King AbdulAziz University, Department of Chemistry
Second semester 1422-1423   Thursday 21/1/1423H

Chem 101, General exam   Time: 1 hour

Name: Number: Section:

Q1 (8 points)	
Q2 (4 points)	
Q3 (4 points)	
Q4 (4 points)	
Total (20 points)	

Useful information:

Speed of light, $c = 3.0\times10^{8}$ m/s

Planck's const., $h = 6.626\times10^{-34}$ J.s

Avogadro's No., $N_a = 6.022\times10^{23}$ mol^{-1}

Energy const. for H atom $B = 2.179\times10^{-18}$ J

Frequency const. for H atom $B/h = 3.289\times10^{15}$ s^{-1}

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

Gas constant, $R = 0.082$ L atm K^{-1} mol^{-1} = 8.314 $JK^{-1}mol^{-1}$

PERIODIC TABLE

Key: 12 / C / Carbon / 6
- 12 → Relative atomic mass to nearest whole number
- C → Symbol
- 6 → Atomic number

1 H Hydrogen 1																	4 **He** Helium 2
7 **Li** Lithium 3	9 **Be** Beryllium 4											11 **B** Boron 5	12 **C** Carbon 6	14 **N** Nitrogen 7	16 **O** Oxygen 8	19 **F** Flourine 9	20 **Ne** Neon 10
23 **Na** Sodium 11	24 **Mg** Magnesium 12											27 **Al** Aluminum 13	28 **Si** Silicon 14	31 **P** Phosphorus 15	32 **S** Sulfur 16	35.5 **Cl** Chlorine 17	40 **Ar** Argon 18
39 **K** Potassium 19	40 **Ca** Calcium 20	45 **Sc** Scandium 21	48 **Ti** Titanium 22	51 **V** Vanadium 23	52 **Cr** Chromium 24	55 **Mn** Manganese 25	56 **Fe** Iron 26	59 **Co** Cobalt 27	59 **Ni** Nickel 28	63.5 **Cu** Copper 29	65 **Zn** Zinc 30	70 **Ga** Gallium 31	72.5 **Ge** Germanium 32	75 **As** Arsenic 33	79 **Se** Selenium 34	80 **Br** Bromine 35	84 **Kr** Krypton 36
85.5 **Rb** Rubidium 37	86 **Sr** Strontium 38	89 **Y** Yttrium 39	91 **Zr** Zirconium 40	93 **Nb** Niobium 41	96 **Mo** Molybdenum 42	(96) **Tc** Technetium 43	101 **Ru** Ruthenium 44	103 **Rh** Rhodium 45	106 **Pd** Palladium 46	108 **Ag** Silver 47	112 **Cd** Cadmium 48	115 **In** Indium 49	119 **Sn** Tin 50	122 **Sb** Antimony 51	128 **Te** Tellurium 52	127 **I** Iodine 53	131 **Xe** Xenon 54
133 **Cs** Cesium 55	137 **Ba** Barium 56	139 **La** Lanthanum 57	178.5 **Hf** Hafnium 72	181 **Ta** Tantalum 73	184 **W** Tungsten 74	186 **Re** Rhenium 75	190 **Os** Osmium 76	192 **Ir** Iridium 77	195 **Pt** Platinum 78	197 **Au** Gold 79	201 **Hg** Mercury 80	204 **Tl** Thallium 81	207 **Pb** Lead 82	209 **Bi** Bismuth 83	(210) **Po** Polonium 84	(210) **At** Astatine 85	(222) **Rn** Radon 86
(223) **Fr** Francium 87	(226) **Ra** Radium 88	(227) **Ac** Actinium 89	(261) **Rf** Rutherfordium 104	(262) **Db** Dubnium 105	(266) **Sg** Seaborgium 106	(264) **Bh** Bohrium 107	(265) **Hs** Hassium 108	(268) **Mt** Meitnerium 109									

