CHEMISTRY 4A
Professor Richard Mathies

November 14, 1994

THIRD MIDTERM

Name:_____

TA:_____

Begin by writing your name on all pages. You must **show all your work** in the space provided for each question. Look over all the problems and do the ones that you know first. Then go back to work on the more difficult ones in the time remaining. Relevant tables, constants and some equations will be found in the appendix. Good Luck!

(1) _____ /12

(2) _____ /10

(3) _____ /20

(4) _____ /25

(5) _____ /10

TOTAL_____/ 77

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(12) 1. Decide whether each of the following statements is true or false and briefly explain your logic. **10 Words or less please !!**

(a) The change of free energy for a reaction is always zero.

(b) An endothermic reaction is never spontaneous.

(c) If ΔG for a reaction is negative then the reaction is fast.

(d) ΔS for the universe is always $\geq$ zero.

(10) 2. (a) I performed a demonstration where I added concentrated NH_4OH to a $CuNO_3$ solution. Initially a white precipitate formed which dissolved upon addition of more ammonia to give a deep blue-colored solution. Explain the chemistry behind these observations.

(b) In class, Professor Wemmer popped a large ballon that turned out to be filled with helium. After the balloon popped, the helium spontaneously mixed with the atmosphere (dusty) in the room. What are the signs of ΔT, ΔH, ΔE, ΔS and ΔG for the helium in this process?

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(20) 3. If the cork of a wine bottle is not well sealed, oxygen will leak into the bottle and oxidize the ethanol to acetic acid (a.k.a. vinager). This tastes bad!! The balanced reaction is

$$C_2H_5OH\ (aq) + O_2\ (g) \Rightarrow CH_3COOH\ (aq) + H_2O\ (l)$$

(a) What is ΔG° for this reaction?

(b) What is the equilibrium constant for this reaction at 25 C?

(c) What is ΔG for this reaction if the initial concentration of ethanol is 0.1 M, the partial pressure of oxygen is 0.2 atm, and acetic acid is present in only trace amounts ($1X10^{-5}$ M)? Lets keep the temperature at 25 C.

Name_____

(25) 4. (a) In the calomel half-cell, solid calomel (Hg_2Cl_2) is placed in a solution of 1 M KCl. The solubility product of calomel is $2X10^{-18}$. Calomel is unique in that it dissolves to form Hg_2^{2+} and two chloride ions. Calculate the final concentration of Hg_2^{2+} in the KCl solution once equilibrium is established.

(b) One mole of ice at 0° C is converted to one mole of liquid water at 0° C. Calculate ΔG, ΔH, ΔS, ΔE, q and w for this process. The pressure is constant at 1 atm and ΔH_{fus} = 6,007 J/mol. For the purposes of this problem, you may ignore the density difference between solid and liquid water. C_p (water) = 75 J/mole K

(c) One mole of an ideal monatomic gas slowly and adiabatically expands against a constant external pressure of 1 atm from 10 L to 20 L. The initial temperature of the gas was 200 K. Calculate ΔH, ΔS, ΔE, q and w for this process. Take C_p = 2.5 R and remember $C_p = C_v + R$.

Name_____

(10) 5. A Chem 4 student wanted to determine the heat of reaction of ammonium chloride (NH_4Cl) with sodium hydroxide. She first had to calibrate the calorimeter followed by performing the reaction.

(a) She first set up a styrofoam calorimeter with 250 ml of water in it and added 5.34 g of NH_4Cl to the calorimeter to establish the calibration. The temperature of the solution dropped by 1.4° C. The heat of solution of ammonium chloride is 14,800 J/mole. What is the heat capacity of the calorimeter in J/K?

(b) She then took 125 ml of water with 5.34 g of NH_4Cl equilibrated to 23.0° C, and added 125 ml of water with 4.00 g of NaOH dissolved in it (also at 23.0° C). After mixing, the temperature of the solution in the calorimeter rose by 0.3° C. Write the balanced reaction that occured and determine the desired heat of reaction in J/mole.

