COPPERBELT UNIVERSITY

CHEMISTRY DEPATMENT

CH110 TUTORIAL SHEET 2-STOICHIOMETRY 10 August 2015

Question 1 – Counting by Weighing and Atomic Masses

a) Explain the concept of "counting by weighing" using toffee sweets as your example [2]

Solution:

When the average mass of toffee sweet (m_{av}) is known, the mass M for a number of toffee sweets (N) is given by the formula: $\mathrm{M} = \mathrm{N} \times \mathrm{m_{av}}$. Thus, from this equation, counting N sweets is equivalent to weighing M toffee sweets using a balance.

b) Atomic masses are relative masses. What does this mean? [2]

Solution:

Masses of all nuclides of elements are obtained by comparing them to atomic mass of ^{12}C which is defined to have a value of 12 amu.

c) The atomic mass of boron (B) is given in the periodic table as 10.81 atomic mass units (amu or u), yet no single atom of boron has a mass of 10.81 u. Explain. [2]

Solution:

The atomic mass of boron (B) in the periodic table is an average value for all stable isotopes of boron that exist in nature.

d) When a sample of natural copper is vapourised and injected into a mass spectrometer only two isotopes, namely, ^{63}Cu and ^{65}Cu, are seen. Use the atomic mass and percent isotopic abundance data of these isotopes shown in the table below to calculate the average mass of natural copper. [2]

Isotope	Atomic Mass (amu)	Isotopic Abundance (%)
^{63}Cu	62.93	69.09
^{65}Cu	64.93	30.91

Solution:

$$A_{Cu} = \sum_{i=1}^{n=2} \frac{F_i}{100} \times A_i = 62.93 \times 0.6909 + 64.93 \times 0.3091 = 63.5482 \approx 63.55$$

e) The element europium exists in nature as two isotopes. ^{151}Eu has a mass of 150.9196 amu and ^{153}Eu has a mass of 152.9209 amu. The average atomic mass of europium is 151.96 amu. Calculate the relative abundance of the two europium isotopes. [2]

Solution:

We know that $A_{Eu} = \sum_{i=1}^{n=2} \frac{F_i}{100} \times A_i = \frac{1}{100}\left((F_1 \times A_1) + (F_2 \times A_2)\right)$ (E.1)

Since $F_1+F_2=100$, we can set $F_2=100-F_1$ (E.2)

Substituting E.2 into E.1 gives $100 \times A_{Eu} = \left((F_1 \times A_1) + \left((100 - F_1) \times A_2\right)\right)$(E.3)

Or $100 \times A_{Eu} = \left((F_1 \times A_1) - (F_1 + A_2)\right) + A_2 = F_1(A_1 - A_2) + 100 \times A_2$ (E.4)

Using E.4 to solve for F_1 gives $100 \times (A_{Eu} - A_2) = F_1(A_1 - A_2)$ or

$$F_1 = \frac{100 \times (A_{Eu} - A_2)}{A_1 - A_2} \quad \text{(E.5)}$$

Substituting A_{Eu} = 151.96, A_1 or ^{151}Eu=150.9196 and A_2 or ^{153}Eu=152.9209 amu gives

$$F_1 = \frac{100 \times (151.96 - 152.9209)}{150.9196 - 152.9209} = 48.01\%$$

Substituting this value into Equation E.2 gives

$$F_2 = 100 - 48.01 = 51.19\%$$

Thus the relative abundances of ^{151}Eu and ^{153}Eu are 48.01% and 51.19%, respectively.

<u>Question 2 – The Mole and Molar Mass of an Element</u>

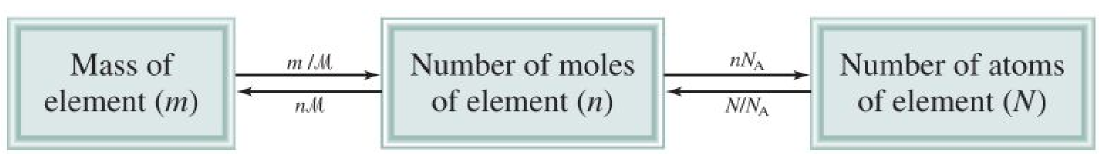
a) Explain the terms mole, molar mass and Avogadro's number. [3]

Solutions:

Mole (mol)the number equal to the number of carbon atoms in exactly 12 grams of pure ^{12}C.Avogadro's numberis the number of one mole or 12 grams of pure ^{12}C which is 6.022×10^{23}. Molar mass is the mass of mole of a substance, for example 1 mole of ^{12}C is 12g.

b) Draw a schematic diagram showing the relationships between mass (m in grams) of an element and the number of moles (n) and between number of moles and number of atoms (N) of an element. [5] *Hint: Consult Raymond Chang's 10th Edition*.

