Chemistry 135 Semester 01-2012
Homework for Submission #4: Key

1) Calculate the number of moles of sodium contained in 0.100 mol of sodium carbonate. (2)

Solution

Sodium carbonate is Na_2CO_3. Conversion factor is $\dfrac{2 \text{ mol Na}}{1 \text{ mol } Na_2CO_3}$. Hence:

$$0.100\ mol\ \text{Na}_2\text{CO}_3 \equiv 0.100\ mol\ \text{Na}_2\text{CO}_3 \times \frac{2\ mol\ \text{Na}_2\text{CO}_3}{1\ mol\ \text{Na}_2\text{CO}_3} = \underline{\underline{0.200\ mol\ \text{Na}}} \text{ to 3 s.f.}$$

2) Calculate the number of moles of oxygen atoms present in 1.20 mol of silver nitrate. (2)

Solution

Silver nitrate is $AgNO_3$ and so the conversion factor is $\dfrac{3\ mol \text{ of O atoms}}{1\ mol\ \text{AgNO}_3}$ and so:

$$1.20\ mol\ \text{AgNO}_3 \equiv 1.20\ mol\ \text{AgNO}_3 \times \frac{3\ mol \text{ of O atoms}}{1\ mol\ \text{AgNO}_3} = \underline{\underline{3.60\ mol \text{ O atoms}}} \text{ to 3 s.f.}$$

3) Calculate the number of moles of oxygen gas liberated when 0.536 mol of lead(II) nitrate are heated. (2)

Solution

Equation is: $2PbNO_3(s) \rightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$

and so the conversion factor is $\dfrac{1\ mol \text{ of } \text{O}_2}{2\ mol\ \text{Pb(NO}_3)_2}$. Therefore:

$$0.536\ mol\ \text{Pb(NO}_3)_2 \equiv 0.536\ mol\ \text{Pb(NO}_3)_2 \times \frac{1\ mol \text{ of } \text{O}_2}{2\ mol\ \text{Pb(NO}_3)_2} = \underline{\underline{0.268\ mol\ \text{O}_2}} \text{ to 3 s.f.}$$

4) Calculate the number of moles of nitrogen gas that must be combined with hydrogen to form 0.750 mol of ammonia. (2)

Solution

Equation is: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

and so the conversion factor is $\dfrac{1\ mol \text{ of } \text{N}_2}{2\ mol\ \text{NH}_3}$. Therefore:

$$0.750\ mol\ \text{NH}_3 \equiv 0.750\ mol\ \text{NH}_3 \times \frac{1\ mol \text{ of } \text{N}_2}{2\ mol\ \text{NH}_3} = \underline{\underline{0.375\ mol\ \text{N}_2}} \text{ to 3 s.f.}$$

5) Calculate the percentage composition of copper(II) sulfate 5-water ($CuSO_4.5H_2O$), otherwise referred to as "copper(II) sulfate crystals" – the normal form of copper(II) sulfate produced by crystallisation from water.(3)

Solution

Depending on the values of relative atomic mass chosen, that is, the number of significant figures, answers must be given to the same number of significant figures. 3, 4 or 5 significant figures are best. Answers to 5 significant figures are given here. If values to only (say) 2 significant figures are used, answers cannot be given to more figures than that.

RAM's taken from BLB are:

Cu = 63.546, S = 32.065, O = 15.9994, H = 1.00794 and so their molar masses are:

63.546 g mol^{-1}, 32.065 g mol^{-1}, 15.9994 g mol^{-1}, 1.00794 g mol^{-1} respectively.

But 1 mol of $CuSO_4.5H_2O$ contains

1 mol Cu, 1 mol S, (4+5) mol O and 10 mol H

Which weigh

63.546 g, 32.065 g, 9×15.9994 g, and 10×1.00794 g respectively.

But the molar mass of $CuSO_4.5H_2O$ is g mol^{-1}, which means that 1 mol of it weighs 249.685 g.

Hence percentages by mass are:

Cu: $\dfrac{63.546}{249.685} = 0.2545047\ldots = \underline{\underline{25.450\%}}$

S: $\dfrac{32.065}{249.685} = 0.1284218\ldots = \underline{\underline{12.842\%}}$

O: $\dfrac{9 \times 15.9994}{249.685} = 0.5767050\ldots = \underline{\underline{57.671\%}}$

H: $\dfrac{10 \times 1.00794}{249.685} = 0.04036846\ldots = \underline{\underline{4.0368\%}}$ all to 5 sig. figs.

The solution may be expressed more economically in the following way:
RFM of $CuSO_4.5H_2O$ = 63.546 + 32.065 + (9×15.9994) + (10×1.00794) = 249.685

Element	Cu	S	O	H
RAM	63.546	32.065	15.9994	1.00794
%	$\frac{63.546}{249.685}$ = 0.2545047... = $\underline{\underline{25.450\%}}$	$\frac{32.065}{249.685}$ = 0.1284218... = $\underline{\underline{12.842\%}}$	$\frac{9\times15.9994}{249.685}$ = 0.5767050... = $\underline{\underline{57.671\%}}$	$\frac{10\times1.00794}{249.685}$ = 0.04036846... = $\underline{\underline{4.0368\%}}$

6) A compound has the following composition by mass: 32.0% carbon, 6.71% hydrogen, 42.6% oxygen and 18.7% nitrogen. Find its empirical formula, and its molecular formula if its RMM is 225.2. (3)

Solution

This is one way of solving the problem. RAM's accurate to only 3 s.f.s are adequate here.

