Lakehead UNIVERSITY

DEPARTMENT OF CHEMISTRY
Midterm Examination
Chemistry 1110 (Modern Chemistry I)
12 October, 2011

SOLUTIONS

1. Multiple choice, **select 1 answer only**. Do *all 12* questions (2 points each, 24 total):

(i) Heat capacity is,

(d) the amount of energy required to heat an object up by 1°

(ii) Absolute zero temperature is,

(b) 0 K

(iii) Thermodynamics talks about a "system" and its "surroundings". Thus, the surroundings of a thermodynamic system are:

(b) the entire universe except for the system

(iv) If 0.10 mol of H_2 effuses through a hole in a container in 4.6 s, how long will it take 0.10 mol of N_2 to effuse through the same hole?

(d) 17 s

The ratio of *rates* is inversely proportional to the ratio of the molar masses, so the ratio of of *times* (time = 1/rate) will be directly proportional, therefore $t_{N2} = t_{He}\ (MWt_{N2} / MWt_{He})^{½}$.

(v) Iron ore (hematite) is converted to iron metal by the reaction:

$$2\ Fe_2O_3\ (s)\ +\ 2\ C\ (s)\ \rightarrow\ 4\ Fe\ (s)\ +\ 3\ CO_2\ (g)$$

Calculate the standard enthalpy of the reaction (as written) if ΔH_f° of Fe_2O_3 (*s*) is -826 kJ/mol and that of CO_2 (*g*) is -393.5.

(b) 472 kJ/mol

$\Delta H_f^\circ = 4*\Delta H_f^\circ(Fe) + 3*\Delta H_f^\circ(CO_2) - 2*\Delta H_f^\circ(Fe_2O_3) - 2*\Delta H_f^\circ(C)$
$= 4(0) + 3(393.5) - 2(826) - 2(0)$

(vi) 100.0 g of hematite (Fe_2O_3) was converted to iron by the reaction in (v). If 60.0 g of iron was isolated, what is the percent yield?

(d) 85.8%

Theoretical yield of Fe = $100\text{g } Fe_2O_3\left(\frac{1\text{mol } Fe_2O_3}{159.70\text{g}}\right)\left(\frac{4\text{mol Fe}}{2\text{mol } Fe_2O_3}\right)\left(\frac{55.85\text{g}}{1\text{mol Fe}}\right) = 69.96\text{g Fe}$

Therefore, %yield = 60.0/69.96 * 100% = 85.8%

(vii) What type of reaction is the conversion of hematite to iron metal (as shown in (v))?

(c) this is a redox reaction

The iron changes from Fe^{3+} to Fe^0, the C changes from C^0 to C^{4+}.

(viii) Charles's Law explains the behaviour of an ideal gas as temperature varies. By this law,

(e) both (b) and (c)

((b) as temperature increases, volume increases (at constant pressure), (c) at absolute 0 (0 K), the volume of an ideal gas is 0)

(ix) The insecticide DDT ($C_{14}H_9Cl_5$) is made by the following reaction:

$$2\ C_6H_5Cl + HOC_2Cl_3 \rightarrow C_{14}H_9Cl_5 + H_2O$$

What is the maximum yield if 632 g of C_6H_5Cl is reacted with 485 g of HOC_2Cl_3?

(d) 995 g

Theoretical moles from C_6H_5Cl = $632\text{g } C_6H_5Cl\left(\frac{1\text{mol } C_6H_5Cl}{112.56\text{g}}\right)\left(\frac{1\text{mol DDT}}{2\text{mol } C_6H_5Cl}\right) = 2.81\text{mol DDT}$

Theoretical moles from HOC_2Cl_3 = $485\text{g } HOC_2Cl_3\left(\frac{1\text{mol } HOC_2Cl_3}{147.39\text{g}}\right)\left(\frac{1\text{mol DDT}}{1\text{mol } HOC_2Cl_3}\right) = 3.29\text{mol DDT}$

C_6H_5Cl is limiting, therefore 2.81 mol of DDT is produced

mass of DDT = (2.81 mol) (354.48 g/mol) = 995 g

(x) What is the correct IUPAC name of $Fe_2(SO_4)_3$?

(a) iron(III) sulfate

(xi) Ammonium nitrate is a fertilizer and also one component of an explosive popular with terrorists. What is its chemical formula?

(e) $NH_4\ NO_3$

(xii) Gasses are transported in cylinders at high pressure (non-ideal conditions). If the 40.0 L nitrogen tank in my research lab contains 12.0 kg of gas at 20.°C, what is the pressure in the tank? For N_2, the van der Waals constants are a = 1.39 atm L^2 mol^{-2} and b = 0.0391 L mol^{-1}.

c) 284 atm

Using van der Waal's equation, $\left(P + \frac{n^2 a}{V^2}\right) \cdot (V - nb) = nRT$, solve for P.

