Chem 111 -ANSWER KEY

WORKSHEET- STOICHIOMETRY AND Chemical Formulas Calculations

SET A: (Time required, 1 hour)

1) A compound with the formula, $B_xH_{20}O_3$, contains 36.14 % by mass oxygen. What is the value of the integer, x ?

1) Ans: x = 6

Setup:

$$36.14\,g\,O\left(\frac{1\text{ mole O}}{16.00\,g\,O}\right)\left(\frac{20\text{ moles H}}{3\text{ moles O}}\right)\left(\frac{1.010\,g\,H}{1\text{ mole H}}\right) = 15.21\,g\,H$$

Find mass of "B" in 100g sample:-

100g sample − 36.14g O − 15.21g H = 48.65 g B

B	H	O
$\frac{48.65g}{10.80g/mole}$	$\frac{15.21g}{1.010g/mole}$	$\frac{36.14g}{16.00g/mole}$
4.505 mole	15.06 mole	2.259 mole
$\frac{4.505}{2.259}$	$\frac{15.06}{2.259}$	$\frac{2.259}{2.259}$
2	$6.666 = 6\frac{2}{3}$	1
6	20	3

Empirical Formula $B_6H_{20}O_3$

$x = 6$

SET A

2) A mixture of cobalt(II) oxide and cobalt(III) oxide contains 32.50 % by mass cobalt (II) oxide. What is the total number of oxide ions in a 122 g of the mixture ? 2) Ans: 1.22×10^{24} oxide ions

Setup:

$$32.50 \text{ g CoO}\left(\frac{1 \text{ mole CoO}}{74.90 \text{ g CoO}}\right)\left(\frac{1 \text{ mole } O^{2-} \text{ ion}}{1 \text{ mole CoO}}\right) = .4345 \text{ mole } O^{2-} \text{ ion}$$

$$67.50 \text{ g } Co_2O_3\left(\frac{1 \text{ mole } Co_2O_3}{165.8 \text{ g } Co_2O_3}\right)\left(\frac{3 \text{ moles } O^{2-} \text{ ions}}{1 \text{ mole } Co_2O_3}\right) = 1.221 \text{ mol } O^{2-} \text{ ion}$$

$$\text{Total moles } O^{2-} = 0.4345 \text{ mole} + 1.221 \text{ mole} = 1.659 \text{ mole } O^{2-} \text{ ion}$$

$$122 \text{ g mixture}\left(\frac{1.659 \text{ mole } O^{2-} \text{ ions}}{100 \text{ g mixture}}\right)\left(\frac{6.02 \times 10^{23}\ O^{2-} \text{ ions}}{1 \text{ mole } O^{2-} \text{ ion}}\right) = 1.22 \times 10^{24}\ O^{2-} \text{ ion}$$

3) A sulfur containing compound is treated chemically to convert all its sulfur into barium sulfate. A 8.19 mg sample of the compound gave 5.46 mg barium sulfate.

a) What is the percentage of sulfur in the compound? 3a) Ans: 9.18 % S

Setup:

$$5.46 \times 10^{-3} \text{ g } BaSO_4\left(\frac{1 \text{ mole } BaSO_4}{233.3 \text{ g } BaSO_4}\right)\left(\frac{1 \text{ mole S}}{1 \text{ mole } BaSO_4}\right)\left(\frac{32.0 \text{ g S}}{1 \text{ mole S}}\right) = 7.52 \times 10^{-4} \text{ g S}$$

$$\% \text{ S} = \frac{7.52 \times 10^{-4} \text{ g S}}{8.19 \times 10^{-3} \text{ g compound}} \times 100 = 9.18 \%$$

b) If there is one sulfur atom in the molecule , what is the molar mass of the compound ?

