1}{219 \text{ mmHg}} = -2321 \text{ K}^{-1} \cdot -1.67 \times 10^{-4} \text{ K}^{-1}$$

$$\ln \frac{P_1}{219 \text{ mmHg}} = 0.388$$

$$\frac{P_1}{219 \text{ mmHg}} = e^{0.388} = 1.47$$

$$P_1 = 323 \text{ mmHg}$$

- b) What is the normal boiling point for isopropyl alcohol?

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

$$\ln \frac{760}{219} = \frac{-19300 \frac{\text{J}}{\text{mol}}}{8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}}} \left(\frac{1}{T_2} - \frac{1}{297 \text{ K}} \right)$$

$$\ln (3.47) = -2321 \left(\frac{1}{T_2} - \frac{1}{297 \text{ K}} \right)$$

$$1.24 = -3848.9 \left(\frac{1}{T_2} - \frac{1}{297 \text{ K}} \right)$$

$$-5.36 \times 10^{-4} = \left(\frac{1}{T_2} - 3.37 \times 10^{-3} \right)$$

$$\frac{1}{T_2} = 3.11 \times 10^{-3}$$

$$T_2 = 353 \text{ K}$$

Periodic Table of the Elements

	IA																	VIII A	
1	1 H 1.008																		2 He 4.00
		IIA										IIIA	IVA	VA	VIA	VIIA			
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		
			IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB							
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 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)										

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

$$PV = nRT$$

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

$$\text{density of H}_2\text{O} = 1.00 \frac{\text{g}}{\text{cm}^3}$$

$$q = \text{mass} \cdot \text{Specific heat} \cdot T$$

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

$$\text{density of H}_2\text{O} = 1.00 \frac{\text{g}}{\text{cm}^3}$$

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

<u>Ion</u>	<u>Solubility</u>	<u>Exceptions</u>
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