CHEM 1515.001
Exam II
John II. Gelder
March 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, a solubility table, and a table of ionic structures and packing. 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 4, 5 and 9.

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	____ (25)	____ (26)	____ (20)	____ (29)	____ (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) $Al(s) + KOH(aq) + H_2O(l) \rightarrow \mathbf{H_2(g) + K^+(aq) + Al(OH)_4^-(aq)}$

b) $Na_2CO_3(s) + \mathbf{2}HCl(aq) \rightarrow \mathbf{2Na^+(aq) + 2Cl^-(aq) + CO_2(g) + H_2O(l)}$

c) $\mathbf{2}Na_3PO_4(aq) + \mathbf{3}Ba(NO_3)_2(aq) \rightarrow \mathbf{Ba_3(PO_4)_2(s) + 6Na^+(aq) + 6NO_3^-(aq)}$

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

1b)

Ionic equation:

$\mathbf{Na_2CO_3(s) + 2H^+(aq) + 2Cl^-(aq) \rightarrow 2Na^+(aq) + 2Cl^-(aq) + CO_2(g) + H_2O(l)}$

Net Ionic equation:

$\mathbf{Na_2CO_3(s) + 2H^+(aq) + \cancel{2Cl^-(aq)} \rightarrow 2Na^+(aq) + \cancel{2Cl^-(aq)} + CO_2(g) + H_2O(l)}$

$\mathbf{Na_2CO_3(s) + 2H^+(aq) \rightarrow 2Na^+(aq) + CO_2(g) + H_2O(l)}$

(12) 3. When a liquid solute is added to a liquid solvent we discussed three steps important to the solution process as it related to the enthalpy of the solution.

a) List the three steps and indicate whether the step is exothermic or endothermic;

1. solute-solute attractive forces must be overcome.....endothermic
2. solvent-solvent attractive forces must be overcome.....endothermic
3. solute-solvent attractive forces are formed.....exothermic

b) In terms of these three steps explain why a particular solute does not dissolve in a particular solvent.

If a solute does not dissolve than the energy released in step 3) above is less than the sum of the energies in steps 1 and 2. So the overall enthalpy of the reaction is positive and the favorable entropy of mixing is not sufficient for solution formation to occur.

(10) 4. A certain metal has a density of 10.200 g mL^{-1} at 25 ˚C. It crystallizes in a body-centered cubic unit cell with an atomic radius of 1.36×10^{-8} cm. Calculate the molar mass of the element and identify the substance.

$$l = \frac{4r}{\sqrt{3}} = \frac{4 \cdot 1.36 \text{ x } 10^{-8} \text{ cm}}{\sqrt{3}} = 3.1 \text{ x } 10^{-8} \text{ cm}$$

volume of the unit cell is $(3.1 \text{ x } 10^{-8} \text{ cm})^3 = 3.06 \text{ x } 10^{-23} \text{ cm}^3$

$$3.06 \text{ x } 10^{-23} \text{ cm}^3 \cdot 10.200 \frac{\text{g}}{\text{cm}^3} = 3.12 \text{ x } 10^{-22} \text{ g}$$

Since the unit cell is body-centered there are $\frac{2 \text{ atom}}{\text{unit cell}}$ **. We use Avogadro's number to get the number of moles of atoms in the unit cell.**

$$\frac{2 \text{ atom}}{\text{unit cell}} \left(\frac{1 \text{ mol}}{6.02 \text{ x } 10^{23} \text{ atoms}} \right) = 3.32 \text{ x } 10^{-24} \text{ mol}$$

molar mass of the element is $\frac{3.12 \text{ x } 10^{-22} \text{ g}}{3.32 \text{ x } 10^{-24} \text{ mol}} = 95.1 \text{ g mol}^{-1}$

the unknown element is molybdenum.