3b) Ans: 349 g/mole

Setup:

$$5.48 \times 10^{-3} \text{ g } BaSO_4\left(\frac{1 \text{ mole } BaSO_4}{233.3 \text{ g } BaSO_4}\right)\left(\frac{1 \text{ mole S}}{1 \text{ mole } BaSO_4}\right) = .0235 \times 10^{-3} \text{ mole S}$$

$$.0235 \times 10^{-3} \text{ mole S}\left(\frac{1 \text{ mole compound}}{1 \text{ mole S}}\right) = .0235 \times 10^{-3} \text{ mole compound}$$

$$\text{molar mass of compound} = \frac{8.19 \times 10^{-3} \text{ g compound}}{.0235 \times 10^{-3} \text{ mole compound}}$$

$$= 349 \text{ g/mole}$$

SET A

4) An alloy of Co, Rh and Mn contains these elements in the atomic ratio of 2 : 5 : 2 , respectively. What is the mass of a sample of this alloy containing a total of 8.75×10^{21} atoms ? 4) Ans: 1.20 g

Setup:

$$.75 \times 10^{21} \text{ atoms} \left(\frac{1 \text{ molecule}}{9 \text{ atoms}}\right)\left(\frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ molecules}}\right)\left(\frac{742.1 \text{ g compound}}{1 \text{ mole compound}}\right)$$

$$= 1.20 \text{ g compound}$$

5) The percent of aluminum in the compound, Al_2X_3, is 18.56 %. What is the molar mass of element X ?

Setup: 5) Ans:79.00 g/mole

$$18.56 \text{ g Al} \left(\frac{1 \text{ mole Al}}{27.00 \text{ g Al}}\right)\left(\frac{3 \text{ moles X}}{2 \text{ moles Al}}\right) = 1.031 \text{ mole X}$$

$$\text{mass of X} = 100 \text{ g compound} - 18.56 \text{ g Al} = 81.44 \text{ g X}$$

$$\text{molar mass of X} = \frac{81.44 \text{ g}}{1.031 \text{ mole X}} = 79.00 \text{ g/mole}$$

SET A

6) 3.9104 g sample of a compound made of carbon, hydrogen, nitrogen, and oxygen is burned completely. 3.820 g CO_2 and 3.125 g H_2O are produced. Analysis of nitrogen showed that the compound contains 46.62 % by mass nitrogen. The molar mass of the compound is about 170 ± 15 g/mole.

a) Calculate the empirical formula of the compound. 6a) Ans: $C_2H_8N_3O$

Setup:

$$CHNO + O_2 \rightarrow CO_2 + H_2O + \cdots$$

$$3.820\,g\,CO_2\left(\frac{1\,mole\,CO_2}{44.00\,g\,CO_2}\right)\left(\frac{1\,mole\,C}{1\,mole\,CO_2}\right)\left(\frac{12.00\,g\,C}{1\,mole\,C}\right) = 1.042\,g\,C$$

$$3.125\,g\,H_2O\left(\frac{1\,mole\,H_2O}{18.00\,g\,H_2O}\right)\left(\frac{2\,moles\,H}{1\,mole\,H_2O}\right)\left(\frac{1.010\,g\,H}{1\,mole\,H}\right) = 0.3507\,g$$

mass of nitrogen in 3.9104 g compound:

$$\frac{46.62\,g\,N}{100\,g\,compound} \times 3.9104\,g\,compound = 1.823\,g\,N$$

mass of oxygen: 3.9104 g compound − 1.042 g C − .3507 g H − 1.823 g N = 0.6947 g O

C	H	N	O
$\frac{1.042\,g}{12.00\,g/mole}$	$\frac{.3507\,g}{1.010\,g/mole}$	$\frac{1.823\,g}{14.00\,g/mole}$	$\frac{.6947\,g}{16.00\,g/mole}$
.08683 mole	.3472 mole	.1302 mole	.04342 mole
$\frac{.08683}{.04342}$	$\frac{.3472}{.04342}$	$\frac{.1302}{.04342}$	$\frac{.04342}{.04342}$
2	8	3	1

$C_2H_8N_3O$

b) What is the molecular formula of the compound? 6b) Ans: $C_4H_{16}N_6O_2$

Setup:

$$\frac{\text{molar mass of molecular formula}}{\text{molar mass of empirical formula}} = \frac{170}{90} = \frac{2}{1}$$

$C_4H_{16}N_6O_2$

SET A

7) 169 g $FeCr_2O_4$, 298 g K_2CO_3 and an excess of O_2 (g) are sealed in a reaction vessel and allowed to react at high temperature. The amount of K_2CrO_4 obtained is 194 g. Calculate the percent yield of K_2CrO_4.

