LAST NAME: ____

FIRST NAME: ____

Student Number: ____

CHM 1311 D
Midterm #1
Fall 2017

Please keep your work covered at all times and keep your eyes on your own paper! Cheating or any appearance of cheating will result in an F in the course and possible expulsion from the university.

There are 8 pages in this test, for a total of 40 marks. A periodic table and data sheets are provided at the end. You may rip these pages off of the exam and use them to cover your work during the test. Any scratch work should be done on the back of these pages.

Please show all work to receive partial credit.

Make sure that units are included in your final answer.

You have 90 minutes to complete the test.

A

Question 1. Short answer questions (1 mark each)

a) A 5.00 L flask is filled with argon gas at 1.35 atm and 31.0 °C. After a 3.00 mol sample of nitrogen gas is added at this temperature, what is the partial pressure of argon?

$P_{Ar} = 1.35$ atm

b) Are the bond energies used to estimate reaction energies exothermic or endothermic?

B.E. > 0 ∴ ENDOTHERMIC

(ENERGY IS NEEDED TO BREAK A BOND)

c) At constant pressure an ideal gas inside a piston contracted, involving 250 J of work and releasing 500 J of heat. What is the value of ΔE for the gas in this process?

$q = -500$ J

$w = 250$ J

$\Delta V < 0 \quad \therefore w > 0$

$\Delta U = q + w$

$= -500\text{ J} + 250\text{ J}$

$= -250\text{ J}$

d) A micropipette can remove 1 mL of liquid from a solution to an accuracy of 1 µL. How many significant figures should you use to record the volume of the aliquot of solution removed by this pipette?

4 SIG FIGS

$(1000. \pm 1\ \mu L)$

e) Write the chemical symbol for the element containing 13 protons, 10 electrons and 14 neutrons.

$^{27}Al^{3+}$

f) If the standard heat of formation of liquid H_2O is -285 kJ mol^{-1}, then what will be the heat of the reverse reaction performed with 0.50 mol of liquid H_2O?

$\Delta H^{\circ}_{R} = -\Delta H^{\circ}_{f} \times 0.5$ mol

$= -(-285\text{ kJ mol}^{-1})(0.5\text{ mol}) = 143\text{ kJ}$

Question 2. Short calculations

a) What is the root mean squared speed of an oxygen (O_2) molecule at 298 K? (2 marks)

$$\bar{V} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3\,(8.314\text{ J K}^{-1}\text{mol}^{-1})(298\text{ K})}{(32.00\text{ g mol}^{-1})(10^{-3}\text{ kg g}^{-1})}}$$

$= 481.9$ m/s

b) How many **millimeters** thick is a square piece of aluminum (density = 2.70 g cm^{-3}) measuring 22.86 cm in length and width, with a mass of 2.568 g? (2 marks)

$$d = \frac{m}{V} = \frac{m}{\ell^2 \times h} \qquad h = \frac{m}{\ell^2 \times d}$$

$$= \frac{2.568 g}{(22.86 cm)^2 (2.70 g\, cm^{-3})}$$

$$= 0.00182 cm$$

$$= 0.0182 mm$$

c) Calculate the change in volume for an ideal gas that does 325 J of work at a pressure of 1.0 atm and 298 K. (2 marks)

$$w = -325 J = -p \Delta V$$

$$\Delta V = \frac{-w}{p} = \frac{325 J}{(1.0 atm)(101325 Pa\, atm^{-1})}$$

$$= 3.21 \times 10^{-3} m^3$$

$$= 3.21 L$$

d) 4.00 L of an ideal gas at 20.0 °C is put into a refrigerator, causing a 4-fold decrease in the temperature of this gas. What is the new volume of this gas? (2 marks)

$$\frac{nR}{p} = \frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad V_2 = \frac{V_1 T_2}{T_1} = \frac{(4.00 L)(273.15 + 5.0)K}{(273.15 + 20.0)K}$$