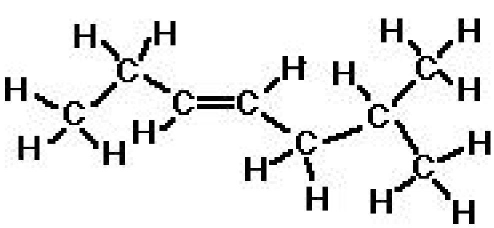
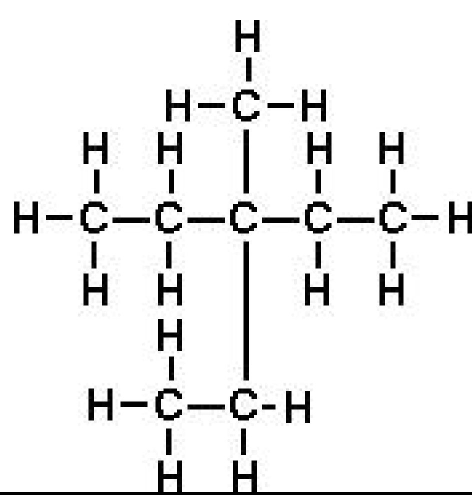
(10) 5. In magnesium oxide the ionic radius of Mg^{2+} is 0.65 Å and the ionic radius of O^{2-} is 1.40 Å. Assuming the oxide ion defines the unit cell and the cation occupies holes in the lattice, describe a probable structure for the ionic compound.

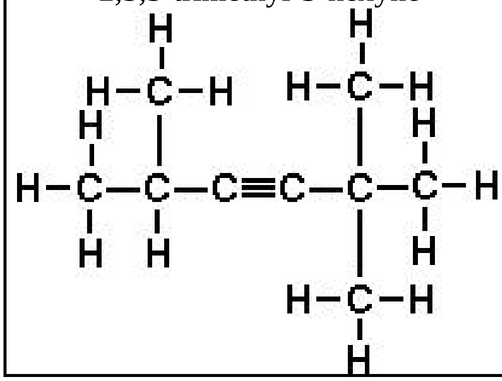
Determine the cation/anion ratio

$$\frac{0.65 \text{ Å}}{1.40 \text{ Å}} = 0.464$$

according to the Lattice Types and Radius Ratios of Cations and Anions information on the Useful Information page MgO crystallizes in the Rock Salt unit cell. This is the same as the sodium chloride unit cell. So the unit cell is face-centered cubic in oxide ions with magnesium cations in every octahedral hole.

(6) 6. Give the name or draw the Lewis structure for each of the following compounds.

 ***trans*-6-methyl-3-heptene**	3-ethyl-3-methylpentane 	

2,5,5-trimethyl-3-hexyne 		

(10) 7. Draw and name four of the structural isomers for C_6H_{10}.

(10) 8. Which member of the following pairs is more soluble in water? Provide a brief explanation supporting your choice. Also provide a brief explanation why you ruled out the other choice.

a) HCl or C_4H_9Cl

HCl is more soluble. HCl is a polar covalent molecule that dissociates completely into ions when added to water. C_4H_9Cl is nonpolar, or very nearly nonpolar, has only London Dispersion forces, and is insoluble in water.

b) CH_3NH_2 or $(CH_3)_3N$

CH_3NH_2 and $(CH_3)_3N$ can hydrogen bond in water. But CH_3NH_2 will form more hydrogen bonds with water compared to $(CH_3)_3N$ and is more soluble.

(29) 9. A solution of formic acid, HCOOH, is prepared by 54.0 g of formic acid in enough water to make 250 mLs of solution.

a) calculate the molarity of the solution;

$$\mathbf{54.0\ g\left(\frac{1\ mol}{46\ g}\right) = 1.17\ mol}$$

$$\mathbf{\frac{1.17\ mol}{0.250\ L} = 4.70\ M}$$

b) the solution described above is also 20.0 % by weight formic acid. Calculate the mole fraction of formic acid in the solution;

