LAST NAME: ____

FIRST NAME: ____

Student Number: ____

CHM 1311 D
Prof. Goto
Midterm #1
Fall 2019

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 <u>40 marks</u>. 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.

Warning:
Cellular phones, unauthorized electronic devices or course notes are not allowed during this exam. Phones and devices must be turned off and stored in your bag. Do not keep them in your possession, such as in your pockets. If caught with such a device or document, academic fraud allegations will be filed which may result in your obtaining a **0** (zero) for the midterm.

Question 1. Short answer questions (9 marks)

a) How many significant digits should be in the answer to this calculation?

$$\frac{243.66-38.221}{400-8.1} = \frac{205.44 \leftarrow 5}{392 \leftarrow 3}$$

3 SIG DIGS

b) How many neutrons are contained in $^{110}Ag^{+}$?

47 PROTONS

OF NEUTRONS = 110 - 47 = 63

c) How many atoms of hydrogen are in 0.150 mol of H_3PO_4?

$$n_{H_3PO_4} \times \frac{3\,mol\,H}{1\,mol\,H_3PO_4} \times N_A$$

$$= 0.150\,mol \times 3 \times 6.022 \times 10^{23}\,ATOMS/mol$$

$$= 2.71 \times 10^{23}\,ATOMS$$

d) A balloon filled with air comprised of nitrogen and oxygen is brought into a cold room. Will the partial pressure of oxygen in the trapped air increase, decrease or stay the same?

NO CHANGE

$V\downarrow$ AS $T\downarrow$ BUT P_T IS CONSTANT

e) When a piece of chocolate cake is removed from the fridge, the cake reaches room temperature while the icing on top remains cold to the touch. What has higher heat capacity, cake or frosting?

FROSTING

f) Oxygen gas reacts with hydrogen gas to form water in an exothermic reaction. Which bond has the larger bond dissociation energy, the H – H bond or O – H bond?

O – H

g) If a gas in an open-end manometer has a pressure of 732 torr, then what will be the height difference in mercury level between the two sides of the manometer on a day where the atmospheric pressure is 760 torr? 760 - 732 = 28 mm Hg

h) A gas is compressed while it releases 250 J of heat, such that ΔE is -365 J. How much work was done?

$q = 250\,J$ $\Delta E = -365\,J$

$$w = \Delta E - q = -365\,J + 250\,J$$

$$= -115\,J$$

i) What is the concentration of chloride in a 0.625 M solution of aluminum chloride?

$$[Cl^-] = 0.625\,M \times \frac{3\,mol\,Cl^-}{1\,mol\,AlCl_3}$$

$$= 1.88\,M$$

Question 2. Short calculations (10 marks)

a) How many kilograms is a cube-shaped marshmallow measuring 1 8 mm along each side with a density of 0.55 g/mL? (2 marks)

$$d = \frac{m}{V} \qquad m = dV = d \times l^3 = 0.55\ \frac{g}{cm^3} \times (1\ 8\ mm)^3 \left(\frac{1cm}{10\ mm}\right)^3$$

$$= 3.2g\ (10^{-3}\ kg/g)$$

$$= 3.2 \times 10^{-3}\ kg$$

b) What is the molecular formula of a compound with a molecular mass of 176.1 g/mol that contains an equal number of nitrogen, oxygen and carbon atoms, and two hydrogen atoms for every carbon atom? (2 marks) $M_{NOCH_2} = 14.01 + 16.00,\ 12.01 + 1.008 \times 2]\ g/mol$

M $= 44.036$

$$\frac{M}{M_{NOCH_2}} = \frac{1\ 6.1}{41.036} = 4 \qquad N_4O_4C_4H_8$$

c) A $\overset{V_1}{\underline{\text{25 mL}}}$ aliquot of a 2.65 M solution is diluted to a total volume of $\overset{V_2}{\underline{\text{500. mL}}}$. A $\overset{V_3}{\underline{\text{25 mL}}}$ portion of that solution is diluted by adding 125 mL of water. What is the final concentration? (3 marks)

$$c_1V_1 = c_2V_2$$

$$c_2 = \frac{c_1V_1}{V_2} = \frac{(2.65M)\ \overset{V_1}{\ }\ 5mL)}{500\ mL} = 0.13\overline{25}M$$

$$C_2V_3 = C_3(V_3 + V_4)$$

$$c_3 = \frac{c_2V_3}{V_3 + V_4} = \frac{(0.13\overline{25}M)(25mL)}{25mL + 125mL} = 0.022M$$

d) Write the balanced chemical equation for the reaction of solid calcium carbonate is added aqueous hydrochloric acid, which produces aqueous calcium chloride, carbon dioxide gas, and liquid water. (3 marks)