$$= 3.80 L$$

e) If it takes 22 hours for a helium-filled balloon to shrink to half its original volume at 298 K, 1.0 atm due to effusion, how long would it take for the balloon to shrink to half its original volume under the same conditions, if it was instead filled with oxygen? (2 marks)

$$\frac{\text{RATE He}}{\text{RATE } O_2} = \sqrt{\frac{M_{O_2}}{M_{He}}} = \frac{\frac{\cancel{\text{MASS LOST}}}{t_{He}}}{\frac{\cancel{\text{MASS LOST}}}{t_{O_2}}} = \frac{t_{O_2}}{t_{He}}$$

$$t_{O_2} = 22 \text{ HOURS} \sqrt{\frac{32.00 g/mol}{4.003 g/mol}}$$

$$= 62 \text{ HOURS}$$

f) What would the concentration of potassium be if a 35.0 mL sample of 0.025 M K_2SO_4 was added to 50.0 mL of 0.50 M K_3PO_4? (3 marks)

$$C_{K^+} = \frac{n_{K^+}}{V} = \frac{C_{K_2SO_4} V_{K_2SO_4} \times \frac{2\,mol\,K^+}{1\,mol\,K_2SO_4} + C_{K_3PO_4} V_{K_3PO_4} \times \frac{3\,mol\,K^+}{1\,mol\,K_3PO_4}}{V_{K_2SO_4} + V_{K_3PO_4}}$$

$$= \frac{(0.025\,M)(35.0\,mL)(2) + (0.50\,M)(50\,mL)(3)}{(35.0 + 50.0)\,mL}$$

$$= 6.090\ M$$

Question 3.

A customer to a pawn shop wants to sell a ring weighing 13.5 g. To determine the composition of the ring the pawn shop owner places it into a pot of boiling water. The hot is then transferred to a coffee cup calorimeter containing 25.0 mL of room temperature (25.0°C) water. Using the data in the table below, determine what this ring made out of, given that the temperature of the water in the calorimeter rose to 26.2 °C? (4 marks)

Specific heat capacities	(J g^{-1} °C^{-1})
liquid water	4.184
gold	0.126
brass	0.380
stainless steel	0.500

$$q_{RING} = -q_{H_2O}$$

$$m_R C_R (T_2 - T_{1,R}) = -m_{H_2O} C_{H_2O} (T_2 - T_{1,H_2O})$$

$$C_R = \frac{m_{H_2O} C_{H_2O} (T_2 - T_{1,H_2O})}{m_R (T_2 - T_{1,H_2O})}$$

$$= -\frac{(25.0\,mL)(1.00\,g/mL)(4.184\,J\,^{\circ}C^{-1}g^{-1})(26.2 \cdot 25.0)^{\circ}C}{(13.5\,g)(26.2 - 100.0)^{\circ}C}$$

$$= 0.126\ J\,g^{-1}\,^{\circ}C^{-1}$$

= HEAT CAPACITY OF GOLD

∴ RING IS MADE OF GOLD

Question 4. Answer the questions below. <u>You may need to use data provided on the equation sheet.</u>

a) Calculate the standard combustion enthalpy for liquid butanol. (3 marks)

$$C_4H_{10}O_{(l)} + 6O_{2(g)} \rightarrow 4CO_{2(g)} + 5H_2O_{(l)}$$

$$\Delta H_R^\circ = \Sigma\nu\Delta H^\circ_{f,\text{PRODUCTS}} - \Sigma\nu\Delta H^\circ_{f,\text{REACTANTS}}$$

$$= 4\Delta H_f^\circ(CO_{2(g)}) + 5\Delta H_f^\circ(H_2O_{(l)}) - \Delta H_f^\circ(C_4H_{10}O_{(l)})$$

$$= 4(-393.5\ \text{kJ mol}^{-1}) + 5(-285.83\ \text{kJ mol}^{-1}) - (-327.0\ \text{kJ mol}^{-1})$$

$$= -2676.2\ \text{kJ mol}^{-1}$$

b) Calculate $\Delta E^o_{\text{Reaction}}$ for the standard combustion of liquid butanol. (3 marks)

$$\Delta E_R^\circ = \Delta H_R^\circ - RT\Delta n_{gas}$$

$$= -2676.2\ \text{kJ mol}^{-1} - (8.314\ \text{J K}^{-1}\text{mol}^{-1})(298.15\text{K})(4-6)(10^{-3}\text{kJ J})$$

$$= -2671.2\ \text{kJ mol}^{-1}$$

Question 5.

