CHEM 1314.03
Exam II KEY
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Name ______________________

TA's Name ______________________

Lab Section ______________________

INSTRUCTIONS:

1. This examination consists of a total of 9 different pages. The last four pages include a periodic table, a solubility table, a table of enthalpy's 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 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 3 – 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	____ (34)	____ (25)	____ (21)	____ (20)	____ (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. If no reaction occurs write NR.

a) $\mathbf{2}Al(s) + Fe_2O_3(s) \rightarrow \mathbf{Al_2O_3(s) + 2Fe(l)}$

b) $Na_2SO_4(aq) + \mathbf{2}NH_4Cl(aq) \rightarrow \mathbf{(NH_4)_2SO_4(aq) + 2NaCl(aq)}$

c) $Mg(s) + Cu^{2+}(aq) \rightarrow \mathbf{Mg^{2+}(aq) + Cu(s)}$

d) $\mathbf{3}Na_2CO_3(aq) + \mathbf{2}Fe(NO_3)_3(aq) \rightarrow 6\mathbf{NaNO_3(aq) + Fe_2(CO_3)_3(s)}$

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

1b)

Ionic equation:

$$\mathbf{2NH_4^+(aq) + SO_4^{2-}(aq) + 2Na^+(aq)) + 2Cl^-(aq) \rightarrow 2NH_4^+(aq) + SO_4^{2-}(aq) + 2Na^+(aq)) + 2Cl^-(aq)}$$

Net Ionic equation:

~~$\mathbf{2NH_4^+(aq)}$~~ + ~~$\mathbf{SO_4^{2-}(aq)}$~~ + ~~$\mathbf{2Na^+(aq)}$~~ + ~~$\mathbf{2Cl^-(aq)}$~~ → ~~$\mathbf{2NH_4^+(aq)}$~~ + ~~$\mathbf{SO_4^{2-}(aq)}$~~ + ~~$\mathbf{2Na^+(aq)}$~~ + ~~$\mathbf{2Cl^-(aq)}$~~

All ions cancel..no net ionic equation...no reaction.

1d)

Ionic equation:

$$\mathbf{6Na^+(aq) + 3CO_3^{2-}(aq) + 2Fe^{3+}(aq) + 6NO_3^-(aq) \rightarrow 6Na^+(aq) + Fe_2(CO_3)_3(s) + 6NO_3^-(aq)}$$

Net Ionic equation:

~~$\mathbf{6Na^+(aq)}$~~ + $\mathbf{3CO_3^{2-}(aq) + 2Fe^{3+}(aq)}$ + ~~$\mathbf{6NO_3^-(aq)}$~~ → ~~$\mathbf{6Na^+(aq)}$~~ + $\mathbf{Fe_2(CO_3)_3(s)}$ + ~~$\mathbf{6NO_3^-(aq)}$~~

$$\mathbf{2Fe^{3+}(aq) + 3CO_3^{2-}(aq) \rightarrow Fe_2(CO_3)_3(s)}$$

(10) 3. An explosive, trinitrotoluene, is prepared by reacting toluene with nitric acid according to the equation

$$C_7H_8(l) + 3HNO_3(aq) \rightarrow C_7H_5(NO_2)_3(l) + 3H_2O(l)$$

What mass of toluene and nitric acid are required to produce 50.0 g of trinitrotoluene?

$$\mathbf{50.0\ g\ TNT \left(\frac{1\ mol}{227\ g}\right) = 0.220\ Mol\ TNT}$$

$$\mathbf{0.220\ Mol\ TNT \left(\frac{1\ mol\ C_7H_8}{1\ mol\ TNT}\right)\left(\frac{92.0\ g}{1\ mol\ C_7H_8}\right) = 20.3\ g\ C_7H_8}$$

$$\mathbf{0.220\ Mol\ TNT \left(\frac{3molHNO_3}{1molTNT}\right)\left(\frac{63.0\ g}{1\ mol\ HNO_3}\right) = 41.6\ g\ HNO_3}$$

(15) 4. Boric acid is formed in the reaction between boron trifluoride and water. The reaction is,

$$4BF_3 + 3H_2O \rightarrow H_3BO_3 + 3HBF_4$$

What is the maximum number of grams of boric acid which can be obtained when 150. g of boron trifluoride is reacted with 35.0 g of water?

150. g $BF_3\left(\frac{1 \text{ mol } BF_3}{67.8 \text{ g}}\right)$ = 2.21 mol B **35.0 g $H_2O\left(\frac{1 \text{ mol } H_2O}{18.0 \text{ g}}\right)$ = 1.94 mol H_2O**

2.21 mol $BF_3\left(\frac{3 \text{ mol } H_2O}{4 \text{ mol } BF_3}\right)$ = 1.66 mol H_2O required

1.66 mol H_2O required and 1.94 mol H_2O are available. So the water is in excess and BF_3 is limiting.

2.21 mol $BF_3\left(\frac{1 \text{ mol } H_3BO_3}{4 \text{ mol } BF_3}\right)\left(\frac{61.8 \text{ g}}{1 \text{ mol } H_3BO_3}\right)$ = 34.1 g H_3BO_3

Calculate the final mass of both reactants after the reaction has gone to completion.

0 g of BF_3 left

1.66 mol $H_2O\left(\frac{18.0 \text{ g } H_2O}{1 \text{ mol } H_2O}\right)$ = 29.9 g H_2O reacted

35.0 g – 29.9 g = 5.1 g H_2O remain unreacted.