Element	C	H	O	N
Percentages	32.0	6.71	42.6	18.7
Mass in 100 g of compound	32.0 g	6.71 g	42.6 g	18.7 g
Molar masses	12.0 g mol^{-1}	1.01 g mol^{-1}	16.0 g mol^{-1}	14.0 g mol^{-1}
# of moles present in 100 g	$\frac{32}{12}$ = 2.66..	$\frac{6.71}{1.01}$ = 6.64..	$\frac{42.6}{16}$ = 2.66..	$\frac{18.7}{14}$ = 1.33..
Dividing by the smallest gives	2.99..	4.97..	1.99..	1
Rounding to whole numbers	2	5	2	1

Hence the empirical formula is $\underline{\underline{C_2H_5O_2N}}$.
Since this gives a relative formula mass of (2 × 12.0) + (5 × 1.01) + (2 × 16.0) + 14.0 = 75.05, and 3 times this is 225.15, the molecular formula must be 3 times the empirical formula: $\underline{\underline{C_6H_{15}O_6N_3}}$

Another method is to consider 225.2 g of compound (i.e. 1 mol of it), calculate the grams of each element present according to the percentages, and then convert these to moles. This gives the molecular formula, which can then be divided by 3 to give the empirical formula.

7) A 0.1005 g sample of compound X is burned completely in excess oxygen, producing 0.2829 g of carbon dioxide and 0.1159 g of water. Find the empirical formula of X, given that it is a compound of carbon, hydrogen and oxygen only. If the compound has a molar mass of 312 g mol^{-1} to 3 s.f., determine its molecular formula. Suggest the names of two compounds that this formula might refer to. (You may answer question 7 on a separate sheet of paper if you wish.)

Solution

The carbon and hydrogen present in the carbon dioxide and water must have originated in the compound X. The oxygen, on the other hand, need not, since oxygen is supplied for the combustion. The total mass of carbon and hydrogen must be found and then the total subtracted from the mass of compound X to find the mass of oxygen present. The moles of carbon, hydrogen and oxygen atoms are in the ratio of the number of atoms in the formula. In this type of problem it is desirable to use the most accurate values of relative atomic masses, otherwise rounding errors may lead to a wrong answer. Note that masses are given to 4 significant figures, so RAM's should be accurate to at least 4 s.f.

$$Molar\ mass\ of\ CO_2 = 12.0107 + 2\times15.9994 = 44.0095\,\mathrm{g\,mol^{-1}}$$

$$\therefore 0.2829\,g\,CO_2 \equiv 0.2829\,g \times \frac{1\,mol}{44.0095\,\mathrm{g\,mol^{-1}}} = 6.42815...\times10^{-3}\,mol\,CO_2 \equiv 6.42815...\times10^{-3}\,mol\,C$$

$$\therefore Mass\ of\ C = 6.42815...\times10^{-3}\,mol \times 12.0107\,g\,mol^{-1} = 7.72066...\times10^{-2}\,g$$

$$Molar\ mass\ of\ H_2O = 2\times1.0079 + 15.9994 = 18.0152\,\mathrm{g\,mol^{-1}}$$

$$\therefore 0.1159\,g\,H_2O = 0.1159\,g \times \frac{1\,mol}{18.0152\,\mathrm{g\,mol^{-1}}} = 6.433456...\times10^{-3}\,mol\,H_2O \equiv 2\times6.433456...\times10^{-3}$$

$$= 1.2968...\times10^{-2}\,mol\,H$$

$$\therefore Mass\ of\ H = 1.2968...\times10^{-2}\,mol \times 1.0079\,g\,mol^{-1} = 1.2968...\times10^{-2}\,g$$

$\therefore \textit{Mass of } O = \textit{Mass of } X - (\textit{mass of } C + \textit{mass of } H) = 0.1005\,g - (7.72066... \times 10^{-2}\ g + 1.2968... \times 10^{-2}\ g)$
$= 0.103247...g = 0.103247...g \div 15.9994\ g\ mol^{-1} = 6.45322... \times 10^{-4}\,mol$

Element	C	H	O
# of moles present	$6.42815... \times 10^{-3}$	$1.2968... \times 10^{-2}$	$6.45322... \times 10^{-4}$
Dividing by the smallest gives	9.9611…	19.938…	1
Rounding to whole numbers gives	10	20	1

Hence empirical formula is C10H20O
The RFM corresponding to this formula is (10×12)+(20×1)+16 = 156 to the nearest whole number. Since the RMM of the compound is 312, and 2×156 is 312, the molecular formula must be twice the empirical formula, that is C20H40O2.

A search on Google for this formula gives two results: arachidic acid and phytanic acid, though in fact the molecular formula could apply to many other compounds.