Solution:



c) What three conversion factors and in what order would you use them to convert the mass of a compound into atoms of a particular element in that compound – for example, from 1.00 g aspirin ($C_9H_8O_4$) to number of hydrogen atoms in the 1.00 g sample. [5] *Hint: Consult Zumdahl and Zumdahl's 9th Edition*.

Solution:

The three conversion factors are:

- Molar mass of compound or M_r (g/mol),
- Avogadro's number giving molecules of the compound or N_A(molecules/mol) and
- Number of atoms of an element per molecule of the compound or n_{El}.

The above factors are to be used according to the equation $N = \frac{m}{M_r} \times N_A \times n_{El}$

The molar mass of aspirin is $M_r = 9 \times M_c + 8 \times M_H + 4 \times M_O$ which is

$M_r = 9 \times 12.00 + 8 \times 1.008 + 4 \times 16.00 = 180.064$g/mol

$N_A = 6.022 \times 10^{23} molecules/mol$ and $n_H = 8\ hydrogen\ atoms/molecule$

The number of hydrogen atoms in a molecule of aspirin is

$$N = 1g \times \frac{1}{180.064\ g/mol} \times 6.022 \times 10^{23} molecules/mol \times 8\ hydrogen\ atoms/molecule$$

$= \frac{8 \times 6.022 \times 10^{23}}{180.064} = 2.675 \times 10^{22}$hydrogen atoms.

d) A silicon chip used in an integrated circuit of Thelma's laptop has a mass of 2.84 mg. Determine both the number of moles of atoms and the number of atoms in the chip. [4]

Solutions:

The number of moles, n, is given as $n = \frac{m}{M_r}$ or

$$n = \frac{2.84 \times 10^{-3} g}{28.09\ g/mol} = \mathbf{1.01 \times 10^{-4} mol}$$

The number of atoms, N, is given as N= $n \times N_A$ or

$$N = \frac{2.84 \times 10^{-3} g}{28.09\ g/mol} \times 6.022 \times 10^{23} atoms/mol$$

$$= 1.01 \times 10^{-4} \times 6.022 \times 10^{23} atoms$$

=**6.09 x 10^{19} atoms**

e) Cobalt (Co) is a metal that is added to steel to improve its resistance to corrosion. Calculate both the number of moles in a sample of cobalt containing 5.00×10^{20}atoms and the mass of the sample.

Solution

n=N/N_A = $\frac{5.00 \times 10^{20}}{6.022 \times 10^{23}} = \mathbf{8.30 \times 10^{-4}}$**moles** and

$$\mathrm{m = n \times M_r = 8.30 \times 10^{-4} \times 58.93\ g = 0.0489\ g} = \mathbf{48.9\ mg}$$

Question 3 – Molar Mass and Percent Composition of a Compound

a) Calculate the molar masses of calcite or calcium carbonate and the natural herbicide juglone whose chemical formulae are $CaCO_3$ and $C_{10}H_6O_3$, respectively. [2]

Solutions:

Calcium Carbonate is $CaCO_3$. Its molar mass is M_r=M_{Ca}+M_C+3M_O, that is,

M_r=40.08+12+48.00 = 100.08 g/mol

Juglone is $C_{10}H_6O_3$. Its molar mass is M_r=10M_C+6M_H+3M_O, that is,

M_r=120.0 + 6.048+48.00 = 174.048 g/mol

b) A sample of calcite contains 4.86 moles. What is the mass in grams of this sample? What is the mass of the CO_3^{2-} ions present? [2]

Solutions:

Calcite's ($CaCO_3$) mass is $m = n \times M_r$, that is,

m=4.86 mol$\times$ 100.08 g/mol = 486 g

the mass of the CO_3^{2-} ions present is given by calcite mass x % carbonate/100,

m=486 g $\times$0.6 =292 g

c) A sample of 1.56×10^{-2}g of pure juglone was extracted from black walnut husks. How many moles of juglone does this sample represent? [2]

