# *A Guide to Quantitative Aspects of Chemical Change*

## Teaching Approach

Quantitative chemistry has considerable importance in the chemistry curricula in the FET CAPS curriculum, since it is a topic that is studied in both Grade 10 and 11 and it is included in the final Grade 12 chemistry exam. With this in mind it is very important that enough time is spent on making sure that students understand the concepts and the relationships between them.

The approach that needs to be followed is to make sure that students first understand the meaning of the mole and grasp the size of Avogadro's number. They need to realise that a mole is a measure of the amount (or number) of items. These items may be atoms, molecules or ions. Make sure that learners know the difference between molecular mass and molar mass.

Secondly they need to understand the four different ways to calculate the number of moles of a substance i.e. making use of the mass, the number of particles, the concentration and the molar volume.

Once these concepts are in place, the focus should change to solving stoichiometric calculations. Four basic steps need to be followed to solve this type of calculation.

The steps are

1. Balance the equation.
2. Convert the amounts of a given substance to moles.
3. Using the mole ratio, calculate the moles of substance yielded by the reaction.
4. Convert moles of the required substance back to the desired quantity.

The only way to make sure that the concepts discussed in this series is thoroughly understood is by making use of extensive practice.

## Video Summaries

Some videos have a 'PAUSE' moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given.

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day's lesson; if desired, learners can be given specific questions to answer in preparation for the next day's lesson

### 1. Atomic Mass

In this lesson we define mole and look at the difference between relative molecular mass. We also do some calculations.

### 2. The Mole Concept

In this lesson we will look at how to find the number of particles in a sample of a substance.

### 3. Mole Calculations

We discuss the relationship between the number of moles, mass and the molar mass. The second concept is the number of particles in a mole.

### 4. Introducing Empirical Formula and Percentage Composition

Any element and compound known to us has an empirical formula. In this lesson we investigate how this formula is calculated from given values, and determined through experiments. The percentage composition of compounds is also determined.

### 5. Working with Empirical Formula and Percentage Composition

In this lesson we do complex examples of questions that involve empirical formula and percentage composition

### 6. Molar Concentrations

In this video we define and calculate the concentration of a solution as the number of moles per volume.

## 7. Molar Volume of Gases

The definition of molar volume is stated as: one mole of gas occupies 22,4 $dm^3$ at 0°C and 1 atmosphere. In this lesson we explain the molar volume and do some calculations to calculate the number of moles under these conditions.

## 8. Introducing Stoichiometric Calculations

In this lesson we look at how stoichiometric calculations are done by making use of four basic steps. We also visit a laboratory where we see the difference between a qualitative experiment and a quantitative calculation.

## 9. Exploring Stoichiometric Calculations

In this lesson we use everything that we studied so far to do some stoichiometric calculations.

## Resource Material

| | | |
|---|---|---|
| **1. Atomic Mass** | http://wps.pearsoned.com.au/cd1/49/12619/3230494.cw/index.html | A resource on atomic mass and the mole concept. |
| **2. Mole Concept** | http://en.wikipedia.org/wiki/Mole_(unit) | An encyclopaedia on mole (unit). |
| | http://wps.pearsoned.com.au/cd1/49/12619/3230494.cw/index.html | A resource on atomic mass and the mole concept. |
| **3. Mole Calculations** | https://www.youtube.com/watch?v=Ik4zE8IXWs8 | A video on how to Calculate the number of moles, given the mass of a substance. |
| | http://chemwiki.ucdavis.edu/Physical_Chemistry/Atomic_Theory/The_Mole_and_Avogadro's_Constant | A resource on mole and Avogadro constant. |
| | http://misterguch.brinkster.net/conversionsworksheets.html | A worksheet involving unit conversions and mole calculations. |
| 4. **Empirical Formula and Percentage Composition** | http://www.kentchemistry.com/links/bonding/empirical.htm | Empirical and molecular formula calculations. |
| | http://www.chem.tamu.edu/class/majors/tutorialnotefiles/empirical.htm | This page defines empirical formula and gives step by step instructions on determining an empirical formula. |
| **5. Working with Empirical Formula and Percentage Composition** | http://www.kentchemistry.com/links/bonding/percentcomp.htm | A video demonstration on how to calculate the percentage composition by mass. |
| **6. Molar Concentrations** | http://www.docbrown.info/page04/4_73calcs11msc.htm | A resource on molarity, volumes and the concentration of solutions. |
| | http://misterguch.brinkster.net/pra_solutionworksheets.html | Worksheet about dissolved stuff. |
| 7. **Molar Volume of Gases** | http://en.wikipedia.org/wiki/Molar_volume | An encyclopaedia on molar volume. |
| | http://www.sciencegeek.net/Chemistry/taters/Unit5MolarVolume.htm | This page provides instructions on how to do calculations using standard molar volume. |