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

Question 3. (3 marks)
A sample of Br_2 (*g*) takes 15 minutes to effuse through a membrane. How long would it take the same number of moles of H_2 (*g*) to effuse through the same membrane?

$$\frac{\text{RATE } Br_2}{\text{RATE } H_2} = \sqrt{\frac{M_{H_2}}{M_{Br}}} = \sqrt{\frac{2(1.008)}{2(79.90)}} = 0.1123$$

$$= \frac{\dfrac{\cancel{n}}{\Delta t_{Br}}}{\dfrac{\cancel{n}}{\Delta t_{H_2}}} = \frac{\Delta t_{H_2}}{\Delta t_{Br_2}}$$

$$\Delta t_{H_2} = 0.1123\ \Delta t_{Br_2}$$
$$= (0.1123)(15\ \text{min})$$
$$= 1.7\ \text{min}$$

Question 4. (3 marks)
It is possible to use liquid nitrogen to make ice cream. Given that the heat capacity of cream is 3.35 J g^{-1} $^{o}C^{-1}$ and one litre of liquid nitrogen can absorb 79.7 kJ of heat before it evaporates, how many litres of liquid nitrogen are required to bring the temperature of **1.99k**g of cream from 4°C down to -20°C?

$$C_{CREAM} = 3.35\ J\ g^{-1}\ {}^{\circ}C^{-1} \qquad \frac{q_{N_2}}{L} = 79.7\ kJ/L$$

$$m = 995g$$

$$\Delta T = (-20 - 4)^{\circ}C = -24^{\circ}C$$

TOTAL HEAT TO BE ABSORBED

$$q_{TOTAL} = -mc\Delta T$$
$$= -(1.99kg)(3.35\ J\ g^{-1}\ {}^{\circ}C^{-1})(-24.0^{\circ}C)(10^3\ g/kg)$$
$$= 159.\overline{996}\ kJ$$

$$\frac{q}{V} = \frac{q_{N_2}}{L} \qquad V = \frac{q_{TOTAL}}{q_{N_2}/L} = \frac{159.\overline{996}\ kJ}{79.7\ kJ/L}$$

$$= 2.01\ L$$

Question 5. (4 marks)
Acetic acid mixed was mixed with baking soda to produce CO2 gas. What is the mass of carbon dioxide produced in a reaction that allowed 95.3 mL of gas to be collected over water at 300.15 K, 1.00 atm, given that the vapour pressure of water at 300.15 K is 24.6 mm Hg?

$$m = nM = \frac{PV\ M}{RT} = \frac{(P_T - P_{H_2O})\ V\ M}{RT}$$

$$= \frac{\left[1.00\ \text{atm} - 24.6\ \text{mm Hg}\left(\frac{1\ \text{atm}}{760\ \text{mmHg}}\right)\right](0.0953\ L)(12.01 + 16.00 \times 2)\ g/mol}{\left(0.08206\ \frac{atm \cdot L}{K \cdot mol}\right)(300.15\ K)}$$

$$= 0.165\ g$$

Question 6. (4 marks)
Chlorine has two naturally occurring isotopes, ^{35}Cl (34.97 g/mol) and ^{37}Cl (36.97 g/mol). What is the percent abundance of each isotope, given that the average isotopic mass of chlorine is 35.45 g/mol?

$$M_{Cl} = \underbrace{\%\,^{35}Cl}_{x}\ M_{^{35}Cl} + \underbrace{\%\,^{37}Cl}_{1-x}\ M_{^{37}Cl}$$

$$M_{Cl} = x M_{^{35}Cl} + M_{^{37}Cl} - x M_{^{37}Cl}$$

$$x = \frac{M_{Cl} - M_{^{37}Cl}}{M_{^{35}Cl} - M_{^{37}Cl}}$$

$$= \frac{35.45 - 36.97}{34.97 - 36.97} = 0.76$$

$\therefore$ % ABUNDANCE OF ^{35}Cl IS 76%
^{37}Cl IS 24%

Question 7.