Solutions:

Moles of jugloneis= m/M_r , that is,

n =$\frac{1.56 \times 10^{-2}}{174.048}$mol = $\mathbf{8.97 \times 10^{-5}}$mol

d) Bees release about 1 µg (1×10^{-6}g) of isopentyl acetate ($C_7H_{14}O_2$) when they sting. This compound is responsible for the scent of bananas and its scent in the bee sting fluid attracts other bees to join the attack. How many molecules of isopentyl acetate are released in a typical bee sting? How many atoms of carbon are present? [2]

Solutions:

Molecules of isopentyl acetate is N= $\frac{m}{M_r} \times N_A$, that is,

Since M_r = 7x12.00+14x1.008+2x16.00 = 130.112 g/mol

m/M_r = **n =$\frac{1 \times 10^{-6}}{130.112}$ moles**

n$\times$ N_A=$\frac{1 \times 10^{-6}}{130.112} \times \mathbf{6.022 \times 10^{23}}$ = $\mathbf{4.63 \times 10^{15}}$ molecules

e) In 1987 the first substance to act as a superconductor at a temperature above that of liquid nitrogen (77 K) was discovered. The approximate formula of this substance is $YBa_2Cu_3O_7$. Calculate the percent composition by mass of this material. [2]

Solutions:

Elemental molar masses are M_Y=88.91 g/mol; M_{Ba}=137.3 g/mol; M_{Cu}=63.55 g/mol and M_O=16.00

Molar mass of the substance $YBa_2Cu_3O_7$ is given as

$M_r=M_Y+2M_{Ba}+3M_{Cu}+7M_O$= 88.91+ 2x137.3 +3x63.55 +7x16.00 g/mol = 666.01 g/mol

Percent composition of each element is given by table below

Element	**Element Molar Mass**	**Element mass in mole of compound**	**% Composition**	
Y	M_Y=88.91	M_Y=88.91	$100 \times \frac{M_Y}{M_r}$	$100 \times \frac{88.91}{666.01} = 13.4$
Ba	M_{Ba}=137.3	$2M_{Ba}$=274.6	$100 \times \frac{2 \times M_{Ba}}{M_r}$	$100 \times \frac{274.6}{666.01} = 41.2$
Cu	M_{Cu}=63.55	$3M_{Cu}$=190.65	$100 \times \frac{3 \times M_{Cu}}{M_r}$	$100 \times \frac{190.65}{666.01} = 28.6$
O	M_O=16.00	$7M_O$=112.00	$100 \times \frac{7 \times M_O}{M_r}$	$100 \times \frac{112.0}{666.01} = 16.8$

<u>Question 4 – Determining the Formula of a Compound</u>

a) What is the difference between the empirical and molecular formulas of a compound? Can they ever be the same? Explain. [3]

Solution:

*Empirical formula*isthe simplest whole-number ratio of atoms in a compound.
*Molecular formula*isthe exact formula of a molecule, giving the types of atoms and the number of each type.
The relationship between the two is $\times$ $\mathbf{Empirical\ formula} = \mathbf{Molecular\ formula}$ **.**
Yes the two can be the same when n=1

b) An organic compound containing carbon, hydrogen and oxygen is combusted to analyse it. Explain how the data relating to the mass of CO_2 produced and the mass of H_2O produced can be manipulated to determine the empirical formula. [4]

Solution:

Let

m_s be the mass of the sample,
m_C be the mass of carbon in the sample
m_H be the mass of hydrogen in the sample
m_O be the mass of oxygen in the sample

Then we know that

$m_s = m_C + m_H + m_O$ (1)

On combustion of m_s let

m_{CO_2} be the mass of carbon dioxide produced and

m_{H_2O} be the mass of water produced

We know that the fractions of carbon and hydrogen in the carbon dioxide (or m_{CO_2}) and in water (or m_{H_2O}), respectively are given by equations (2) and (3)

$$m_{carbon} = \frac{m_{CO_2} \times M_C}{M_{CO_2}} \quad (2)$$

$$m_{hydrogen} = \frac{m_{H_2O} \times M_H}{M_{H_2O}} \quad (3)$$

Where M_{CO_2}, M_C, M_H and M_{H_2O} are the molar masses of carbon dioxide, carbon, hydrogen and water.