2. In the space below, answer **2 of the following 3** questions. If you need more room, use the back of this page. (5 points each, 10 points total)

(a) Give two ways in which ideal gasses deviate from real gasses. Using the kinetic-molecular theory, explain how this would cause a difference in the pressure of a real gas *vs*. pressure of an ideal gas.

1. I was looking for something that said volume of ideal gasses are 0, as opposed to real gasses which have a volume. This could also be stated as "point masses" for an ideal gas, or that an ideal gas's volume is 0 at 0K.
2. I was looking for something that said that intermolecular interactions were ignored in ideal gasses, but in real gasses they are attractive.
3. Some comment about how #1 causes the pressure to increase (especially at high P, or low T), and/or how the intermolecular forces in #2 are attractive and would serve to lower the pressure.

(b) Iron workers temper their metals by repeatedly heating the metal (in a charcoal flame) and cooling in a bucket of water. A wrought-iron candelabra, mass 550. g at a temperature of a charcoal flame (1400. K) is dunked into a bucket containing 10.00 L of water at 0°C. Recalling that water has a density of (exactly) 1 g/mL, what is the final temperature of the water and iron? Specific heats are: s_{water} = 4.18 J K^{-1} g^{-1}; s_{iron} = 0.45 J K^{-1} g^{-1}.

The two final temperatures must be the same (if they weren't there would be a temperature gradient and heat would continue to flow between them!). Thus, using $q = sm\Delta T$, and noting that $q_{H2O} = -q_{Fe}$,

10.00 L of water = 10 000 mL = 10 000 g H_2O

note that this can be done in °C or K (actually in °C is easier because you cancel a term with the 0°C). In K,
(4.18 J/Kg)(10000 g)(T_f - 1400.K) = -(0.45 J/Kg)(550. g)(T_f - 273.K)

rearranged and solved for T_f = 280 K (or 6.6°C)

(c) 1.50 g of sodium hydroxide (NaOH (*s*)) was added to 100.00 mL of aqueous sulfuric acid (H_2SO_4 (*aq*), concentration 0.250 *M*). Assuming the addition of NaOH does not change the volume of the solution, calculate the amount of excess acid or base left in the solution after the reaction takes place.

First balance the acid-base equation. Net equation would be:

$$2\ NaOH\ (s)\ +\ H_2SO_4\ (aq)\ \rightarrow\ 2\ H_2O\ (l)\ +\ Na_2SO_4\ (aq)$$

theoretical yield (of Na_2SO_4) based on NaOH = $1.50\text{g NaOH}\left(\frac{1\text{mol NaOH}}{40.00\text{g}}\right)\left(\frac{1\text{mol } Na_2SO_4}{2\text{mol NaOH}}\right) = 0.01875\text{mol}$

theoretical yield based on H_2SO_4 = (0.250 mol/L)(0.10000 L) = 0.0250 mol

Therefore NaOH is the limiting reagent, and 0.01875 mol H_2SO_4 will be used in the reaction
Therefore, 0.0250 - 0.01875 mol = 0.0063 mol H_2SO_4 remaining (can also be stated as 0.61 g or 0.063 mol/L)

Formula Sheet:

gasses

$V \propto \frac{1}{P}$

$V \alpha n$

$V \alpha T$

$P_{total} = P_1 + P_2 + ...$

$PV = nRT$

$$\left(P + \frac{n^2 a}{V^2} \right) \cdot (V - nb) = nRT$$

$$\frac{\text{rate}_A}{\text{rate}_B} = \frac{\bar{u}_A}{\bar{u}_B} = \frac{\sqrt{M_{mB}}}{\sqrt{M_{mA}}}$$

$$\bar{u} = \sqrt{\frac{3RT}{M_m}}$$

thermochemistry

$q = s\, m\, \Delta T$

$q = C_p\, \Delta T$

$\Delta H = q_p = \Delta E + P\Delta V$

general

$E = h\nu\ (= hf)$

$c = \lambda\nu\ (= \lambda f)$

$$\bar{E}_k = \frac{1}{2} m \bar{u}^2$$

constants:

R = 0.08206 L atm/(mol K) = 8.315 kPa dm^3/(mol K) = 8.315 J/(mol K) = 62.36 Torr L/(mol K)

standard conditions (thermodynamic) = 1.0000 atm pressure, 298.15 K, 1.0000 M

1.000 atm = 760. Torr = 101.3 kPa

N_A = 6.022 x 10^{23} mol^{-1}

c = 2.998 x 10^8 m/s

h = 6.626 x 10^{-34} J s

STP = 1.0000 atm pressure and 273.15 K

specific heat of water (s) = 4.18 J °C^{-1} g^{-1}

kilo = 10^3

centi = 10^{-2}

milli = 10^{-3}

nano = 10^{-9}

pico = 10^{-12}

derived units:

