Chapter 3: Mass Relationships in Chemical Reactions
Part I

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Average Atomic Mass

Gallium has two naturally occurring isotopes. The mass of gallium-69 is 68.9256 amu and it is 60.108 % abundant. The mass of gallium-71 is 70.9247 amu and it is 39.892% abundant. Find the atomic mass (average atomic mass) of gallium.

$$\text{Average Atomic Mass} = \left(\frac{\%\text{ abundance of isotope 1}}{100}\right)(\text{mass of isotope 1}) + \left(\frac{\%\text{ abundance of isotope 2}}{100}\right)(\text{mass of isotope 2}) + \ldots$$

Average atomic mass of Gallium (Ga):

$$\frac{(60.108 \text{ x } 68.9256) + (39.892 \text{ x } 70.9247)}{100} = 69.69 \text{ amu}$$

Antimony has two naturally occurring isotopes. The mass of antimony-121 is 120.904 amu and the mass of antimony-123 is 122.904 amu. Calculate the natural abundance of these two isotopes.
The average atomic mass of antimony (Sb = 121.76 amu).

Average atomic mass = ∑ (The natural abundance x Atomic Mass) for each isotope

Remember that the sum of the two abundances must be 100.

Assume that : the natural abundance of ^{121}Sb = X % and ^{123}Sb =Y %

X% + Y% =100% X+Y=1 $\rightarrow$ Y = 1-X

Average atomic mass = (The natural abundance x Atomic Mass) ^{121}Sb +(The natural abundance x Atomic Mass) ^{123}Sb

121.76 = (X * 120.904) + (Y * 122.904)

121.76 = (X * 120.904) + ((1-x) * 122.904)

121.76 = 120.904 X + 122.904 -122.904 X

-1.144 = -2 X

X= 0.572 Y= 1-0.572= 0.428

X%= 57.2 % (^{121}Sb) Y%= 42.8% (^{123}Sb)

Argon has three naturally occurring isotopes: argon-36, argon-38, and argon-40. Based on argon’s reported atomic mass, which isotope do you think is the most abundant in nature? Explain

Answer:
Argon-40

Explanation:
The mass of Argon on the periodic table is 39.948.

The periodic table's atomic mass is the AVERAGE weight of ALL its isotopes.

If one isotope is MORE abundant than the others, the average will be closest to the mass of that isotope. So, the periodic table's 39.948 is closest to Argon-40

Gram-Mole Conversions

$$n = \frac{mass\ (m)}{Molar\ Mass\ (M)}$$

$$n = \frac{N\ (atoms\ or\ molecules)}{N_A\ (Avogadro's\ number)}$$

One mole = N_A ($6.0221367 \text{ x } 10^{23}$)

How many moles are in 2.1×10^{24} atoms of sodium?

$$n = \frac{N}{N_A}$$

$$n = \frac{2.1 \times 10^{24}}{6.022 \times 10^{23}}$$

$$n = 3.49\ mol$$

Gram-Mole Conversions

$$n = \frac{mass\ (m)}{Molar\ Mass\ (M)}$$

$$n = \frac{N\ (atoms\ or\ molecules)}{N_A\ (Avogadro's\ number)}$$

One mole = N_A (6.0221367×10^{23})

How many moles of sucrose, $C_{12}H_{22}O_{11}$, are in a tablespoon of sugar that contains 2.85 g?

m = 2.85 g, n = ???

Molar Mass $C_{12}H_{22}O_{11}$ = (12 x 12.01) + (22 x 1.008) + (11 x 16) = 342.2965 g/mol

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

$$n = \frac{2.85}{342.2965}$$

$$n = 0.00833\ \text{mol}$$

Gram-Mole Conversions

$$n = \frac{mass\ (m)}{Molar\ Mass\ (M)}$$

$$n = \frac{N\ (atoms\ or\ molecules)}{N_A\ (Avogadro's\ number)}$$

A sample of glucose, $C_6H_{12}O_6$, contains 1.52×10^{25} molecules. How many kilograms of glucose is this?

$N = 1.52\times10^{25}$ molecules

m (kg) = ????