$$4\,FeCr_2O_4 + 8\,K_2CO_3 + 7\,O_2 \longrightarrow 8\,K_2CrO_4 + 2\,Fe_2O_3 + 8\,CO_2$$

(Molar mass: $FeCr_2O_4$ = 223.84, K_2CO_3=138.21, K_2CrO_4 =194.19 g/mole)

Setup: 7) Ans: 66.2 %

$$169\text{ g }FeCr_2O_4\left(\frac{1\text{ mole }FeCr_2O_4}{223.8\text{ g }FeCr_2O_4}\right)\left(\frac{2\text{ moles }K_2CO_3}{4\text{ moles }FeCr_2O_4}\right)\left(\frac{138.2\text{ g }K_2CO_3}{1\text{ mole }K_2CO_3}\right)$$

$= 52.15\text{ g }K_2CO_3$ required to react with 169g $FeCr_2O_4$

But, available, there is excess K_2CO_3.
$FeCr_2O_4$ is the limiting reagent.

Let's find the theoretical yield of K_2CrO_4:

$$169\text{ g }FeCr_2O_4\left(\frac{1\text{ mole }FeCr_2O_4}{223.8\text{ g }FeCr_2O_4}\right)\left(\frac{8\text{ moles }K_2Cr_2O_4}{4\text{ moles }FeCr_2O_4}\right)\left(\frac{194.2\text{ g }K_2CrO_4}{1\text{ mole }K_2CrO_4}\right)$$

$= 293\text{ g }K_2CrO_4$

$$\%\text{ yield} = \frac{194\text{ g }K_2CrO_4}{293\text{ g }K_2CrO_4}\times 100$$

$= 66.2\,\%$

SET B: (time required, 1 hour)

1) Excess amount of HCl is added to a mixture of $CaCO_3$ and K_2CO_3. The mixture reacted completely.

$$CaCO_3 + 2\,HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

$$K_2CO_3 + 2\,HCl \longrightarrow 2\,KCl + H_2O + CO_2$$

4.48 g CO_2 and 3.57 g KCl are produced along with some $CaCl_2$ and H_2O. Calculate the mass of the mixture.

1) Ans: 11.10 g mixture

Setup:

mass of K_2CO_3

$$3.57\,g\,KCl\left(\frac{1\,mole\,KCl}{74.6\,g\,KCl}\right)\left(\frac{1\,mole\,K_2CO_3}{2\,moles\,KCl}\right)\left(\frac{138\,g\,K_2CO_3}{1\,mole\,K_2CO_3}\right) = 3.30\,g\,K_2CO_3$$

mass of CO_2 produced in second reaction:

$$3.57\,g\,KCl\left(\frac{1\,mole\,KCl}{74.0\,g\,KCl}\right)\left(\frac{1\,mole\,CO_2}{2\,moles\,KCl}\right)\left(\frac{44.0\,g\,CO_2}{1\,mole\,CO_2}\right) = 1.05\,g\,CO_2$$

mass of CO_2 produced in first reaction

$$4.48\,g\,CO_2 - 1.05\,g\,CO_2 = 3.43\,g\,CO_2$$

mass of $CaCO_3$ reacting to produce 2.83 g CO_2:

$$3.43\,g\,CO_2\left(\frac{1\,mole\,CO_2}{44.0\,g\,CO_2}\right)\left(\frac{1\,mole\,CaCO_3}{1\,mole\,CO_2}\right)\left(\frac{100.1\,g\,CaCO_3}{1\,mole\,CaCO_3}\right) = 7.80\,g\,CaCO_3$$

mass of mixture = 7.80 g $CaCO_3$ + 3.30 g K_2CO_3 = 11.10 g mixture

2) The percent of manganese in the compound, Mn_5X_2, is 42.10 %. What is the molar mass of element X ?

Setup: 2) Ans: 186.9 g/mole

$$42.10 g\ Mn \left(\frac{1\ mole\ Mn}{54.938 g\ Mn}\right)\left(\frac{2\ moles\ X}{5\ moles\ Mn}\right) = 0.3097\ mole\ X$$

mass of X = 100g compound − 42.10 g Mn = 57.90g X

$$\text{molar mass of } X = \frac{57.90 g\ X}{.3097\ mole\ X} = 186.9\ g/mole$$

3) A mixture of potassium phosphate and potassium nitrate contains 36.55 % by mass potassium nitrate. What is the total number of potassium ions in 83.5 g mixture?

