



PHYSICAL SCIENCES GRADE 11

(Quantitative Aspects of
Chemical Change)

LESSONS 1 - 2

28 JUNE - 30 JUNE 2023

Putting Lessons into Perspectives

WINTER HOLIDAYS PROGRAM:

Physical Sciences P2

Saturday 28 JUNE

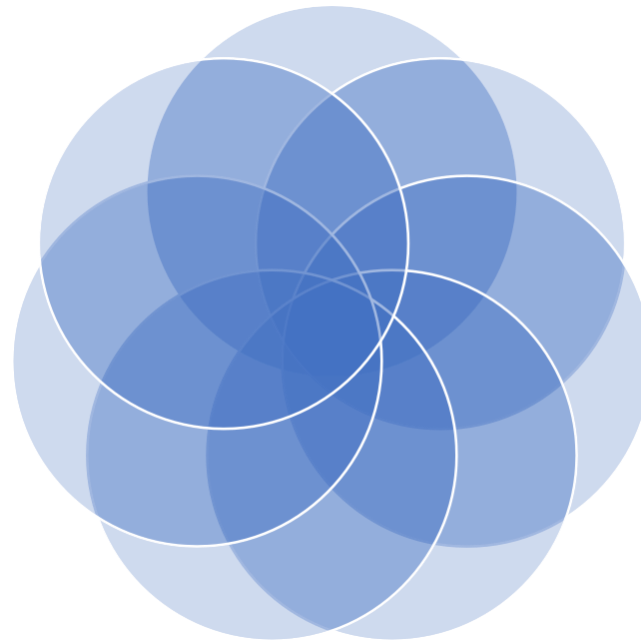
Chemical Change 1 & 2

Sunday 29 JUNE 2025

Chemical change 3

Monday 30 JUNE 2025

Chemical Change 3



Exam Guidelines: Chemical Change

CHEMICAL CHANGE is examined in **Paper 2** (3 hr)

EXAM WEIGHTING

- 92 marks out of 150
– i.e. 61% of the paper.
- Revision of Grade 10 work (*Chemical Change I*)
 - Representing chemical change - balancing chemical equations, conservation of atoms and mass
- Quantitative Aspects (*Chemical Change II*)
 - The mole, molar volume of gases, volume relationships in gaseous reactions, concentration of solutions, more complex stoichiometric calculations
- Energy and Chemical Change (*Chemical Change III*)
 - Energy changes in reactions, exothermic and endothermic reactions, activation energy
- Types of Reaction
 - Acid-base reactions, redox reactions, oxidation numbers

- Define a physical change and give examples.
- Define a chemical change and give examples.
- Write word equations from chemical equations and vice versa
- Use (s), (aq), (l) and (g) to indicate phases.
- Write balanced chemical equations
- Conservation of atoms and mass
- Law of constant composition.
- Interpret balanced equations in terms of conservation of atoms and mass.

TOPIC OVERVIEW : MOLE CONCEPT AND MOLE RELATIONSHIPS

- Describe the mole as the SI unit for amount of substance.
- Define one mole as the amount of substance having the same number of particles as there are atoms in 12 g carbon-12.
- Describe Avogadro's number, N_A , as the number of particles (atoms, molecules, formula-units) present in one mole ($N_A = 6,023 \times 10^{23} \text{ particles} \cdot \text{mol}^{-1}$).
- Calculate number of moles using :

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

TOPIC OVERVIEW: QUANTITATIVE ASPECTS OF CHEMICAL CHANGE – GR 10

- Define relative atomic mass.
- Define molar mass as the mass of one mole of a substance measured in $\text{g}\cdot\text{mol}^{-1}$.
- Calculate the molar mass of a substance given its formula.
- Describe the relationship between molar mass(M) and relative molecular mass and relative formula mass.
- Calculate the molar mass of a substance given its formula.
- Calculate mass, molar mass and number of moles using:

$$C = \frac{n}{v}$$

Molar volume of gases

- State Avogadro's Law, i.e. one mole of any gas occupies the same volume at the same temperature and pressure.
- At STP: 1 mole of any gas occupies 22,4 dm³ at 0 °C (273 K) and 1 atmosphere (101,3 kPa). Thus the molar gas volume, V_m , at STP = 22,4 dm³·mol⁻¹
- Calculate number of moles using :