1

$$n = \frac{N}{N_A}$$

$$n = \frac{1.52 \times 1025}{6.022 \times 10^{23}}$$

$n = 25.24$ mol

2

Molar Mass $C_6H_{12}O_6$ = 180.156 g/mol

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

$$25.24 = \frac{m}{180.156}$$

$m = 4547.27$ g

m = 4.55 kg

Gram-Mole Conversions

$$n = \frac{mass\ (m)}{Molar\ Mass\ (M)}$$

$$n = \frac{N\ (atoms\ or\ molecules)}{N_A\ (Avogadro's\ number)}$$

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$$n = \frac{N}{N_A}$$

$$n = \frac{1.52 \times 1025}{6.022 \times 10^{23}}$$

$$n = 25.24 \text{ mol}$$

2

Molar Mass $C_6H_{12}O_6$ = 180.156 g/mol

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

$$25.24 = \frac{m}{180.156}$$

$$m = 4547.27 \text{ g}$$

m = 4.55 kg

Gram-Mole Conversions

$$n = \frac{mass\ (m)}{Molar\ Mass\ (M)}$$

$$n = \frac{N\ (atoms\ or\ molecules)}{N_A\ (Avogadro's\ number)}$$

How many molecules are in 23 moles of HBr?

N = ??? molecules n = 23 mol

$$n = \frac{N}{N_A}$$

$$23 = \frac{N}{6.022 \times 10^{23}}$$

$$N = 23 \times 6.022 \times 10^{23} = 1.39 \text{ x } 10^{25}\ molecules$$

How many S atoms are in 16.3 g of S?

$$n(S) = \frac{m}{M} = \frac{16.3\ \text{g}}{32.07\ \text{g/mol}} = 0.508\ \text{mol}$$

$$n(S) = \frac{N}{N_A} \Rightarrow N = n x N_A$$

$$= 0.508\ \text{mol}\ x 6.022 x 10^{23}\ \text{atoms/mol}$$

$$= 3.06 x 10^{23}\ \text{atoms}$$

How many oxygen atoms are in 4.5 gram of $KMnO_4$?

1- convert mass to moles

Molar Mass $KMnO_4$ = 39.098+54.938+(4×16)=158.036 g/mol

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

$$n = \frac{4.5}{158.036}$$

$$n = 0.0285 \text{ mol}$$

2- From the formula

1 mol of KMnO4 → 4 mol of oxygen
0.0285 mol of KMno4 → x mol of oxygen
n (mol of oxygen) = 0.1138 mol

3- number of Oxygen atoms

$$0.1138 = \frac{N}{6.022 \times 10^{23}}$$

$$N = 0.1138 \times 6.022 \times 10^{23} = 6.85 \text{ x } 10^{22} \; atoms\ of\ oxygen$$

Percent Composition of Compounds

Glucose, or blood sugar, has the molecular formula $C_6H_{12}O_6$.
a. What is the percent composition of glucose?

$$\frac{\boldsymbol{n} \text{ x molar mass of element}}{\text{molar mass of compound}} \text{ x } 100\%$$

Molar mass of $C_6H_{12}O_6$ = 180.156 g/mol

Molar mass of C = 12.01 g /mol

Molar mass of H = 1.008 g/mol

Molar mass of O = 16.00 g/mol

$$\%C = \frac{\mathbf{6} \text{ x } 12.01}{180.156} \text{ x } 100\% = 40\ \%$$

$$\%H = \frac{\mathbf{12} \text{ x } 1.008}{180.156} \text{ x } 100\% = 6.714\ \%$$

$$\%O = \frac{\mathbf{6} \text{ x } 16}{180.156} \text{ x } 100\% = 53.29\ \%$$

40 % + 6.714 % + 53.29 % = 100.0%

b. How many grams of carbon are in 39.0 g of glucose (the amount of sugar in a typical soft drink)? Answer: 15.6 g C

Percent Composition of Compounds

Which is richer source of nitrogen Urea $(NH_2)_2CO$ or Ammonia NH_3 on a mass percentage basis?

$$\frac{n \text{ x molar mass of element}}{\text{molar mass of compound}} \text{ x } 100\%$$

$$(NH_2)_2CO = \frac{2x14.01}{(2x14.01)+(4x1.008)+12.01+16} \times 100 = \frac{28.02}{60.062} \times 100 = 46.6\%$$

$$NH_3 = \frac{14.01}{(14.01)+(3x1.008)} \times 100 = \frac{14.01}{17.034} \times 100 = 82.2\ \%$$

$\therefore$ NH_3 is richer

Determination of the Empirical and molecular Formula from the Percent Composition by Mass