3) Ans: 6.32×10^{23} ions

Setup:

$$36.55 g\ KNO_3 \left(\frac{1\ mole\ KNO_3}{101.1 g\ KNO_3}\right)\left(\frac{1\ mole\ K}{1\ mole\ KNO_3}\right) = 0.362\ mole\ K$$

$$63.45 g\ K_3PO_4 \left(\frac{1\ mole\ K_3PO_4}{212\ g\ K_3PO_4}\right)\left(\frac{3\ mole\ K}{1\ mole\ K_3PO_4}\right) = .898\ mole\ K$$

Total moles of K = 0.362 mole K + 0.898 mole K = 1.260 mole K

$$1.260\ mole\ K \left(\frac{6.02 \times 10^{23}\ ions\ K}{1\ mole\ K}\right) = 7.58 \times 10^{23}\ atoms\ K$$

present in 100 g sample

$$83.5 g\ mixture \left(\frac{7.58 \times 10^{23}\ ions}{100 g\ mixture}\right) = 6.32 \times 10^{23}\ ions\ K$$

SET B

4) A carbon containing compound was treated chemically to convert all its carbon into $SrCO_3$. A 31.23 g sample of the compound gave 1.203×10^2 g $SrCO_3$.

a) What is the percentage of carbon in the compound? 4a) 31.34 % C

Setup:

$$1.203 \times 10^2 \text{ g } SrCO_3 \left(\frac{1 \text{ mole } SrCO_3}{147.6 \text{ g } SrCO_3}\right)\left(\frac{1 \text{ mole C}}{1 \text{ mole } SrCO_3}\right)\left(\frac{12.00 \text{ g C}}{1 \text{ mole C}}\right)$$

$$= 9.780 \text{ g C}$$

$$\% C = \frac{9.780 \text{ g C}}{31.23 \text{ g compound}} \times 100 = 31.30 \%$$

b) If there are **three** carbon atoms in a molecule of the compound, what is the molar mass of the compound?

Setup: 4b) Ans: 114.8 g/mole

$$\text{no of moles of C} = 1.203 \times 10^2 \text{ g } SrCO_3 \left(\frac{1 \text{ mole } SrCO_3}{147.6 \text{ g } SrCO_3}\right)\left(\frac{1 \text{ mole C}}{1 \text{ mole } SrC\ldots}\right)$$

$$= 0.8150 \text{ mole C}$$

$$.8150 \text{ mole C} \left(\frac{1 \text{ mole of molecules}}{3 \text{ moles C}}\right) = .2720 \text{ mole of mole}\ldots$$

$$\text{molar mass} = \frac{31.23 \text{ g compound}}{0.2720 \text{ mole compound}} = 114.8 \text{ g/}\ldots$$

SET B

5) 80.0 g $KClO_3$ are mixed with 59.5 g HCl and allowed to react according to the equation:

$$2\ KClO_3 + 4\ HCl \longrightarrow 2\ KCl + 2\ ClO_2 + Cl_2 + 2\ H_2O$$

(Molar mass: KCl = 74.6, $KClO_3$ = 122.6, HCl = 36.5, ClO_2= 67.5, Cl_2 = 71.0, H_2O = 18.0 g/mole)

The amount of Cl_2 produced is 18.7 g. Calculate the percent yield of Cl_2.

Setup: 5) Ans: 80.6 %

$$80.0\ g\ KClO_3 \left(\frac{1\ mole\ KClO_3}{122.6\ g\ KClO_3}\right)\left(\frac{1\ mole\ Cl_2}{2\ moles\ KClO_3}\right)\left(\frac{71.0\ g\ Cl_2}{1\ mole\ Cl_2}\right) = 23.2\ g\ Cl_2$$

$$59.5\ g\ HCl \left(\frac{1\ mole\ HCl}{36.5\ g\ HCl}\right)\left(\frac{1\ mole\ Cl_2}{4\ moles\ HCl}\right)\left(\frac{71.0\ g\ Cl_2}{1\ mole\ Cl_2}\right) = 28.9\ g\ Cl_2$$

$KClO_3$ is the limiting reagent; 23.2 g Cl_2 will be formed.