Assume 100 g of solution

$$\mathbf{20\ g\ HCOOH\left(\frac{1\ mol}{46\ g}\right) = 0.435\ mol}$$

$$\mathbf{80\ g\ H_2O\left(\frac{1\ mol}{18\ g}\right) = 4.44\ mol}$$

$$\mathbf{mol\ fraction\ HCOOH = \frac{0.435\ mol}{0.435\ mol + 4.44\ mol} = 0.891}$$

c) assuming formic acid is a nonvolatile, nonelectrolyte calculate the freezing point of this solution;

$$\mathbf{molality = \frac{mol\ HCOOH}{kg\ solvent} = \frac{0.435\ mol\ HCOOH}{0.080\ kg} = 5.44\ molal}$$

$$\mathbf{\Delta T_f = iK_f m = 1 \cdot 1.86\ ^\circ C\ m^{-1} \cdot 5.44\ molal = 10.1\ ^\circ C}$$

$$\mathbf{T_f = -10.1\ ^\circ C}$$

d) formic acid is actually a weak acid. Suggestion a reasonable experimental freezing point (do not calculate) for this solution? Explain your answer.

If formic acid is a weak acid than the number of particles will be slightly more than if formic acid were a nonelectrolyte. So I will be a little larger than 1...say 1.05. So the freezing point will be a little more negative than –10.1 ˚C, like –11 or –12 ˚C.

e) Calculate the density of the solution.

$$\mathbf{\frac{54.0\ g\ HCOOH}{250\ mLs\ solution}\left(\frac{100\ g\ solution}{20.0\ g\ HCOOH}\right) = 1.08\ \frac{g}{mLs}}$$

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 **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

$\Delta T = i k m$ $\quad k_f(H_2O) = 1.86\ \frac{^\circ C}{m}$ $\quad k_b(H_2O) = 0.512\ \frac{^\circ C}{m}$

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

$P_{solution} = \chi_{solvent}\ P^\circ_{solvent}$

edge length (l) = 2r $\quad$ edge length (l) = $2\sqrt{2} \cdot r$ $\quad$ edge length (l) = $\frac{4r}{\sqrt{3}}$

density of $H_2O = 1.00\ \frac{g}{cm^3}$ $\quad 6.023 \times 10^{23}$

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

Simple Ionic Structures Grouped According to Anion Packing

Structure Name	Anion Packing	Coordination Number	Sites Occupied by Cations	Examples
Rock Salt	ccp	6:6 MO	all octahedral	NaCl, LiF, KBr, CdO, FeO
Zinc Blende	ccp	4:4 MO	$\frac{1}{2}$ tetrahedral	ZnS, BeO, SiC
Antifluorite	ccp	4:8 M_2O	all tetrahedral	Li_2O, sulfides
Rutile	distorted ccp	6:3 MO_2	$\frac{1}{2}$ octahedral	TiO_2, GeO_2, MnO_2, OsO_2
Perovskite	ccp	12:6:6 ABO_3	$\frac{1}{4}$ octahedral(B)	$CaTiO_3$, $SrSnO_3$
Spinel	ccp	4:6:4 AB_2O_4	$\frac{1}{8}$ tetrahedral(A) $\frac{1}{2}$ octahedral(B)	$MgAl_2O_4$, $FeAlO_4$
Cesium Chloride	simple cubic	8:8 MO	all cubic	CsCl, CsBr, CsI
Florite	simple cubic	8:4 MO_2	$\frac{1}{2}$ cubic	CaF_2, UO_2, ThO_2

Lattice Types and Radius Ratios of Cations and Anions

Radius Ratio (Cation/Anion)	Lattice Type	Coordination Number of Cation	Anion
A. 1:1 Stoichiometry of Salt (MX)			
0.225 – 0.414	Zinc Blende	4	4
0.414 – 0.732	Rock salt (NaCl)	6	6
0.732 – 1.000	Cesium chloride	8	8
B. 1:2 Stoichiometry of Salt (MX_2)			
0.225 – 0.414	Beta-quartz	4	2
0.414 – 0.732	Rutile (TiO_2)	6	3
0.732 – 1.000	Fluorite (CaF_2)	8	4