But we know that $m_{carbon} = m_C$ and $m_{hydrogen} = m_H$ so that substituting equations (2) and (3) into equation (1) gives equation (4) which when solved for the mass of oxygen gives equation (5)

$$m_s = \frac{m_{CO_2} \times M_C}{M_{CO_2}} + \frac{m_{H_2O} \times M_H}{M_{H_2O}} + m_O \quad (4) \quad \text{or}$$

$$m_O = m_s - \left(\frac{m_{CO_2} \times M_C}{M_{CO_2}} + \frac{m_{H_2O} \times M_H}{M_{H_2O}}\right) \quad (5)$$

Since $M_H = 1.008, M_C = 12.00,\ M_{H_2O} = 18.02\ and\ CO_2 = 44.00$ equations (2), (3) and (5) can be simplified to equations (6), (7) and (8) below.

$$m_{carbon} = \frac{m_{CO_2} \times 12}{44} \quad (6)$$

$$m_{hydrogen} = \frac{m_{H_2O} \times 1.01}{18.02} \quad (7)$$

$$m_O = m_s - \left(\frac{m_{CO_2} \times 12}{44} + \frac{m_{H_2O} \times 1.01}{18.02}\right) \quad (8)$$

With elemental masses of the compound known, that is, the masses of carbon, hydrogen and oxygen known, we can follow the check list for determining the empirical formula of a compound.

c) The most common form of nylon (nylon-6) is 63.68% carbon, 12.38% nitrogen, 9.80% hydrogen, and 14.14% oxygen. Calculate the empirical formula for nylon-6. [2]

Solution:

Here we follow the check list of determining the empirical formula of compound whose elemental percent composition is given.

The check list is tabulated below

List elements	C	N	H	O
1. Write given % composition	63.68	12.38	9.80	14.14
2. Assume 100 g sample & write corresponding element masses	63.68	12.38	9.80	14.14
3. Get moles of each element, that is, calculate $n_i = \frac{m_i}{M_{ri}}$	$n_C = \frac{63.68}{12.00}$	$n_N = \frac{12.38}{14.01}$	$n_H = \frac{9.808}{1.008}$	$n_O = \frac{14.14}{16.00}$
	$or\ n_C = 5.31$	$n_N = 0.884$	$or\ n_H = 9.72$	$n_O = 0.884$
4. Mole ratio of the smallest n_i	$\frac{5.31}{0.884} \approx 6$	$\frac{0.884}{0.884} \approx 1$	$\frac{9.72}{0.884} \approx 11$	$\frac{0.884}{0.884} \approx 1$
5. Empirical formula using appropriate subscripts is	$C_6NH_{11}O$			

Determine the molecular formula of a compound that contains 26.7% P 12.1% N and 61.2% Cl, and has a molar mass of 580 g/mol. [4]

Solution:

The appropriate steps for doing this are:

(i) First get the empirical formula which will be of the form $P_xN_yCl_z$

The check list is tabulated below

List elements	P	N	Cl
1. Write given % composition	26.7	12.1	61.2
2. Assume 100 g sample & write corresponding element masses	26.7	12.1	61.2
3. Get moles of each element, that is, calculate $n_i = \frac{m_i}{M_{ri}}$	$n_P = \frac{26.7}{30.97}$	$n_N = \frac{12.1}{14.01}$	$n_{Cl} = \frac{61.2}{35.45}$
	$or\ n_C = 0.862$	$n_N = 0.864$	$or\ n_H = 1.73$
4. Mole ratio of the smallest n_i	$\frac{0.862}{0.862} \approx 1$	$\frac{0.864}{0.862} \approx 1$	$\frac{1.73}{0.862} \approx 2$
5. Empirical formula using appropriate subscripts is	$PNCl_2$		

(ii) Then get the empirical formula molar mass, M_{Emp}, which will be given by the relation $M_{Emp} = xM_P + yM_N + zM_{Cl}$.

Since $M_P = 30.97,\ M_N = 14.01\ and\ M_{Cl} = 35.45\ and\ x = y = 1$ and $z = 2$ we have $M_{Emp} = 30.97 + 14.01 + 2 \times 35.45 = 115.88 \approx \mathbf{116\ g}$

(iii) Next, determine the integer value, n, such that the relation $n \times M_{Emp} = M_r$ where M_r=580 g is the molar mass of the compound.