Hydrogen gas, H_2(g) is passed over Fe_2O_3(s) at 400°C. Water vapour is formed together with an iron oxide containing 72.3% Fe by mass. What is the empirical formula of this iron oxide? (4 marks)

$$H_{2(g)} + Fe_2O_{3(s)} \rightarrow Fe_xO_y + H_2O_{(g)}$$

$$n_{Fe} = \frac{72.3\text{g}}{55.8\text{g mol}^{-1}} = 1.29\bar{6}\ \text{mol}$$

$$n_O = \frac{100.0\text{g} - 72.3\text{g}}{16.00\text{g mol}^{-1}} = 1.73\bar{1}\ \text{mol}$$

$$Fe_{\frac{1.29\bar{6}}{1.29\bar{6}}}\ O_{\frac{1.73\bar{1}}{1.296}} = FeO_{1.33} \times 3 = Fe_3O_4$$

Question 6.

For the chemical reaction:

$$Cl_2\,(g) + 4\ NaClO\,(aq) \rightarrow 4\ NaCl\,(aq) + 2\ ClO_2\,(g)$$

1.00 L of chlorine gas at 10.0 °C, 4.66 atm was dissolved in 750.0mL of 2.00 M sodium hypochlorite.

a) Assuming complete reaction, how many grams of chlorine dioxide will be produced in this reaction? (6 marks)

n_{ClO_2} PRODUCED FROM Cl_2: $n_{ClO_2} = n_{Cl_2} \times \frac{2\ mol\ ClO_2}{1\ mol\ Cl_2} = \frac{pV}{RT} \times 2$

$$= \frac{(4.66\ atm)(1.00\ L)(2)}{(0.08206\ L \cdot atm \cdot K^{-1} \cdot mol^{-1})(273.15 + 10.0)K}$$

$= 0.4011\ mol$

n_{ClO_2} PRODUCED FROM $NaClO$: $n_{ClO_2} = n_{NaClO} \times \frac{2\ mol\ ClO_2}{4\ mol\ NaClO}$

$= C_{NaClO} V_{NaClO} \left(\frac{1}{2}\right)$

$= (2.00\ M)(750.0\ mL)(10^{-3}\ L\ mL^{-1})\left(\frac{1}{2}\right)$

$= 0.750\ mol$

$\therefore Cl_2$ IS LIMITING

$m_{ClO_2} = n_{ClO_2} M_{ClO_2}$

$= (0.4011\ mol)(35.45 + 2 \times 16.00)\ g/mol$

$= 27.1\ g$

b) If the percent yield of the reaction is 86.4%, what is the mass of chlorine dioxide that will actually be produced? (1 mark)

$\%\ YIELD = \frac{ACTUAL\ YIELD}{THEORETICAL\ YIELD} \times 100\%$

$ACTUAL\ YIELD = \frac{\%\ YIELD}{100\%} \times THEORETICAL\ YIELD$

$= (0.864)(27.1\ g)$

$= 23.4\ g$

10:37

Constants and Conversion Factors

1 mmHg = 1 torr   760 mmHg = 1 atm   1 atm = 101.325 kPa   1 atm = 1.013125 bar
1 bar = 10^5 Pa   1 cm^3 = 1 mL = 1000 μL   1 dm^3 = 1000 mL = 1 L   1 m^3 = 1000 L
1 cal = 4.184 J   1 L = 1000 mL   1 m = 100 cm   1 m = 10^{12} pm