140 **Ce** Cerium 58	141 **Pr** Praseodymium 59	144 **Nd** Neodymium 60	145 **Pm** Promethium 61	150 **Sm** Samarium 62	152 **Eu** Europium 63	157 **Gd** Gadolinium 64	159 **Tb** Terbium 65	162.5 **Dy** Dysprosium 66	165 **Ho** Holmium 67	167 **Er** Erbium 68	169 **Tm** Thulium 69	173 **Yb** Ytterbium 70	175 **Lu** Lutetium 71
232 **Th** Thorium 90	231 **Pa** Protactinium 91	238 **U** Uranium 92	237 **Np** Neptunium 93	244 **Pu** Plutonium 94	(243) **Am** Americium 95	(247) **Cm** Curium 96	(247) **Bk** Berkelium 97	(251) **Cf** Californium 98	(252) **Es** Einsteinium 99	(257) **Fm** Fermium 100	(258) **Md** Mendelevium 101	(259) **No** Nobelium 102	(262) **Fm** Lawrencium 103

1. (8 points)

Consider hydrazine, N_2H_4. (Show your work)

A	What is its molecular weight in grams?
B	What is its empirical (simple) formula?
C	How many moles are there in 2.65 g of hydrazine?
D	How many grams of hydrazine are there in 1.2×10^{27} molecules of hydrazine?
E	How many hydrogen atoms are there in 1.769 mol of hydrazine?
F	How many grams of hydrogen can be obtained from 100.0 g of hydrazine?
G	How many neutrons are there in one molecule of hydrazine?
H	What is the molar concentration of 0.02 g of N_2H_4 in 439mL of solution?

2. (4 points)

(a) Consider the electronic transition from the principal quantum number n = 4 to n =1 in the hydrogen atom. Is energy emitted or absorbed for this transition? What is the wavelength of the associated photon?

(b) List the various subshells, and the number of orbitals in each subshell, for the shell with a principal quantum number of 3.

Shell	Subshells	Number of orbitals for each subshell
n = 3		

3. (4 points) In an experiment 489.6 g of BF_3 were reacted with 160.2 g of H_2O, according to the following reaction:

$$2BF_3\,(aq) + 3H_2O\,(g) \;\Rightarrow\; B_2O_3\,(s) + 6\,HF\,(g)$$

a- What is the theoretical yield of B_2O_3 in grams?

Theoretical yield =

b- How many moles of the excess reactant remain?

moles of excess reactant =

c- If the reaction yield is 73%, what is the actual yield of B_2O_3 in grams?

Actual yield (B_2O_3) =

4. (4 points)

a) Diagram the resonance forms of *SCS* ; assigning the formal charge on each atom, the C atom is the central atom.

b) Calculate the de Broglie wavelength of an electron traveling at 15% of the speed of light.

λ =	m

Consider hydrazine, N_2H_4 (Show your work)

a. What is its molecular weight in grams?

N_2H_4

Molecular weight = $14 \times 2 + 4 \times 1 = 32 g/mol$

b. What is its empirical (simple) formula?

NH

c. How many moles are there in 2.65 g of hydrazine?

$$\# moles = \frac{2.65g}{32g/mol} = 0.083mol$$

d. How many grams of hydrazine are there in 1.2×10^{27} molecules of hydrazine?

1 mol N_2H_4 = 6.02×10^{23} molecules

X mol = 1.2×10^{27} molecules

$$x = \frac{1.2 \times 10^{27}}{6.02 \times 10^{23}} = 2.0 \times 10^{3}\, mol$$

$2.0 \times 10^{3} \times 32 = 6.4 \times 10^{4}$ g

e. How many hydrogen atoms are there in 1.2×10^{27} molecules of hydrazine?

There are 4 H atoms in one N_2H_4 molecule

1.2×10^{27} molecules : $1.2 \times 10^{27} \times 4$ =

4.8×10^{27} H atoms

f. How many grams of hydrogen can be obtained from 100.0 g of hydrazine ؟

$$\%H = \frac{4\times1}{32}\times100 = 12.5\%$$

In 100 g of hydrazine:

$$weight\ of\ hydrogen = \frac{12.5}{100}\times100 = 12.5g$$

g. How many neutrons are there in one molecule of hydrazine ؟

$${}^{1}_{1}H : zero\ neutrons$$

$${}^{14}_{7}N : 14 - 7 = 7\ neutrons$$

In one molecule: 2×7 = 14 neutrons

h. What is the <u>molar concentration</u> of 0.02 g of N_2H_4 in 439mL of solution؟