Thus $\mathbf{n} \times \mathbf{116} = \mathbf{580\ or\ n} = \frac{\mathbf{580}}{\mathbf{116}} = \mathbf{5}$

(iv) Finally to get the molecular formula of the compound, multiply each subscript of the empirical with n so that the molecular formula is given as $P_{n\times x}N_{n\times y}Cl_{n\times z}$.

This gives the formula $\mathbf{P_5N_5Cl_{10}}$

<u>Question 5 – Chemical Equations</u>

a) Can the subscripts in a chemical formula be fractions? Explain. [2] Can the coefficients in a balanced chemical equation be fractions? Explain. [2] Changing the subscripts of chemicals can balance equations mathematically. Why is this unacceptable? [1]

Solutions:

Subscripts can only be integers. The show the number of atoms in the compound.
Yes they can be but the convention is that they should be smallest integers.
Changing subscripts is not acceptable since it changes the compounds.

b) According to the law of conservation of mass, mass cannot be gained or destroyed in a chemical reaction. Why can't you simply add the masses of two reactants to determine the total mass of the product? [2]

Solution:

Stoichiometry requires us to deal with the mole method, that coefficients of chemical reactions should be considered to be in terms of moles not masses.

c) A balanced chemical equation contains a large amount of information? What information is given in a balanced equation [5]*Hint: Check Zumdahl and Zumdahl 9thEdition*Page 105.

Table 3.2 | Information Conveyed by the Balanced Equation for the Combustion of Methane

Reactants		Products
$CH_4(g) + 2O_2(g)$	$\longrightarrow$	$CO_2(g) + 2H_2O(g)$
1 molecule + 2 molecules	$\longrightarrow$	1 molecule + 2 molecules
1 mole + 2 moles	$\longrightarrow$	1 mole + 2 moles
6.022×10^{23} molecules + 2 (6.022×10^{23} molecules)	$\longrightarrow$	6.022×10^{23} molecules + 2 (6.022×10^{23} molecules)
16 g + 2 (32 g)		44 g + 2 (18 g)
80 g reactants	$\longrightarrow$	80 g products

d) Which of the following equations best represents the reaction of nitrogen and hydrogen to form ammonia?
Justify your choice, and for choices you did not pick, explain what is wrong with them. [5]

Solutions:

(i) $6N_2 + 6H_2 \longrightarrow 4NH_3 + 4N_2$ – N should not be on both sides and coefficient and should be irreducible

(ii) $N_2 + H_2 \longrightarrow NH_3$ – unbalanced

(iii) $N + 3H \longrightarrow NH_3$ – showing atomic reactants or radicals instead of molecules

(iv) $\mathbf{N_2 + 3H_2 \longrightarrow 2NH_3}$

(v) $2N_2 + 6H_2 \longrightarrow 4NH_3$ – reducible coefficients

e) Balance the following equations

Solutions:

(i) $Fe_3O_4(s) + H_2(g) \longrightarrow Fe(s) + H_2O(g)$ [1]

$\mathbf{Fe_3O_4(s) + 4H_2(g) \longrightarrow 3Fe(s) + 4H_2O(g)}$ [1]

(ii) $Fe_3O_4(s) + CO(g) \longrightarrow Fe(s) + CO_2(g)$ [1]

$\mathbf{Fe_3O_4(s) + 4CO(g) \longrightarrow 3Fe(s) + 4CO_2(g)}$

(iii) $Ca(OH)_2(aq) + H_3PO_4(aq) \longrightarrow H_2O(l) + Ca_3(PO_4)_2(s)$ [1]

$\mathbf{3Ca(OH)_2(aq) + 2H_3PO_4(aq) \longrightarrow 6H_2O(l) + Ca_3(PO_4)_2(s)}$ [1]

(iv) $KO_2(s) + H_2O(l) \longrightarrow KOH(l) + O_2(g) + H_2O_2(aq)$ [1]

$\mathbf{KO_2(s) + 2H_2O(l) \longrightarrow 2KOH(aq) + O_2(g) + H_2O_2(aq)}$ **[1]**

f) Give balanced equations for each of the following chemical reactions

(i) Glucose ($C_6H_{12}O_6$) reacts with oxygen gas to produce gaseous carbon dioxide and water vapour. [2]

Solution:

$C_6H_{12}O_6(s) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$ – unbalanced equation!