Avogadro's Number	N_A	$6.022\text{x}10^{23}\ \text{mol}^{-1}$
Gas constant	R	$8.31451\ \text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
	R	$0.08206\ \text{atm}\cdot\text{L}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
	R	$8.31451\ \text{L}\cdot\text{kPa}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
	R	$0.0831451\ \text{bar L}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$

Data

$\Delta H_f^o\left(\text{C}_4\text{H}_{10}\text{O}(l)\right) = -327.0\ \text{kJ mol}^{-1}$ $\Delta H_f^o\left(\text{H}_2\text{O}(l)\right) = -285.83\ \text{kJ mol}^{-1}$

$\Delta H_f^o\left(\text{CO}_2(g)\right) = -393.5\ \text{kJ mol}^{-1}$ $\Delta H_f^o\left(\text{H}_2\text{O}(g)\right) = -241.8\ \text{kJ mol}^{-1}$

Equations

$$T(\text{in K}) = T(\text{in }^{\text{o}}\text{C}) + 273.15\ \text{K} \qquad n = \frac{m}{M} = \frac{N}{N_A} \qquad \%\ \text{Yield} = \frac{\text{actual yield}}{\text{theoretical yield}}$$

$$c(\text{mol/L}) = \frac{n}{V} \qquad c_1V_1 = c_2V_2 = n \qquad p = \frac{mg}{A}$$

$$p = dgh \qquad pV = nRT \qquad \frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$p_T = p_1 + p_2 + p_3 + \ldots \qquad p_A = X_A \times p_T \qquad X_A = \frac{n_A}{n_T}$$

$$d = \frac{m}{V} = \frac{p \cdot M}{RT} \qquad E_K = \frac{1}{2}m\text{v}^2 \qquad \bar{E} = \frac{3RT}{2N_A}$$

$$\bar{v} = \sqrt{\frac{3RT}{M}} \qquad \frac{Rate\ A}{Rate\ B} = \sqrt{\frac{M_B}{M_A}} \qquad p = \frac{nRT}{(V-nb)} - a\frac{n^2}{V^2}$$

$$\Delta E = w + q \qquad w = F \times d = -p\Delta V \qquad q_{\text{calorimeter}} = C_{cal}\Delta T$$

$$\Delta E_{\text{reaction}} = \Sigma BE_{\text{reactant bonds broken}} - \Sigma BE_{\text{product bonds formed}} \qquad \Delta E_{\text{molar}} = \frac{\Delta E}{n}$$

$$\Delta H^o_{\text{reaction}} = \Sigma v_p \Delta H^o_{f,p} - \Sigma v_r \Delta H^o_{f,r} \qquad \Delta H_{\text{reaction}} = \Delta E_{\text{reaction}} + RT\Delta n_{gas} \qquad H = E + pV$$

The Modern Periodic Table

MAIN-GROUP ELEMENTS (groups 1–2) · TRANSITION ELEMENTS (groups 3–12) · MAIN-GROUP ELEMENTS (groups 13–18)

4	Atomic number
Be	Atomic symbol
9.012	Atomic mass (u)

- ▨ Metals (main-group)
- ▨ Metals (transition)
- ▨ Metals (inner transition)
- ▨ Metalloids
- ☐ Nonmetals

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** 1.008																	2 **He** 4.003
2	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
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	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** 65.41	31 **Ga** 69.72	32 **Ge** 72.61	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		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)
7	87 **Fr** (223)	88 **Ra** (226)		104 **Rf** (263)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (267)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 **Cn** (285)	113 **Uut** (284)	114 **Fl** (289)	115 **Uup** (288)	116 **Lv** (292)	117 **Uus**	118 **Uuo** (294)

As of June 2012, elements 114 and 116 have been officially recognized. Elements 113, 115, 117, and 118 are pending verification by IUPAC.

INNER TRANSITION ELEMENTS

6	Lanthanides	57 **La** 138.9	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
7	Actinides	89 **Ac** (227)	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	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)