Copper reacts with nitric acid to form the poisonous gas NO_2 in the following reaction:

$$Cu\,(s) + 4\,HNO_3\,(aq) \rightarrow Cu(NO_3)_2\,(aq) + 2\,NO_2\,(g) + 2\,H_2O\,(l)$$

a) What volume of NO_2 gas would be produced if 1.00 g of copper is added to 275 mL of 0.250 M nitric acid and allowed to react in an open flask at 298.15 K? (5 marks)

FROM Cu : $n_{NO_2} = n_{Cu} \times \frac{2\,mol\,NO_2}{1\,mol\,Cu} = \frac{m}{M} \times 2$

$= \frac{1.00\,g \times 2}{6355\,g/mol} = 0.0314\overline{7}\,mol$

FROM HNO_3 : $n_{NO_2} = n_{HNO_3} \times \frac{2\,mol\,NO_2}{4\,mol\,HNO_3} = cV \times \frac{1}{2}$

$= (0.250\,\frac{mol}{L})(0.275\,L)\,\frac{1}{2}$

$= 0.03437\,mol$ ← MORE PRODUCT

∴ COPPER IS LIMITING

$V = \frac{nRT}{P}$

$= \frac{(0.0314\,mol)(0.08206\,L \cdot atm\,K^{-1}mol^{-1})(298.15\,K)}{1\,atm}$

$= 768\,mL$

b) What volume of NO_2 would be produced if this reaction had an 83% yield? (1 mark)

$V = 768\,L \times 0.83\% = 637\,L$

b) How much work would be done by the gas produced by the complete reaction of 1 mol of copper at 298.15 K? (2 marks)

$w = -p\Delta V$

$= \Delta n_g RT$

$= -(2-0)(8.314\,J\,K^{-1}mol^{-1})(298.15K)$

$= -5\,kJ$

Constants and Conversion Factors

1 mmHg = 1 torr
1 atm = 1.013125 bar
1 cm^3 = 1 mL = 1000 μL
1 L = 1000 mL

760 mmHg = 1 atm
1 L atm = 101.325 J
1 dm^3 = 1000 mL = 1 L
1 m = 100 cm = 1000 mm

1 atm = 101325 Pa
1 bar = 10^5 Pa
1 m^3 = 1000 L
1 m = 10^9 nm = 10^{12} pm

1 kPa = 1000 Pa
1 cal = 4.184 J

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	$0.0831451\ \text{bar L}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$

Equations

$$T(\text{in K}) = T(\text{in }^{\circ}\text{C}) + 273.15\ \text{K}$$

$$n = \frac{m}{M} = \frac{N}{N_A}$$

$$\%\ \text{Yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$c(\text{mol}/\text{L}) = \frac{n}{V}$$

$$c_1V_1 = c_2V_2 = n$$

$$p = \frac{mg}{A}$$

$$p = dgh$$

$$pV = nRT$$

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$p_T = p_1 + p_2 + p_3 + \ldots$$

$$p_A = X_A \times p_T$$

$$X_A = \frac{n_A}{n_T}$$

$$d = \frac{m}{V} = \frac{p \cdot M}{RT}$$

$$E_K = \frac{1}{2}m\text{v}^2$$

$$\bar{E} = \frac{3RT}{2N_A}$$

$$\frac{Rate\ A}{Rate\ B} = \sqrt{\frac{M_B}{M_A}}$$

$$p = \frac{nRT}{(V - nb)} - a\frac{n^2}{V^2}$$

$$\Delta E = w + q$$

$$w = F \times d = -p\Delta V$$

$$q_{\text{calorimeter}} = C_{cal}\Delta T$$

$$\Delta E_{\text{reaction}} = \Sigma BE_{\text{reactant bonds broken}} - \Sigma BE_{\text{product bonds formed}}$$

$$\Delta H^o_{\text{reaction}} = \Sigma v_p \Delta H^o_{f,p} - \Sigma v_r \Delta H^o_{f,r}$$