$\mathbf{C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(g)}$ **- balanced equation**

(ii) Solid iron (III) sulphide reacts with gaseous hydrogen chloride to form solid iron (III) chloride and hydrogen sulphide gas. [2]

Solution:

$Fe_2S_3(s) + HCl(g) \longrightarrow FCl_3(s) + H_2S(g)$ – unbalanced equation

$\mathbf{Fe_2S_3(s) + 6HCl(g) \longrightarrow 2FCl_3(s) + 3H_2S(g)}$ **– balanced equation**

(iii) Carbon disulphide reacts with ammonia gas to produce hydrogen sulphide gas and ammonium thiocynate (NH_4SCN). [2]

$CS_2(s) + NH_3(g) \longrightarrow NH_4SCN(s) + H_2S(g)$ – unbalanced equation

$\mathbf{CS_2(s) + 2NH_3(g) \longrightarrow NH_4SCN(s) + H_2S(g)}$ **– balanced equation**

Question 6 – Stoichiometric Calculations: Amounts of Reactants and Products

a) How many steps are in the problem solving strategy for calculating masses of reactants and products in chemical reactions? List them. [6]*Hint Check Zumdahl and Zumdahl 9th Edition Page 111.*

Solutions:

There are 5 steps shown below.

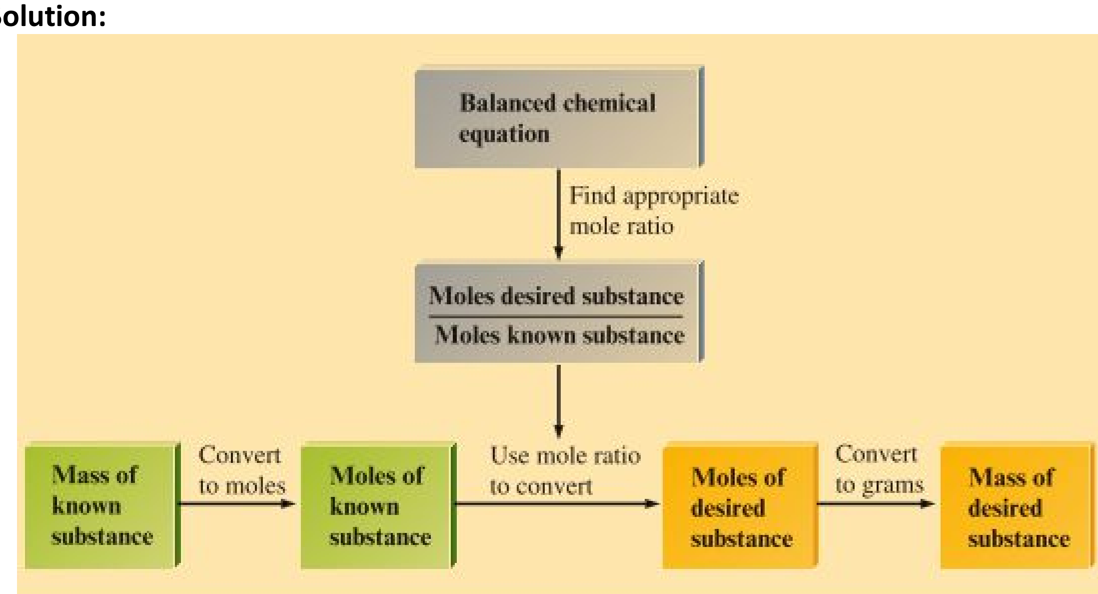
Problem-Solving Strategy

Calculating Masses of Reactants and Products in Chemical Reactions

1. Balance the equation for the reaction.
2. Convert the known mass of the reactant or product to moles of that substance.
3. Use the balanced equation to set up the appropriate mole ratios.
4. Use the appropriate mole ratios to calculate the number of moles of the desired reactant or product.
5. Convert from moles back to grams if required by the problem.

b) Give a schematic diagram summarising the steps you have listed in (a) above. [4]

Solution:



c) Use the approach outlined in (i) or (ii) to solve the two questions below

(i) One of relatively few reactions that takes place directly between two solids at room temperature is

$$\mathrm{Ba(OH)_2 \cdot 8H_2O(s) + NH_4SCN(s) \longrightarrow Ba(SCN)_2(s) + H_2O(l) + NH_3(g)}$$

In this equation, the $\cdot\,\mathrm{8H_2O}$ in $\mathrm{Ba(OH)_2 \cdot 8H_2O}$ indicates the presence of eight water molecules. This compound is called barium hydroxide octahydrate.