$$\%\ yield = \frac{18.7\ g\ Cl_2}{23.2\ g\ Cl_2} \times 100 = 80.6\ \%$$

SET B

6) 28.50 g sample of a compound of carbon, sulfur, hydrogen, and oxygen is burned. 35.25 g CO_2 and 14.65 g SO_2 are produced. Analysis of hydrogen showed that the compound contains 8.514 % hydrogen by mass. The molar mass of the compound is 500 ± 5 g/mole.

a) Calculate the empirical formula of the compound. 6a) Ans: $C_7H_{21}S_2O_5$

Setup:

$C_xH_yS_zO_k + O_2 \longrightarrow CO_2 + SO_2 + \ldots$

$35.25\,g\,CO_2\left(\frac{1\,mole\,CO_2}{44.0\,g\,CO_2}\right)\left(\frac{1\,mole\,C}{1\,mole\,CO_2}\right)\left(\frac{12.00\,g\,C}{1\,mole\,C}\right) = 9.614\,g\,C$ present in 28.50 g sample

$14.65\,g\,SO_2\left(\frac{1\,mole\,SO_2}{64.00\,g\,SO_2}\right)\left(\frac{1\,mole\,S}{1\,mole\,SO_2}\right)\left(\frac{32.00\,g\,S}{1\,mole\,S}\right) = 7.325\,g\,S$ in 28.50 g sample

$28.50\,g\,sample\left(\frac{8.514\,g\,H}{100\,g\,sample}\right) = 2.426\,g\,H$ present in 28.50 g sample

mass of oxygen = 28.50 g − 9.614 g C − 7.325 g S − 2.426 g H = 9.135 g O

C	H	S	O
$\frac{9.614\,g}{12.00\,g/mole}$	$\frac{2.426\,g}{1.010\,g/mole}$	$\frac{7.325\,g}{32.00\,g/mole}$	$\frac{9.135\,g}{16.00\,g/mole}$
.8011 mole	2.402 mole	.2289 mole	.5706 mole
$\frac{0.8011}{0.2289}$	$\frac{2.402}{0.2289}$	$\frac{0.2289}{0.2289}$	$\frac{0.5706}{0.2289}$
3.5	10.5	1	2.49
7	21	2	5

b) What is the molecular formula of the compound ? 6b) Ans: $C_{14}H_{42}S_4O_{10}$ ← Answer

Setup:

molar mass of empirical formula = 249 g/mole

$\frac{\text{molar mass of molecular formula}}{\text{molar mass of empirical formula}} = \frac{500}{249} = \frac{2}{1}$

Answer $C_{14}H_{42}S_4O_{10}$

SET C:

1) A phosphorus containing compound is treated chemically to convert all its phosphorus into $Mg_3(PO_4)_2$. A 7.88 g sample of the compound gave 4.75 g $Mg_3(PO_4)_2$. What is the percentage by mass of phosphorus in the compound?

Setup: 1) Ans: 14.2 % P

$$4.75 g\ Mg_3(PO_4)_2 \left(\frac{1\ mole\ Mg_3(PO_4)_2}{262.9 g\ Mg_3(PO_4)_2}\right)\left(\frac{2\ moles\ P}{1\ mole\ Mg_3(PO_4)_2}\right)\left(\frac{31.0 g\ P}{1\ mole\ P}\right) = 1.12 g\ P$$

$$\%P = \frac{1.12 g\ P}{7.88 g\ compound} \times 100 = 14.2\%P$$

2) The percent by mass of boron in the compound, B_7X_3, is 42.1 % . What is the molar mass of X ?

Setup: 2) Ans: 34.7 g/mole

$$42.1 g\ B \left(\frac{1\ mole\ B}{10.8 g\ B}\right)\left(\frac{3\ moles\ X}{7\ moles\ B}\right) = 1.67\ mole\ X$$

$$mass\ of\ X = 100 g\ compound - 42.1 g\ X = 57.9 g\ X$$

$$molar\ mass\ of\ X = \frac{57.9 g\ X}{1.67\ mole\ X} = 34.7\ g/mol$$

SET C

3) A 39.11 g sample of a compound containing Cr is analyzed to show the presence of 86.22 % Cr. It is found that there are **five** chromium atoms per molecule of the compound. What is the molar mass of the compound?