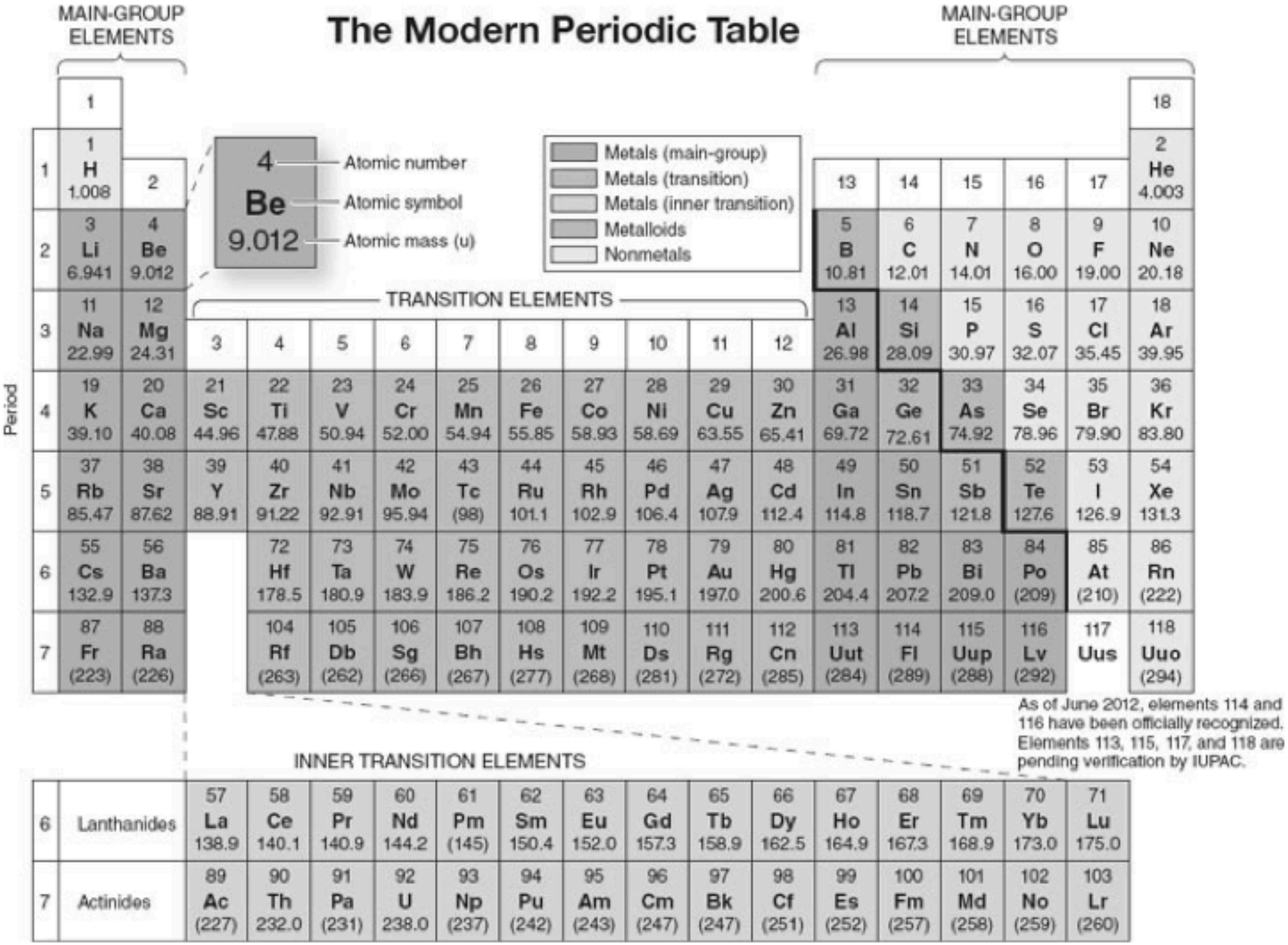
$$q = mc\Delta T$$

$$q = nC_m\Delta T$$

$$\Delta E_{\text{molar}} = \frac{\Delta E}{n}$$

$$\Delta H_{\text{reaction}} = \Delta E_{\text{reaction}} + RT\Delta n_{gas}$$

$$H = E + pV$$



The Modern Periodic Table

MAIN-GROUP ELEMENTS

TRANSITION ELEMENTS

MAIN-GROUP ELEMENTS

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)