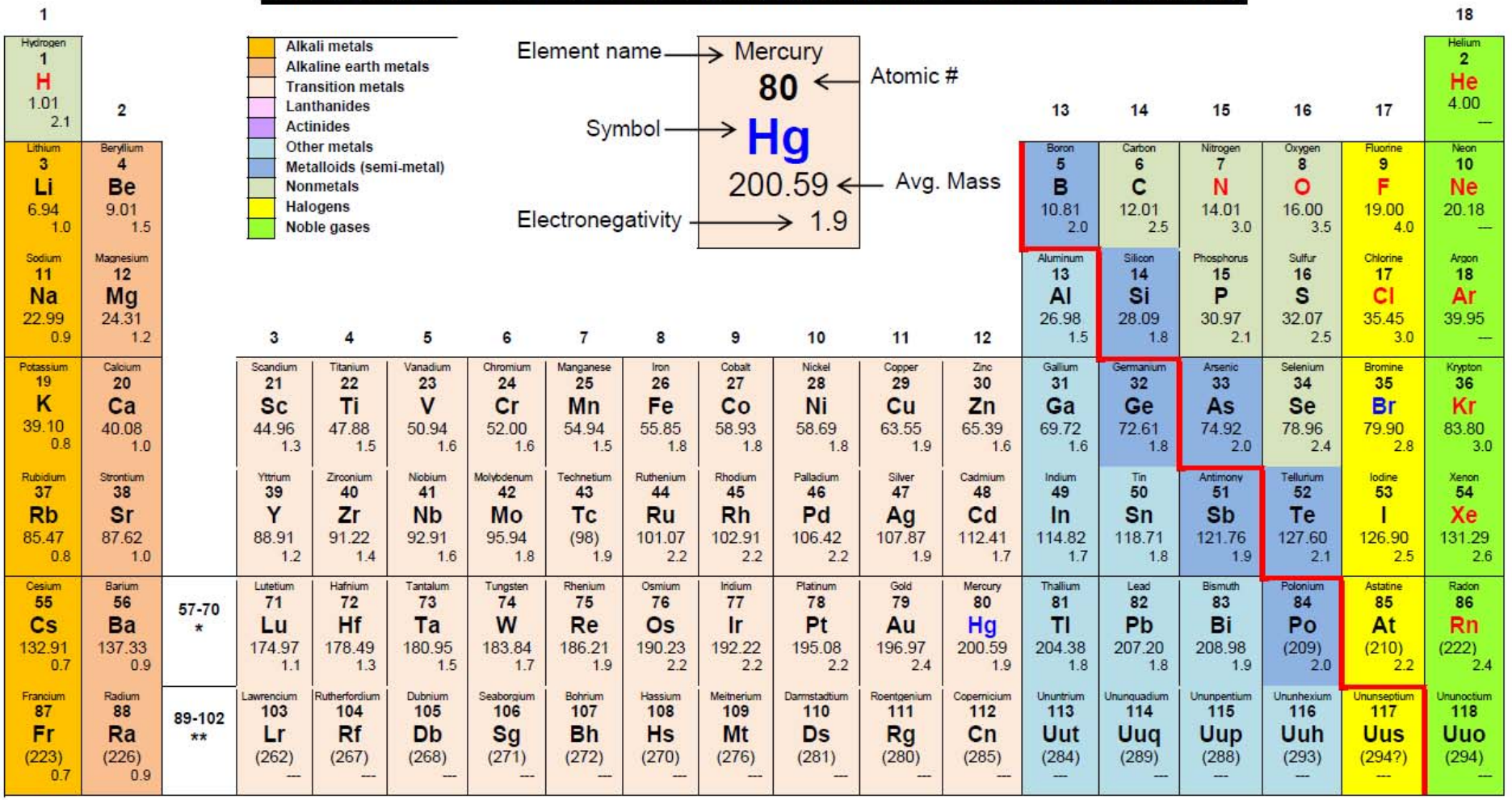
N = kg m s^{-2}

J = kg m^2 s^{-2}

mL = cm^3

Pa = N m^{-1}

The Periodic Table of the Elements (with Electronegativities)