1. Balance the equation. [1]

Solution:

$$\mathrm{Ba(OH)_2 \cdot 8H_2O(s)} + \mathbf{2}\mathrm{NH_4SCN(s) \longrightarrow Ba(SCN)_2(s)} + \mathbf{10}\mathrm{H_2O(l)} + \mathbf{2}\mathrm{NH_3(g)}$$

2. What mass of ammonium thiocyanate (NH_4SCN) must be used if it is to react completely with 6.5 g barium hydroxide octahydrate? [2]

Solution:

Molar mass of barium hydroxide octahydrate is given by the formula$M_r = M_{Ba} + 2 \times M_{OH} + 8 \times M_{H_2O}$, that is,
$M_r = 137.3 + 2 \times 17.01 + 8 \times 18.02 = \mathbf{298.47\ g}$

The number of moles of 6.5 g barium hydroxide octahydrate is

$$n = \frac{6.5}{298.47}\ or\ \frac{6.5}{2.9847} \times 10^{-2} mol = \mathbf{2.17 \times 10^{-2}\ mols}$$

For every mole of barium hydroxide octahydrate used, two moles of ammonium thiocyanate are consumed. This means that the number of thiocyanate used is

$$n = 2 \times 2.17 \times 10^{-2} = \mathbf{4.34 \times 10^{-2} mols}$$

The mass of thiocyanate used will be given the relation
$m = n \times M_r$

But $M_r = 2 \times M_N + 4 \times M_H + M_S + M_C$ or
$M_r = \ 2 \times 14.01 + 4 \times 1.008 + 32.07 + 12.00 = \mathbf{76.122\ g/mol}$

Thus,
$m = n \times M_r = 4.34 \times 10^{-2}\mathrm{mols} \times 76.122 \frac{\mathrm{g}}{\mathrm{mol}} = \mathbf{3.30\ g}$

(ii) Solid lithium hydroxide is used in space vehicles to remove exhaled carbon dioxide from the living environment by forming solid lithium carbonate and liquid water. What mass of gaseous carbon dioxide can be absorbed by 1.00 kg of lithium hydroxide? [3]

Solution:

First write the unbalanced chemical equation for the reaction

$$\mathrm{LiOH} + \mathrm{CO_2} \longrightarrow \mathrm{Li_2CO_2} + \mathrm{H_2O}$$

Next write the balanced equation

$$\mathbf{2LiOH} + \mathbf{CO_2} \longrightarrow \mathbf{Li_2CO_2} + \mathbf{H_2O}$$

Next convert the mass of lithium hydroxide given to moles using the equation

$$n = \frac{m_{LiOH}}{M_{LiOH}} = \frac{1000\ g}{23.949\ g/mol} = \boldsymbol{41.76\ moles}$$

Next observe, the mole method, that 2 moles of lithium hydroxide absorbs 1 mole of carbon dioxide.

Therefore 41.8 moles of lithium hydroxide will absorb 20.9 moles of carbon dioxide.

Next convert the moles of carbon dioxide absorbed to mass in grams using the equation

$$m_{CO_2} = n_{CO_2} \times M_{CO_2} = 20.88 \times 44.01 = \mathbf{918.93\ g}$$

Question 7 – Stoichiometric Calculations: Limiting Reactant

a) What is the limiting reactant problem? [2]

Solution:

The limiting reactant problem, is a chemistry problem in which one identifies the limiting reagent of the reaction and finds the number of moles of the limiting reagent. The moles of the limiting reagent enables one to use the mole method to determine the amount of the

(i) excess reagent used and unused in the reaction
(ii) product formed in the reaction.

b) Explain the steps of the method you use to solve the limiting reactant problems. [5]

Solution:

Referring to Zumdahl 9th Edition on page 123 gives the list below.