خطوات الحل

1. ننشأ جدول نضع فيه العناصر المذكورة في السؤال
2. نعتبر أن النسبة المئوية معبر عنها بالجرام فلو كان عندنا 100 جرام من المركب فهذه ال 100 جرام موزعة على العناصر حسب نسبتها.
3. نوجد عدد المولات n لكل عنصر باستخدام القانون n=m/M .
4. نقسم عدد المولات على أصغر مول من العناصر.
5. الأرقام التي نحصل عليها تمثل empirical formula بشرط أن تكون أعداد صحيحة أما في حالة ظهور أعداد عشرية فنقوم بضرب الأرقام التي في الأسفل الموجودة في الصيغة بأعداد بدأ من 2، 3.......حتى نحصل على أعداد صحيحة.
6. في حال طلب molecular formula فلابد من توفير الوزن الجزئيي (molar mass) للمركب في السؤال ثم نقوم بإيجاد (molar mass) للصيغة الاولية empirical formula وحساب النسبة بينهما باستخدام العلاقة

$$\text{Ratio} = \frac{\text{molar mass of compound}}{\text{empirical molar mass}}$$

ثم نضرب الناتج في اعداد الذرات في empirical formula

These steps are written by Dr.Effat

Empirical and Molecular Formulas

Spodumene, lithium aluminium inosilicate, is one of the most common lithium-containing minerals. It consists of 3.730% Li, 14.50% Al, 30.18% Si, and 51.59% O. What is the empirical formula of spodumene?

	Li	**Al**	**Si**	**O**
% →100g	3.73 g	14.5 g	30.18 g	51.95 g
n=m/M	3.73/6.941 =0.537 mol	14.5/27 =0.537 mol	30.18/28.0855 = 1.075 mol	51.95/16 =3.247 mol
÷ on smallest no. of mole	0.537/0.537 =1	1.116 /0.537 = 1	1.075/0.537 = 2	3.247/0.537 = 6
The empirical formula	Li	Al	Si_2	O_6
	$LiAlSi_2O_6$			

PNA is a compound of C,N,H and O, determine the percent composition of O and the empirical formula from 19.8% C, 2.5 %H and 11.6%N and the molecular mass if molar mass is about 120 g?

O% = 100 – (19.8 +2.5+11.6) = 66.1%

	C	**H**	**N**	**O**
% →100g	19.8g	2.5g	11.6g	66.1g
n=m/M	19.8/12.01 =1.648mol	2.5/1.008 =2.48 mol	11.6/14.01 = 0.828mol	66.1/16 =4.1 mol
÷ on smallest no. of mole	1.648/0.828 =1.99 = 2	2.48 /0.828 = 2.99=3	0.828/0.828 =1	4.1/0.828 =4.95=5
The empirical formula	C_2	H_3	N_1	O_5
	$C_2H_3NO_5$			

Molar mass of empirical formula = (2x12.01) + (3x1.008)+14.01+(5x16)=121.054 g

Ratio = 120 / 121.054 = 0.99 = 1

∴ 1X($C_2H_3NO_5$) = $C_2H_3NO_5$

∴molecular formula has the same empirical formula

Elemental analysis of styrene shows its percent composition to be 92.26 % C and 7.75% H. Its molecular mass is found to be 104.15 g/mol. What are the empirical and molecular formulas of styrene?

	C	**H**
% →100g	92.26 g	7.75 g
n=m/M	92.26/12.01 =7.68 mol	7.75/1.008 =7.68 mol
÷ on smallest no. of mole	7.68/7.68 =1	7.68 /7.68 =1
The empirical formula	C	H
	CH	

Molar mass of empirical formula = (12.01) + (1.008) = 13.018 g/mol

Ratio = 104.15 / 13.018 = 8

∴ 8X(***CH***) = C_8H_8

Balancing chemical equations

Balance the following chemical equation:

___ AgI + ___ $Fe_2(CO_3)_3$ → ___ FeI_3 + ___ Ag_2CO_3

$6\ AgI + Fe_2(CO_3)_3 \rightarrow 2\ FeI_3 + 3\ Ag_2CO_3$

___ H_2SO_4 + ___ $B(OH)_3$ → __ $B_2(SO_4)_3$ + ___ H_2O

$3\ H_2SO_4 + 2\ B(OH)_3 \rightarrow B_2(SO_4)_3 + 6\ H_2O$

$C_4H_{10} + O_2 \longrightarrow CO_2 + H_2O$

$$C_4H_{10} + \frac{13}{2}O_2 \rightarrow 4CO_2 + 5H_2O$$

$$2\times[C_4H_{10} + \frac{13}{2}O_2 \rightarrow 4CO_2 + 5H_2O]$$

$$2C_4H_{10} + 13\ O_2 \rightarrow 8CO_2 + 10H_2O$$