1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hydrogen 1 H 1.01 2.1																		Helium 2 He 4.00 —
Lithium 3 Li 6.94 1.0	Beryllium 4 Be 9.01 1.5												Boron 5 B 10.81 2.0	Carbon 6 C 12.01 2.5	Nitrogen 7 N 14.01 3.0	Oxygen 8 O 16.00 3.5	Fluorine 9 F 19.00 4.0	Neon 10 Ne 20.18 —
Sodium 11 Na 22.99 0.9	Magnesium 12 Mg 24.31 1.2												Aluminum 13 Al 26.98 1.5	Silicon 14 Si 28.09 1.8	Phosphorus 15 P 30.97 2.1	Sulfur 16 S 32.07 2.5	Chlorine 17 Cl 35.45 3.0	Argon 18 Ar 39.95 —
Potassium 19 K 39.10 0.8	Calcium 20 Ca 40.08 1.0		Scandium 21 Sc 44.96 1.3	Titanium 22 Ti 47.88 1.5	Vanadium 23 V 50.94 1.6	Chromium 24 Cr 52.00 1.6	Manganese 25 Mn 54.94 1.5	Iron 26 Fe 55.85 1.8	Cobalt 27 Co 58.93 1.8	Nickel 28 Ni 58.69 1.8	Copper 29 Cu 63.55 1.9	Zinc 30 Zn 65.39 1.6	Gallium 31 Ga 69.72 1.6	Germanium 32 Ge 72.61 1.8	Arsenic 33 As 74.92 2.0	Selenium 34 Se 78.96 2.4	Bromine 35 Br 79.90 2.8	Krypton 36 Kr 83.80 3.0
Rubidium 37 Rb 85.47 0.8	Strontium 38 Sr 87.62 1.0		Yttrium 39 Y 88.91 1.2	Zirconium 40 Zr 91.22 1.4	Niobium 41 Nb 92.91 1.6	Molybdenum 42 Mo 95.94 1.8	Technetium 43 Tc (98) 1.9	Ruthenium 44 Ru 101.07 2.2	Rhodium 45 Rh 102.91 2.2	Palladium 46 Pd 106.42 2.2	Silver 47 Ag 107.87 1.9	Cadmium 48 Cd 112.41 1.7	Indium 49 In 114.82 1.7	Tin 50 Sn 118.71 1.8	Antimony 51 Sb 121.76 1.9	Tellurium 52 Te 127.60 2.1	Iodine 53 I 126.90 2.5	Xenon 54 Xe 131.29 2.6
Cesium 55 Cs 132.91 0.7	Barium 56 Ba 137.33 0.9	57-70 *	Lutetium 71 Lu 174.97 1.1	Hafnium 72 Hf 178.49 1.3	Tantalum 73 Ta 180.95 1.5	Tungsten 74 W 183.84 1.7	Rhenium 75 Re 186.21 1.9	Osmium 76 Os 190.23 2.2	Iridium 77 Ir 192.22 2.2	Platinum 78 Pt 195.08 2.2	Gold 79 Au 196.97 2.4	Mercury 80 Hg 200.59 1.9	Thallium 81 Tl 204.38 1.8	Lead 82 Pb 207.20 1.8	Bismuth 83 Bi 208.98 1.9	Polonium 84 Po (209) 2.0	Astatine 85 At (210) 2.2	Radon 86 Rn (222) 2.4
Francium 87 Fr (223) 0.7	Radium 88 Ra (226) 0.9	89-102 **	Lawrencium 103 Lr (262) —	Rutherfordium 104 Rf (267) —	Dubnium 105 Db (268) —	Seaborgium 106 Sg (271) —	Bohrium 107 Bh (272) —	Hassium 108 Hs (270) —	Meitnerium 109 Mt (276) —	Darmstadtium 110 Ds (281) —	Roentgenium 111 Rg (280) —	Copernicium 112 Cn (285) —	Ununtrium 113 Uut (284) —	Ununquadium 114 Uuq (289) —	Ununpentium 115 Uup (288) —	Ununhexium 116 Uuh (293) —	Ununseptium 117 Uus (294?) —	Ununoctium 118 Uuo (294) —

*lanthanides	Lanthanum 57 La 138.91 1.1	Cerium 58 Ce 140.12 1.1	Praseodymium 59 Pr 140.91 1.1	Neodymium 60 Nd 144.24 1.1	Promethium 61 Pm (145) 1.1	Samarium 62 Sm 150.36 1.2	Europium 63 Eu 151.97 1.1	Gadolinium 64 Gd 157.25 1.2	Terbium 65 Tb 158.93 1.1	Dysprosium 66 Dy 162.50 1.2	Holmium 67 Ho 164.93 1.2	Erbium 68 Er 167.26 1.2	Thulium 69 Tm 168.93 1.3	Ytterbium 70 Yb 173.04 1.1
**actinides	Actinium 89 Ac (227) 1.1	Thorium 90 Th 232.04 1.3	Protactinium 91 Pa 231.04 1.5	Uranium 92 U 238.03 1.4	Neptunium 93 Np (237) 1.4	Plutonium 94 Pu (244) 1.3	Americium 95 Am (243) 1.3	Curium 96 Cm (247) 1.3	Berkelium 97 Bk (247) 1.3	Californium 98 Cf (251) 1.3	Einsteinium 99 Es (252) 1.3	Fermium 100 Fm (257) 1.3	Mendelevium 101 Md (258) 1.3	Nobelium 102 No (259) 1.3