CHEM 1314 *3:30 pm Section*
Exam II
John II. Gelder
October 16, 2002

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 solubility table, a Table of Standard Heats of Formation, an Activity Series and some useful equations. All work should be done in this booklet.

2. PRINT your name, TA's name and your lab section number <u>now</u> in the space at the top of this sheet. <u>DO NOT SEPARATE THESE PAGES</u>.

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 3 – 6.

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	____	____	____	____	____
	(40)	(22)	(22)	(16)	(100)

(12) 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) $2Al(s) + Fe_2O_3(s) \rightarrow$ **$Al_2O_3(s) + 2Fe(s)$**

b) $Na_2SO_4(aq) + BaCl_2(aq) \rightarrow$ **$BaSO_4(s) + 2NaCl(aq)$**

c) $2NaOH(aq) + Cu(NO_3)_2(aq) \rightarrow$ **$Cu(OH)_2(s) + 2NaNO_3(aq)$**

d) $Li_2CO_3(s) + 2HCl(aq) \rightarrow$ **$2LiCl(aq) + H_2O(l) + CO_2(g)$**

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

1b)

Ionic equation:

$$\cancel{2Na^{+}(aq)} + SO_4^{2-}(aq) + Ba^{2+}(aq) + \cancel{2Cl^{-}(aq)} \rightarrow BaSO_4(s) + \cancel{2Na^{+}(aq)} + \cancel{2Cl^{-}(aq)}$$

Net Ionic equation:

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

(20) 3. A sample of a pure gaseous hydrocarbon was analyzed by combustion analysis. Results revealed the sample contained 7.691 grams of carbon (C) and 1.709 grams of hydrogen (H).

a) What is the empirical formula of the compound?

$$7.691\ g\ C\left(\frac{1\ mol\ C}{12.0\ g\ C}\right) = 0.6409\ mol\ C$$

$$1.709\ g\ H\left(\frac{1\ mol\ H}{1.01\ g\ H}\right) = 1.695\ mol\ H$$

$$\left(\frac{0.6409\ mol\ C}{0.6409}\right) : \left(\frac{1.695\ mol\ H}{0.6409}\right)$$

1.00 mol C : 2.645 mol H

multiply by 3 (1 C : 2.645 H) = 3 C : 8 H

C_3H_8

b) Another sample of this gaseous hydrocarbon with a mass of 4.16 grams contains 5.69×10^{22} molecules.

i) What is the molar mass of the hydrocarbon?

$$5.69 \times 10^{22}\ molecules\ C_3H_8\left(\frac{1\ mol\ C_3H_8}{6.02 \times 10^{23}\ molecules\ C_3H_8}\right) = 0.0945\ mol\ C_3H_8$$

$$\left(\frac{4.16\ g\ C_3H_8}{0.0945\ mole\ C_3H_8}\right) = 44.0\ \frac{g}{mole}$$

ii) Using the information from part a) what is the molecular formula of the hydrocarbon?

EW * n = MM 44.0 * n = 44.0 n = 1 molecular formula is C_3H_8

(22) 4a. In an experiment liquid hexane, $C_6H_{14}(l)$, is completely combusted to produce $CO_2(g)$ and $H_2O(l)$, according to the equation.

$$2C_6H_{14}(l) + 19O_2(g) \rightarrow 12CO_2(g) + 14H_2O(l)$$

The ΔH° for this reaction is -8.39×10^3 kJ. Calculate ΔH°_f for $C_6H_{14}(l)$.

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

$$\Delta H^\circ_{rxn} = 12\Delta H^\circ_f (CO_2) + 14\Delta H^\circ_f (H_2O(l)) - 2\Delta H^\circ_f (C_6H_{14})$$

$$2\Delta H^\circ_f (C_6H_{14}) = 12\Delta H^\circ_f (CO_2) + 14\Delta H^\circ_f (H_2O(l)) - \Delta H^\circ_{rxn}$$

$$2\Delta H^\circ_f (C_6H_{14}) = (12 \text{ mol}\left(-393.5\frac{\text{kJ}}{\text{mol}}\right) + 14 \text{ mol}\left(-285.85\frac{\text{kJ}}{\text{mol}}\right)) - (-8390\left(\frac{\text{kJ}}{\text{mol}}\right))$$

$$\Delta H^\circ_f (C_6H_{14}) = \frac{-336\frac{\text{kJ}}{\text{mol}}}{2 \text{ mol}} = -168 \text{ kJ}$$

b) A 1.25 g sample of hexane is combusted in a bomb calorimeter according to the reaction in part a). The bomb calorimeter has a heat capacity of 1850 $\frac{J}{^\circ C}$ and holds 4.00 kg of water. The initial temperature of the water in the bomb calorimeter is 23.82 ˚C. Calculate the final temperature of the water and the calorimeter after the reaction is complete.