Name_____

Values of physical constants:

Speed of light: $c = 3.00 \times 10^{8}$ m s^{-1}

Planck's constant: $h = 6.626 \times 10^{-34}$ J s

Boltzman's constant: $k_B = 1.381 \times 10^{-23}$ J K^{-1}

Gas constant: $R = 0.08206$ L atm mol^{-1} K^{-1} $= 8.315$ J mol^{-1} K^{-1}

Avogadro's number: $N_o = 6.023 \times 10^{23}$

Mass of the electron: $m_e = 9.11 \times 10^{-31}$ kg

Rydberg's constant: $R_H = 3.29 \times 10^{15}$ s^{-1}

Gravitational constant: $g = 9.807$ m s^{-2}

Equations

$$\mu = \bar{x} \pm \frac{ts}{\sqrt{n}}$$

Periodic Table:

1A												3A	4A	5A	6A	7A	Noble gases 8A
1 H 1.008	Alkaline earth metals 2A															Halogens 7A	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	Transition metals										13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.70	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
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
55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	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)
87 Fr (223)	88 Ra (226.0)	89 Ac† (227)	104 Rf	105 Ha	106 Unh	107 Uns	108	109 Une									

Alkali metals

*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 157.3	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)	92 U 238.0	93 Np (244)	94 Pu (242)	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)

Substance	ΔH_f° (25°C) kJ mol^{-1}	S° (25°C) J K^{-1} mol^{-1}	ΔG_f° (25°C) kJ mol^{-1}
$C_2H_6(g)$	−84.68	229.49	−32.89
$C_3H_8(g)$	−103.85	269.91	−23.49
n-$C_4H_{10}(g)$	−124.73	310.03	−15.71
	−131.60	294.64	−17.97
n-$C_5H_{12}(g)$	−146.44	348.40	−8.20
$C_6H_6(g)$	82.93	269.2	129.66
$C_6H_6(\ell)$	49.03	172.8	124.50
$CO(g)$	−110.52	197.56	−137.15
$CO_2(g)$	−393.51	213.63	−394.36
$CO_2(aq)$	−413.80	117.6	−385.98
$H_2CO_3(aq)$	−699.65	187.4	−623.08
$HCO_3^-(aq)$	−691.99	91.2	−586.77
$CO_3^{2-}(aq)$	−677.14	−56.9	−527.81
$HCOOH(\ell)$	−424.72	128.95	−361.42
$HCOOH(aq)$	−425.43	163	−372.3
$COOH^-(aq)$	−425.55	92	−351.0
$CH_2O(g)$	−108.57	218.66	−102.55
$CH_3OH(\ell)$	−238.66	126.8	−166.35
$CH_3OH(g)$	−200.66	239.70	−162.01
$CH_3OH(aq)$	−245.93	133.1	−175.31
$H_2C_2O_4(s)$	−827.2	—	—
$HC_2O_4^-(aq)$	−818.4	149.4	−698.34
$C_2O_4^{2-}(aq)$	−825.1	45.6	−673.9
$CH_3COOH(\ell)$	−484.5	159.8	−390.0
$CH_3COOH(g)$	−432.25	282.4	−374.1
$CH_3COOH(aq)$	−485.76	178.7	−396.46
$CH_3COO^-(aq)$	−486.01	86.6	−369.31
$CH_3CHO(\ell)$	−192.30	160.2	−128.12
$C_2H_5OH(\ell)$	−277.69	160.7	−174.89
$C_2H_5OH(g)$	−235.10	282.59	−168.57
$C_2H_5OH(aq)$	−288.3	148.5	−181.64
$CH_3OCH_3(g)$	−184.05	266.27	−112.67
$CF_4(g)$	−925	261.50	−879
$CCl_4(\ell)$	−135.44	216.40	−65.28
$CCl_4(g)$	−102.9	309.74	−60.62
$CHCl_3(g)$	−103.14	295.60	−70.37
$COCl_2(g)$	−218.8	283.53	−204.6
$CH_2Cl_2(g)$	−92.47	270.12	−65.90
$CH_3Cl(g)$	−80.83	234.47	−57.40
$CBr_4(s)$	79	357.94	67
$CH_3I(\ell)$	−15.5	163.2	13.4
$CS_2(\ell)$	89.70	151.34	65.27
$HCN(g)$	135.1	201.67	124.7
$HCN(aq)$	107.1	124.7	119.7
$CN^-(aq)$	150.6	94.1	172.4
$CH_3NH_2(g)$	−22.97	243.30	32.09
$CO(NH_2)_2(s)$	−333.51	104.49	−197.44
$Si(s)$	0	18.83	0