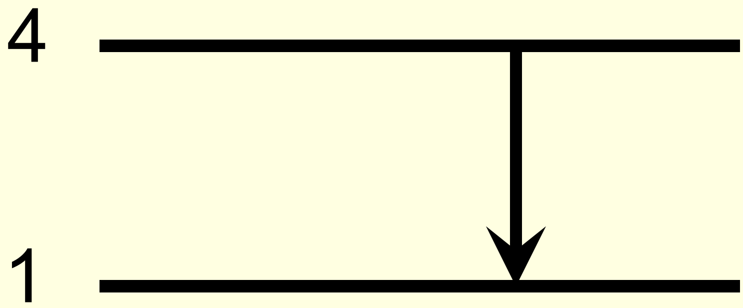
$$M = \frac{n}{V}$$

$$n = \frac{0.02g}{32g/mol} = 6.25 \times 10^{-4}\, mol$$

$$M = \frac{6.25 \times 10^{-4}\, mol}{0.439L} = 1.42 \times 10^{-3}\, M$$

(2.a) Consider the electronic transition From the principal quantum number $n = 4$ to $n = 1$ in the hydrogen atom.

Is energy emitted or absorbed for this transition? What is the wavelength of the associated photon?



Energy is emitted

$$\nu = 3.289 \times 10^{15}\, s^{-1} \left(\frac{1}{1^2} - \frac{1}{4^2} \right)$$

$$= 3.083 \times 10^{15}\, s^{-1}$$

$$\nu = \frac{c}{\lambda} \Rightarrow \lambda = \frac{c}{\nu} =$$

$$\frac{3.00 \times 10^{8} \, m/s}{3.083 \times 10^{15} \, s^{-1}} = 9.7 \times 10^{-8} \, m$$

$=9.7\times10^{-8}$ m$\times10^{9}$nm/m = 97 nm

(2.b)List the various subshells, and the number of orbitals in each subshell, for the shell with a principal quantum number of 3.

Shell(n)	Subshell	Notation	Orbitals (m_l)	#orbitals
3	0	3s	0	1
	1	3p	-1, 0, +1	3
	2	3d	-2, -1, 0, +1, +2	5

3. In an experiment 489.6 g of BF_3 were reacted with 160.2 g of H_2O, according to the following reaction:

$$2BF_3(aq)+3H_2O(g) \Rightarrow B_2O_3(s)+6HF(g)$$

a. What is the theoretical yield of B_2O_3 in grams?

#moles of BF_3 = $\frac{489.6g}{68g/mol} = 7.2mol$

#moles of H_2O = $\frac{160.2g}{18g/mol} = 8.9mol$

determine the limiting reagent

for BF_3: $\frac{7.2}{2} = 3.6$

for H_2O: $\frac{8.9}{3} = 2.97$ **(smaller ratio)**

H_2O is the limiting reagent

3 mol H_2O = 1 mol B_2O_3

8.9 mol H_2O = x mol B_2O_3

$$x = \frac{8.9 mol\ H_2O \times 1 mol\ B_2O_3}{3 mol\ H_2O}$$

$$= 2.97 mol\ B_2O_3$$

$$2.97 mol\ B_2O_3 =$$

$$2.97 mol \times 70 g/mol = 208 g$$

b. How many moles of the excess reactant remain?

2 mol BF_3 = 3 mol H_2O

x mol BF_3 = 8.9 mol H_2O

$$x = \frac{8.9 mol\ H_2O \times 2 mol\ BF_3}{3 mol\ H_2O}$$

$$= 5.93 mol\ BF_3$$

7.2 – 5.93 = 1.3 mol

c. If the reaction yield is 73%, what is the actual yield of B_2O_3 in grams

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

$$\frac{73}{100} = \frac{\textit{Actual yield}}{208} = 151.8 \text{ g}$$

Calculate the de Broglie's wavelength of an electron traveling at 15% of the speed of light.

$$\lambda = \frac{h}{mv} =$$

$$\frac{6.626 \times 10^{-34}\, J.s}{9.11 \times 10^{-31}\, kg \times 0.15 \times 3.00 \times 10^{8}\, m/s}$$