Setup: 3) Ans: 301.6 g/mole

Assume there are 100g of the compound:-

$$86.22\,g\,Cr \left(\frac{1\,mole\,Cr}{52.00\,g\,Cr}\right)\left(\frac{1\,mole\,compound}{5\,moles\,Cr}\right) = 0.3316\,mole\,compound$$

$$\text{molar mass of compound} = \frac{100\,g\,compound}{0.3316\,mole\,compound} = 301.6\,g/mole$$

Another method

mass of Cr in 39.11g sample

$$= \frac{86.22\,g\,Cr}{100\,g\,sample} \times 39.11\,g\,sample = 33.72\,g\,Cr \text{ present in } 39.11\,g\text{ sample}$$

$$33.72\,g\,Cr \left(\frac{1\,mole\,Cr}{52.00\,g\,Cr}\right)\left(\frac{1\,mole\,compound}{5\,moles\,Cr}\right) = .1297\,mole\,compound$$

$$\text{molar mass} = \frac{39.11\,g}{.1297\,mole} = 301.5\,g/mole$$

4) The percent by mass of silicon in the compound, Si_8X_3, is 72.33 %. What is the molar mass of element X ?

Setup: 4) ans: 28.65 g/mole

$$72.33\,g\,Si \left(\frac{1\,mole\,Si}{28.00\,g\,Si}\right)\left(\frac{3\,moles\,X}{8\,moles\,Si}\right) = 0.9658\,mole\,X$$

$$\text{mass of } X = 100\,g\,compound - 72.33\,g\,Si = 27.67\,g\,X$$

$$\text{molar mass of } X = \frac{27.67\,g\,X}{0.9658\,mole\,X} = 28.65\,g/mole$$

Set C

5) Consider the following reaction:

$$3\ CaBr_2 + 2\ Na_3PO_4 \longrightarrow Ca_3(PO_4)_2 + 6\ NaBr$$

A reaction mixture contained 22.44 g of $CaBr_2$ and 16.85 g Na_3PO_4.

(Molar mass: $CaBr_2$ = 199.9, Na_3PO_4 = 164.0, $Ca_3(PO_4)_2$ = 207.2, NaBr = 102.9 g/mole)

a) What is the mass of $Ca_3(PO_4)_2$ produced after the reaction is complete ?

Setup: 6a) Ans: 7.753 g

$$22.44\,g\ CaBr_2 \left(\frac{1\ mole\ CaBr_2}{199.9\,g\ CaBr_2}\right)\left(\frac{1\ mole\ Ca_3(PO_4)_2}{3\ moles\ CaBr_2}\right)\left(\frac{207.2\,g\ Ca_3(PO_4)_2}{1\ mole\ Ca_3(PO_4)_2}\right) = 7.739\,g\ Ca_3(PO_4)_2$$

$$16.85\,g\ Na_3PO_4 \left(\frac{1\ mole\ Na_3PO_4}{164.0\,g\ Na_3PO_4}\right)\left(\frac{1\ mole\ Ca_3(PO_4)_2}{2\ moles\ Na_3PO_4}\right)\left(\frac{207.2\,g\ Ca_3(PO_4)_2}{1\ mole\ Ca_3(PO_4)_2}\right) = 10.64\,g\ Ca_3(PO_4)_2$$

the limiting reagent is $CaBr_2$

7.739 g $Ca_3(PO_4)_2$ will be produced.

b) How many grams of **each** reactant is left after the reaction is complete?

Setup: 6b) Ans: zero grams of $CaBr_2$ and 4.58 g Na_3PO_4

$CaBr_2$ is the limiting reagent. $CaBr_2$ will be consumed completely

Let's find mass of Na_3PO_4 reacting:-

$$22.44\,g\ CaBr_2 \left(\frac{1\ mole\ CaBr_2}{199.9\,g\ CaBr_2}\right)\left(\frac{2\ moles\ Na_3PO_4}{3\ moles\ CaBr_2}\right)\left(\frac{164.0\,g\ Na_3PO_4}{1\ mole\ Na_3PO_4}\right) = 12.27\,g\ Na_3PO_4\ reacting$$

mass of Na_3PO_4 left over

16.85 g Na_3PO_4 available − 12.77 g Na_3PO_4 reacting = 4.58 g Na_3PO_4 left over