Problem-Solving Strategy

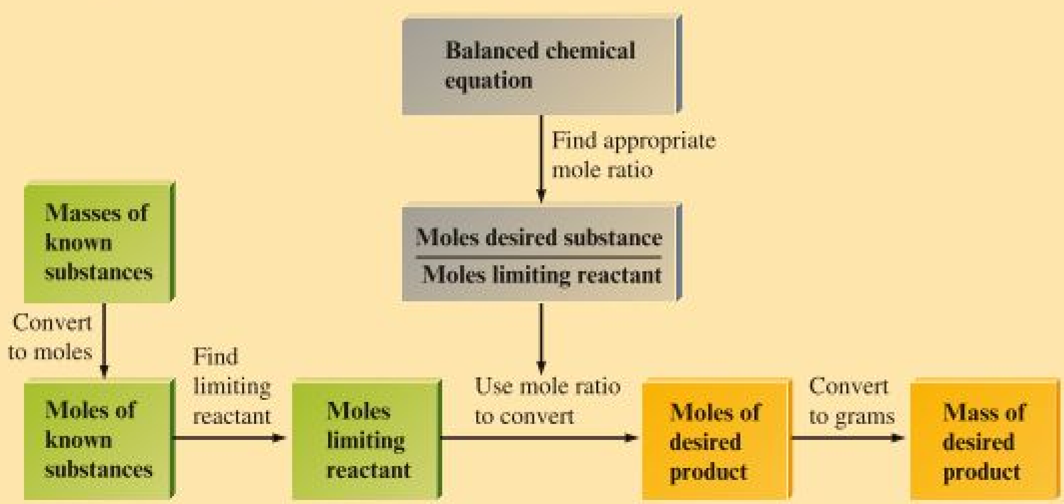
Solving a Stoichiometry Problem Involving Masses of Reactants and Products

1. Write and balance the equation for the reaction.
2. Convert the known masses of substances to moles.
3. Determine which reactant is limiting.
4. Using the amount of the limiting reactant and the appropriate mole ratios, compute the number of moles of the desired product.
5. Convert from moles to grams, using the molar mass.

c) Draw a diagram that summarizes your explanation of how to solve the limiting reactant problems. [4]

Solution:

This process is summarized in the diagram below:



d) A vessel contains $O_2(g)$ and $SO_2(g)$ that react to form $SO_3(g)$. If six moles of O_2 react with five moles of SO_2 in a reaction that goes to completion, what is the limiting reactant? If 96.0 g of SO_2 react with 32.0 g of O_2, what mass of the product will be formed? [5]

Solution:

(i) As indicated above the first step is write and balance the equation for this reaction which given below.

$SO_2 + O_2 \longrightarrow SO_3$ - unbalanced equation

$\mathbf{2SO_2 + O_2 \longrightarrow 2SO_3}$ - balanced equation

(ii) There is no need to convert masses to moles for the reaction involving 6 moles of O_2 with 5 moles of SO_2 because reactants area already given in moles. However for the reaction of 96.0 g of SO_2 with 32.0 g of O_2, **we find the moles of SO_2 are 1.5 moles while O_2 has 1 mole.**

(iii) Determining the limiting reagent for the reaction of 6 moles of O_2 with 5 moles of SO_2we use the balanced equation's stoichiometric ratios by noting that 2 moles of SO_2 uses up a mole O_2. Thus assuming that SO_2 is the limiting reagent, using up all its 5 moles will require 2.5 moles of O_2. **Clearly, the assertion that SO_2 is a limiting reagent is feasible since its 5 moles require 2.5 moles of the 6 moles of O_2 in the reaction vesse**l. On the other hand, assuming that O_2 is the limiting reagent, using up its 6 moles would consume 12 moles of SO_2 which are not available in the reaction vessel as stated in the problem state. This means that the assertion that O_2 is the limiting reagent is invalid.

(iv) Determining the mass of the product for reaction of 96.0 g or 1.5 molof SO_2 with 32.0 g or 1 mole of O_2, requires use to determine the limiting reagent first. Assuming that $SO_2$is the limiting reagent means its 1.5 moles would require only 0.75 mole of the 1 mole of O_2in the reaction vessel to produce 1.5 moles of SO_3. **Thus the mass of SO_3 produced according the equation** $\boldsymbol{m_{SO_3} = n_{SO_3} \times M_r = 1.5 \times 80.07\ \mathrm{g} \approx 120\ \mathrm{g}}$