| | | |
|---|---|---|
| | http://www.docbrown.info/page04/4_73calcs09mvg.htm | This page describes and explains, with fully worked out examples, how to calculate the volume of gas formed from given masses of reactants. You need to know the formula connecting moles, mass and formula mass AND know how to use the molar volume in these gas volume calculation methods. |
| 8. **Introducing Stoichiometric Calculations** | http://m.everythingscience.co.za/grade-10/19-quantitative-aspects-of-chemical-change/19-quantitative-aspects-of-chemical-change-04.cnxmlplus | This page defines stoichiometry and gives examples of stoichiometric calculations. |
| **9. Exploring Stoichiometric Calculations** | https://www.youtube.com/watch?v=65ogAbpko8I | Stoichiometric calculations practice page. |
| | http://iannonechem.com/Sc/workbookanswers/6.answers.htm | A worksheet on stoichiometry. |

# Task

## Question 1

Calculate the relative molecular or formula mass of

1.1 ammonium nitrate
1.2 aluminium oxide
1.3 ethanoic acid, $CH_3COOH$

## Question 2

Calculate the molar mass of

2.1 Sodium carbonate $Na_2CO_3$
2.2 Hydrated magnesium sulfate $MgSO_4.7H_2O$
2.3 Calcium phosphate

## Question 3

3.1 Calculate the number of moles in 7g of nitrogen gas
3.2 Calculate the mass of 0,4 moles of water.
3.3 Calculate the number of moles in 0,25 kg of $Ca(OH)_2$.

## Question 4

4.1 Calculate the number of molecules in 3 g of chlorine gas
4.2 Calculate the mass of $3{,}01 \times 10^{23}$ molecules of iodine

## Question 5

13 g of zinc reacts with 6,4 g of sulfur. What is the empirical formula of zinc sulfide?

## Question 6

Determine the empirical formula of a compound that is composed of 36,5% sodium, 25,4% sulfur, and 38,1% oxygen.

## Question 7

10,2 g of aluminium oxide is strongly heated in the presence of hydrogen gas until it is reduced to 5,4 g of aluminium metal. Determine the empirical formula of aluminium oxide.

## Question 8

Calculate the percentage composition by mass of nitrogen present in ammonium phosphate.

## Question 9

87 g of potassium sulfate makes a solution with a concentration of 0,8 $mol{\bullet}dm^{-3}$ . What is the volume of this solution?

## Question 10

$V_M = 22{,}4\ dm^3$ at S.T.P

308 g of $CO_2$ are released into the atmosphere at STP. What volume will the gas occupy?

### Question 11

If 33 g of hydrogen gas is produced when aluminium metal is dissolved in hydrochloric acid, what mass of aluminium was dissolved?

### Question 12

Consider this balanced equation

$2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2\ H_2O$

12.1 How much $Na_2SO_4$ is formed if 58 g of $H_2SO_4$ reacts with an excess of NaOH ?
12.2 What mass of $Na_2SO_4$ is formed if 62 g of NaOH reacts with an excess of $H_2SO_4$?

### Question 13

Determine the volume of oxygen, calculated at STP, which is liberated when 43,4 g mercury oxide decomposes completely into mercury and oxygen gas.

# Task Answers

## Question 1

1.1 $M_r(NH_4NO_3)$ = 2x14 +4x1 + 3x16
= 80

1.2 $M_r(A\ell_2O_3)$ = 2x27 + 3x16
= 102

1.3 $M_r(CH_3COOH)$ = 2x12 + 4x1 +2x16
= 60

## Question 2

2.1 $M(Na_2CO_3)$ = 2x23 +12+3x16
= 106 $g{\cdot}mol^{-1}$

2.2 $M(MgSO_4.7H_2O)$ = 24 + 32 + 4x16 +7(2x1 +16)
= 246 $g{\cdot}mol^{-1}$

2.3 $M(Ca_3(PO_4)_2$ = 3x40 + 2x31 +8x16
= 310 $g{\cdot}mol^{-1}$

## Question 3

3.1

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

$$n=\frac{7}{28}$$

$$n=0,25 \text{ mol}$$

3.2

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

$$m = n \text{ x } M = 0,4 \text{ x } 18 = 7,2 \text{ g}$$

3.3

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

$$n=\frac{250}{74}$$

$$n= 3,38 \text{ mol}$$

## Question 4

4.1

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

$$\frac{m}{M}=\frac{N}{N_A}$$

$$\frac{3}{71}=\frac{N}{6,02x10^{23}}$$

$$N = 2,54 \text{ x } 10^{22} \text{ molecules of } C\ell_2$$

4.2

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

$$\frac{m}{M} = \frac{N}{N_A}$$

$$\frac{m}{254} = \frac{3,01x10^{23}}{6,02x10^{23}}$$

$$m = 127 \text{ g of } I_2$$

## Question 5

| | Zn | S |
|---|---|---|
| mass | 13g | 6,4g |
| n=m/M | 0,2 mol | 0,2 mol |
| Ratio | 0,2 / 0,2 | 0,2 / 0,2 |
| | 1 | 1 |