	Substance	ΔH_f° (25°C) kJ mol^{-1}	S° (25°C) J K^{-1} mol^{-1}	ΔG_f° (25°C) kJ mol^{-1}
	$PO_4^{3-}(aq)$	−1277.4	−222	−1018.7
	$PCl_3(g)$	−287.0	311.67	−267.8
	$PCl_5(g)$	−374.9	364.47	−305.0
	As(*s*, gray)	0	35.1	0
	As(*g*)	302.5	174.10	261.0
	$As_2(g)$	222.2	239.3	171.9
	$As_4(g)$	143.9	314	92.4
	$AsH_3(g)$	66.44	222.67	68.91
	$As_4O_6(s)$	−1313.94	214.2	−1152.53
	Sb(*s*)	0	45.69	0
	Sb(*g*)	262.3	180.16	222.1
	Bi(*s*)	0	56.74	0
	Bi(*g*)	207.1	186.90	168.2
VI	$O_2(g)$	0	205.03	0
	O(*g*)	249.17	160.95	231.76
	$O_3(g)$	142.7	238.82	163.2
	$OH^-(aq)$	−229.99	−10.75	−157.24
	$H_2O(\ell)$	−285.83	69.91	−237.18
	$H_2O(g)$	−241.82	188.72	−228.59
	$H_2O_2(\ell)$	−187.78	109.6	−120.42
	$H_2O_2(aq)$	−191.17	143.9	−134.03
	S(*s*, rhombic)	0	31.80	0
	S(*s*, monoclinic)	0.33	—	—
	S(*g*)	278.80	167.71	238.28
	$S_8(g)$	102.30	430.87	49.66
	$S^{2-}(aq)$	33.1	−14.6	85.8
	$H_2S(g)$	−20.63	205.68	−33.56
	$H_2S(aq)$	−39.7	121	−27.83
	$HS^-(aq)$	−17.6	62.8	12.08
	SO(*g*)	6.26	221.84	−19.87
	$SO_2(g)$	−296.83	248.11	−300.19
	$SO_3(g)$	−395.72	256.65	−371.08
	$H_2SO_3(aq)$	−608.81	232.2	−537.81
	$HSO_3^-(aq)$	−626.22	139.7	−527.73
	$SO_3^{2-}(aq)$	−635.5	−29	−486.5
	$H_2SO_4(\ell)$	−813.99	156.90	−690.10
	$HSO_4^-(aq)$	−887.34	131.8	−755.91
	$SO_4^{2-}(aq)$	−909.27	20.1	−744.53
	$SF_6(g)$	−1209	291.71	−1105.4
	Se(*s*, black)	0	42.44	0
	Se(*g*)	227.07	176.61	187.06
VII	$F_2(g)$	0	202.67	0
	F(*g*)	78.99	158.64	61.94
	$F^-(aq)$	−332.63	−13.8	−278.79
	HF(*g*)	−271.1	173.67	−273.2
	HF(*aq*)	−320.08	88.7	−296.82
	$XeF_4(s)$	−261.5	—	—