(10) 5. Calculate the mass of oxalic acid that reacts with 0.680 mLs of 2.44×10^{-3} M $KMnO_4$ in excess sulfuric acid. The equation which describes the reaction between oxalic acid, potassium permanganate and sulfuric acid is,

$$2KMnO_4(aq) + 5H_2C_2O_4(aq) + 3H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2MnSO_4(aq) + 10CO_2(g) + 8H_2O(l)$$

0.680 mLs $\left(\frac{1 \text{ L}}{1000 \text{ mLs}}\right)\left(\frac{2.44 \times 10^{-3} \text{ mol } KMnO_4}{1 \text{ L}}\right)\left(\frac{5 \text{ mol } H_2C_2O_4}{2 \text{ mol } KMnO_4}\right)\left(\frac{90.0 \text{ g}}{1 \text{ mol } H_2C_2O_4}\right)$ = 0.373 g of $H_2C_2O_4$

(9) 6. The industrial preparation of nitric acid, the Ostwald Process, converts ammonia to nitric acid. Using the following standard enthalpy of reaction data and Hess' Law determine the enthalpy for production of nitric acid from ammonia. (Note: While ammonia and nitric acid are the only two substances mentioned it should be realized other substances may be needed to obtain a balanced chemical equation which describes the conversion of ammonia to nitric acid.)

Reaction	ΔH°
$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$	–907 kJ
$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$	–114 kJ
$3NO_2(g) + H_2O(g) \rightarrow 2HNO_3(aq) + NO(g)$	–182 kJ

Clearly demonstrate how the given equations are to be manipulated to obtain the final equation.

$$\mathbf{4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g) \quad -907\ kJ}$$
$$\mathbf{3 \cdot (2NO(g) + O_2(g) \rightarrow 2NO_2(g)) \quad -114\ kJ \cdot 3}$$
$$\mathbf{2 \cdot (3NO_2(g) + H_2O(g) \rightarrow 2HNO_3(aq) + NO(g)) \quad -182\ kJ \cdot 2}$$
$$\mathbf{4NH_3(g) + 8O_2(g) \rightarrow 4HNO_3(aq) + 4H_2O(g) \quad -1613\ kJ}$$

(12) 7a. When a sulfide is combusted sulfur dioxide is a product. Calculate ΔH°_{rxn} for the combustion of zinc sulfide.

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

$$\mathbf{\Delta H^\circ_{rxn} = \Sigma\Delta H^\circ_f\ (products) - \Sigma\Delta H^\circ_f\ (reactants)}$$
$$\mathbf{\Delta H^\circ_{rxn} = \left(2\ mol \left(-348\ \frac{kJ}{mol}\right) + 2\ mol \left(-297\ \frac{kJ}{mol}\right)\right)}$$
$$\mathbf{- \left(2\ mol \left(-206\ \frac{kJ}{mol}\right) + 3\ mol \left(0\ \frac{kJ}{mol}\right)\right) = -878\ kJ \cdot (2\ mol\ ZnS)^{-1}}$$

(20) 8a. 45.0 g of water at 33.0 ˚C are added to 24.0 g of water, in a calorimeter, at 21.0 ˚C. The final temperature of the mixture is 27.8 ˚C. Calculate the heat capacity of the calorimeter.

$$q_{hot} = -(q_{cold} + q_{calorimeter})$$

$$4.184\ \frac{J}{g\cdot{}^{\circ}C}\cdot 45.0\ g\cdot(27.8\ {}^{\circ}C - 33.0\ {}^{\circ}C) = -(4.184\ \frac{J}{g\cdot{}^{\circ}C}\cdot 24.0\ g\cdot(27.8\ {}^{\circ}C - 21.0\ {}^{\circ}C) + HC_{calorimeter}\cdot(27.8\ {}^{\circ}C - 21.0\ {}^{\circ}C))$$

$$-979\ J = -(682\ J + HC_{calorimeter}\cdot 6.8\ {}^{\circ}C)$$

$$HC_{calorimeter} = \frac{297\ J}{6.8\ {}^{\circ}C} = 43.7\ \frac{J}{{}^{\circ}C}$$

b. 1.980 g of KOH are added to the same calorimeter used in the experiment in part a) above which now holds 50.0 mLs of water. The initial temperature of the water in the calorimeter 22.6 ˚C. If the final temperature of the solution in the calorimeter after adding the KOH is 31.2 ˚C, calculate the molar heat of solution for KOH. (Assume the specific heat of the solution is equal to the specific heat of pure water.)

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

$$q_{reaction} = -(4.184\ \frac{J}{g\cdot{}^{\circ}C}\cdot 51.98\ g\cdot(31.2\ {}^{\circ}C - 22.6\ {}^{\circ}C) + 43.7\ \frac{J}{{}^{\circ}C}\cdot(31.2\ {}^{\circ}C - 22.6\ {}^{\circ}C))$$

$$= \frac{-2246\ J}{1.98\ g\ KOH}\left(\frac{56.0\ g}{1\ mol\ KOH}\right) = -63.5\ kJ\cdot mol^{-1}$$

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

Specific heat of $H_2O(s) = 2.09 \frac{J}{g\cdot{}^\circ C}$

Specific heat of $H_2O(l) = 4.184 \frac{J}{g\cdot{}^\circ C}$

Specific heat of $H_2O(g) = 1.84 \frac{J}{g\cdot{}^\circ C}$

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

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

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

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

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

$\Delta H = \Delta E + \Delta nRT$

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

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
$TiO_2(s)$	-945	$H_2S(g)$	-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

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