Thus the empirical formula is ZnS

## Question 6

| | Na | S | O |
|---|---|---|---|
| mass | 36,5g | 25,4g | 38,1g |
| n=m/M | 1,59 mol | 0,79 mol | 2,38 mol |
| Ratio | 1,59 / 0,79 | 0,79 / 0,79 | 2,38 / 0,79 |
| | 2 | 1 | 3 |

Thus the empirical formula is $Na_2SO_3$

## Question 7

| | Aℓ | O |
|---|---|---|
| mass | 5,4g | 10,2 - 5,4 = 4,8g |
| n=m/M | 0,2 mol | 0,3 mol |
| Ratio | 0,2 / 0,2 | 0,3 / 0,2 |
| (x2) | 1 | 1,5 |
| | 2 | 3 |

Thus the empirical formula is $A\ell_2O_3$

## Question 8

$M((NH_4)_3PO_4)$ = 3x14 +12 x 1 + 31 + 4x16
= 149 g·mol$^{-1}$

The

$$\% N = \frac{3x14}{149} x100$$

$$\% N = 28,19\%$$

**Question 9**

$$M(K_2SO_4)$$
$$= 2x39 + 32 + 4x16$$
$$= 174 g \cdot mol^{-1}$$

$$c = \frac{n}{V}$$
$$c = \frac{m}{MV}$$
$$0,8 = \frac{87}{174V}$$
$$V = \frac{87}{(0,8)174}$$
$$V = 0,63 \text{ dm}^3$$

**Question 10**

$M(CO_2) = 12 + 16 \times 2$
$= 44 \text{ g} \cdot \text{mol}^{-1}$

$$n = \frac{V}{V_m}$$
$$\frac{m}{M} = \frac{V}{V_m}$$
$$\frac{308}{44} = \frac{V}{22,4}$$
$$V = \frac{(22,4)(308)}{44}$$
$$V = 156,80 \text{ dm}^3$$

**Question 11**

$2\ Al + 6\ HCl \rightarrow 2\ AlCl_3 + 3\ H_2$

$$n = \frac{m}{M}$$
$$n = \frac{33}{2}$$
$$n = 16,5 \text{ mol of hydrogen}$$

3 to 2 ratio, therefore 11 mol of Al was dissolved.

$$n = \frac{m}{M}$$
$$11 = \frac{m}{27}$$
$$m = 11x27$$
$$m = 297 \text{ g of aluminium}$$

## Question 12

$2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2\ H_2O$

12.1 the mole ratio 1 mol $H_2SO_4$ : 1 mol $Na_2SO_4$

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

$$n = \frac{58}{2+32+4x16}$$

$$n=0{,}59 \text{ mol of } H_2SO_4$$

Note that the questions asks "How much?" so the answer is a quantity in mol.

12.2 The mole ratio is 2 mol NaOH : 1 mol $Na_2SO_4$

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

$$n = \frac{62}{23+16+1}$$

$$n=1{,}55 \text{ mol of NaOH}$$

Therefore 1,55 / 2 = 0,775 mol will form

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

$$0{,}775 = \frac{m}{2x23+32+4x16}$$

$$m= 110{,}05 \text{ g of } Na_2SO_4$$

The question asks "What mass?" so the answer is in grams.

## Question 13

$2HgO(s) \rightarrow 2Hg(s) + O_2(g)$

The mole ratio = 2mol HgO : 1 mol $O_2$

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

$$n = \frac{43{,}4}{217}$$

$$n=0{,}2 \text{ mol of HgO}$$

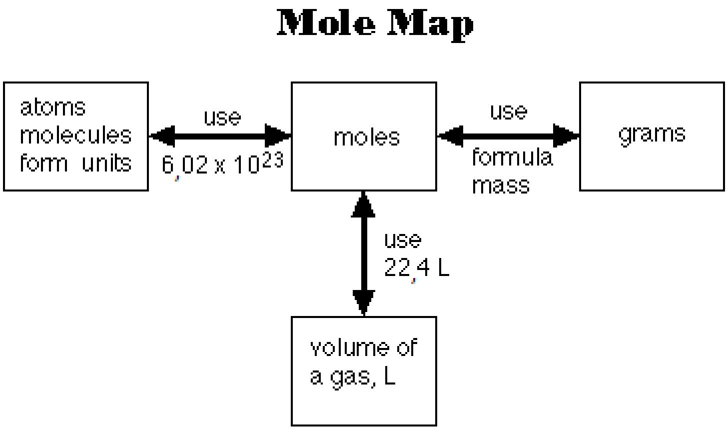
Therefore 0,1 mol of oxygen gas will form

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

$$0{,}1 = \frac{V}{22{,}4}$$

$$V= 2{,}24 \text{ dm}^3 \text{ of } O_2$$

# Appendix


Mole Map
atoms
molecules
form units
use
6,02 x 10^23
moles
use
formula
mass
grams
use
22,4 L
volume of
a gas, L

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