$$1.25 \text{ g } C_6H_{14}\left(\frac{1 \text{ mol } C_6H_{14}}{86.0 \text{ g}}\right)\left(\frac{-8.39 \times 10^3 \text{ kJ}}{2 \text{ mol } C_6H_{14}}\right) = -61`.0 \text{ kJ}$$

$$q_{rxn} = -(q_{water} + q_{calorimeter})$$

$$-61{,}000 \text{ J} = -((4{,}000 \text{ g})(4.184 \frac{J}{g\cdot{}^\circ C}) \Delta T + 1850 \frac{J}{^\circ C} \Delta T)$$

$$-61{,}000 \text{ J} = -(16740 \frac{J}{^\circ C}) \Delta T + 1850 \frac{J}{^\circ C} \Delta T)$$

$$-61{,}000 \text{ J} = -(18590 \frac{J}{^\circ C}) \Delta T)$$

$\Delta T = 3.28$ ˚C

Tf = 23.82 ˚C + 3.28 ˚C = 27.10 ˚C

(22) 5. To remove ozone, O_3, from air, an air sample is passed through an aqueous solution of sodium iodide. The reaction that occurs is described in the equation

$$O_3(g) + 2NaI(aq) + H_2O(l) \rightarrow O_2(g) + I_2(s) + 2NaOH(aq)$$

2.35 grams of ozone are required to completely react with all of the NaI in a 400. mL of solution.

a) how many grams of NaI are in the solution?

$$\mathbf{2.35\ g\ O_3 \left(\frac{1\ mol\ O_3}{48.0\ g\ O_3}\right)\left(\frac{2\ mol\ NaI}{1\ mole\ O_3}\right)\left(\frac{150\ g\ NaI}{1\ mole\ NaI}\right) = 14.7\ g\ NaI}$$

b) what was the concentration of the NaI solution before the reaction started?

$$\mathbf{\left(\frac{0.0979\ mol\ NaI}{0.400\ L}\right) = 0.245\ M}$$

c) How many grams of I_2 are formed in the reaction?

$$\mathbf{2.35\ g\ O_3 \left(\frac{1\ mol\ O_3}{48.0\ g\ O_3}\right)\left(\frac{1\ mol\ I_2}{1\ mole\ O_3}\right)\left(\frac{254\ g\ I_2}{1\ mole\ I_2}\right) = 12.4\ g\ I_2}$$

(10) 6. Carbon monoxide can react with iron(III) oxide as described in the following equation

$$Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 2Fe_{(s)} + 3CO_{2(g)}$$

How many grams of $Fe_{(s)}$ are formed when 18.8 grams of $Fe_2O_{3(s)}$ are combined with 11.1 grams of $CO_{(g)}$?

$$\mathbf{18.8\ g\ Fe_2O_3 \left(\frac{1\ mol\ Fe_2O_3}{160\ g\ Fe_2O_3}\right) = 0.118\ mol\ Fe_2O_3}$$

$$\mathbf{11.1\ g\ CO \left(\frac{1\ mol\ CO}{28.0\ g\ CO}\right) = 0.396\ mol\ NaI}$$

$(moles\ Fe_2O_3)_{initial}$	$(moles\ CO)_{required}$	$(moles\ CO)_{initial}$	Conclusion
0.118	**0.354**	**0.396 mol**	

$$\mathbf{0.118\ mol\ Fe_2O_3 \left(\frac{3\ mol\ CO}{1\ mol\ Fe_2O_3}\right) = 0.354\ mol\ CO}$$

0.354 mol CO required, and 0.396 mol of CO available initially. Therefore CO is in excess and Fe_2O_3 is the limiting reagent.

$$\mathbf{0.118\ mol\ Fe_2O_3 \left(\frac{2\ mol\ Fe}{1\ mol\ Fe_2O_3}\right)\left(\frac{55.8\ g\ Fe}{1\ mol\ Fe}\right) = 13.2\ g\ Fe}$$

(6) 7. 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. If no reaction occurs write NR.

a) $Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow$ $\mathbf{Zn^{2+}_{(aq)} + Cu_{(s)}}$

b) $CaCl_{2(aq)} + Pb_{(s)} \rightarrow$ **NR**

c) $Sn_{(s)} + AgNO_{3(aq)} \rightarrow$ $\mathbf{Sn(NO_3)_{2(aq)} + Ag_{(s)}}$

Periodic Table of the Elements

	IA	IIA	IIIB	IVB	VB	VIB	VIIB		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** (266)	107 **Bh** (264)	108 **Hs** (269)	109 **Mt** (268)	110 (271)	111 (272)	112 (277)		114 (285)		116 (289)		

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

Specific heat of $H_2O(s) = 2.09 \frac{J}{g\cdot °C}$ Specific heat of $H_2O(l) = 4.184 \frac{J}{g\cdot °C}$

Specific heat of $H_2O(g) = 1.84 \frac{J}{g\cdot °C}$ Heat of fusion of $H_2O(s) = 6.01 \frac{kJ}{mol}$

Heat of vaporization of $H_2O(l) = 40.67 \frac{kJ}{mol}$

$R = 0.08203 \frac{L\cdot atm}{mol\cdot K}$ or $R = 8.314 \frac{J}{mol\cdot K}$ $\Delta H = \Delta E + \Delta n RT$

q(heat flow) = mass · specific heat · ΔT

$q_{reaction} = -(q_{calorimeter} + q_{solution})$ $q_{reaction} = -(q_{calorimeter} + q_{water})$

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

Table of Standard Heats of Formation

Substance and State	ΔH_f° (kJ/mol)	Substance and State	ΔH_f° (kJ/mol)
C(*s*) (graphite)	0	$HCl(g)$	-92.3
C(*s*) (diamond)	2	$HBr(g)$	-36.4
$CO(g)$	-110.5	$HI(g)$	26.5
$CO_2(g)$	–393.5	$I_2(g)$	62.25
$CH_4(g)$	–75	$O_2(g)$	0
$CH_3OH(g)$	-201	$O(g)$	249
$CH_3OH(l)$	-239	$O_3(g)$	143
$H_2CO(g)$	-116		
$CCl_4(l)$	-135.4	$N_2(g)$	0
$HCOOH(g)$	-363	$NH_3(g)$	-46
$HCN(g)$	135.1	$NH_3(aq)$	-80
$CS_2(g)$	117.4	$NH_4^+(aq)$	-132
$CS_2(l)$	89.7	$N_2H_3CH_3(l)$	54
$C_2H_2(g)$	227	$N_2H_4(l)$	50.6
$C_2H_4(g)$	52	$NO(g)$	90.25
$CH_3CHO(g)$	-166	$NO_2(g)$	33.18
$C_2H_5OH(l)$	-278	$N_2O(g)$	82.0
$C_2H_5O_2N(g)$	-533	$N_2O_4(g)$	9.16
$C_2H_6(g)$	-84.7	$N_2O_4(l)$	20
$C_3H_6(g)$	20.9	$HNO_3(aq)$	-207.36
$C_3H_8(g)$	-104	$HNO_3(l)$	-174.10
$C_4H_{10}(g)$	-126	$NH_4ClO_4(s)$	-295
$CH_2 = CHCN(l)$	152		
$CH_3COOH(l)$	-484	$S_2Cl_2(g)$	-18
$C_6H_{12}O_6(s)$	-1275	$SO_2(g)$	-296.83
		$H_2S(g)$	-20.6
$Cl_2(g)$	0	$SOCl_2(g)$	-213
$Cl_2(aq)$	-23		
$Cl^-(aq)$	-167	$SiCl_4(g)$	-657
		$SiO_2(s)$	-910.94
		$SiF_4(g)$	-1614.9
$H_2(g)$	0		
$H(g)$	217	$TiO_2(s)$	-944.7
$H^+(aq)$	0	$TiCl_4(g)$	-763
$OH^-(aq)$	-230		
$H_2O(l)$	-286	$ZnO(s)$	-348
$H_2O(g)$	-242	$ZnS(s)$	-206

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	$Li^+ + e^- \rightarrow Li$

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