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

TOPIC OVERVIEW: QUANTITATIVE ASPECTS OF CHEMICAL CHANGE – GR 10

- Define concentration as the number of moles of solute per cubic decimetre of solution.
- Calculate concentration in mol.dm⁻³ using $c = \frac{n}{V}$

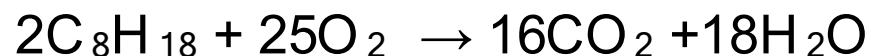
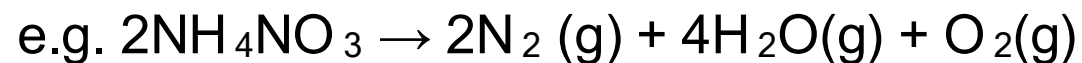
$$C = \frac{n}{v}$$

- Determine percentage composition of an element in a compound.
- Determine the empirical formula for a substance from percentage composition.
- Define an empirical formula as the simplest.
- Determine the number of moles of water of crystallization in salts like $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.
- Define water of crystallization.

TOPIC OVERVIEW: QUANTITATIVE ASPECTS OF CHEMICAL CHANGE – GR 11

- Interpret balanced equations in terms of volume relationships for gases.
- Determine percentage composition of a compound.
- Determine the empirical formula and molecular formula of compounds.
- Do stoichiometric calculations including limiting reagents.
- Determine the percentage yield of a chemical reaction.
- Determine the percentage CaCO_3 in an impure sample of sea shells (purity or percentage composition).

- Stoichiometric calculations with explosions as reactions



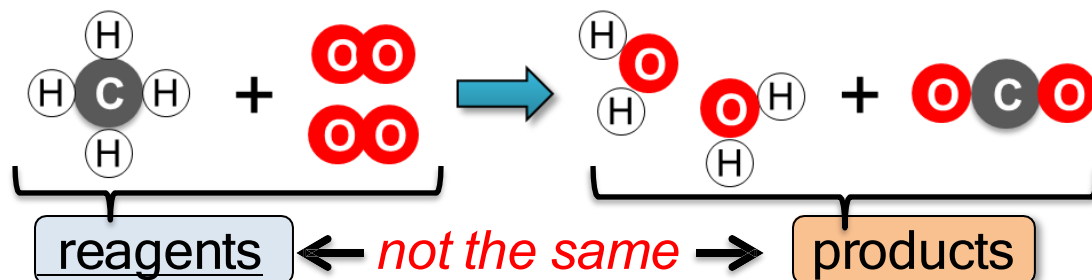
- Stoichiometric calculations using reaction in airbags (sodium azide):



Chemical Change

CHEMICAL CHANGE is a change that involves the formation of 1 (or more) **NEW** substances in a chemical reaction.

It isn't merely a change in form, but a **change in identity**
e.g.: the combustion of methane: $\text{CH}_4 + 2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{CO}_2$



Note: the reagents and products are *radically different*.

The number and type of atoms before the reaction (1C, 4H, 4 O) are however exactly the same as after the reaction (1C, 4H, 4O) - **CHEMICAL CHANGE** is thus essentially a *re-arrangement of atoms ...*

In different words: we have a **CONSERVATION OF ATOMS**, and indeed of also of mass.

There are many *different types* of chemical reactions ...

By the end of this section, you will be able to:

- Derive chemical equations from narrative descriptions of chemical reactions.
- Write and balance chemical equations in molecular, total ionic, and net ionic formats.

Types of Reactions - Recap

- **Synthesis** reactions -when 2 (or more) different molecules / atoms combine to form a single new molecule: $X + Y \rightarrow XY$
 $2H_2 + O_2 \rightarrow 2H_2O$ or $4Fe + 3O_2 \rightarrow 2Fe_2O_3$
- **Decomposition** reactions - when a substance decomposes / breaks up into simpler substances: $XY \rightarrow X + Y$
 $CaCO_3 \rightarrow CaO + CO_2$ or $2H_2O_2 \rightarrow 2H_2O + O_2$
 - **Replacement** and **Combustion** reactions, etc.

WRITING AND BALANCING CHEMICAL EQUATIONS

- When atoms gain or lose electrons to yield ions, or combine with other atoms to form molecules, their symbols are modified or combined to generate chemical formulas that appropriately represent these species.
- Extending this symbolism to represent both the identities and the relative quantities of substances undergoing a chemical (or physical) change involves writing and balancing a **chemical equation**.

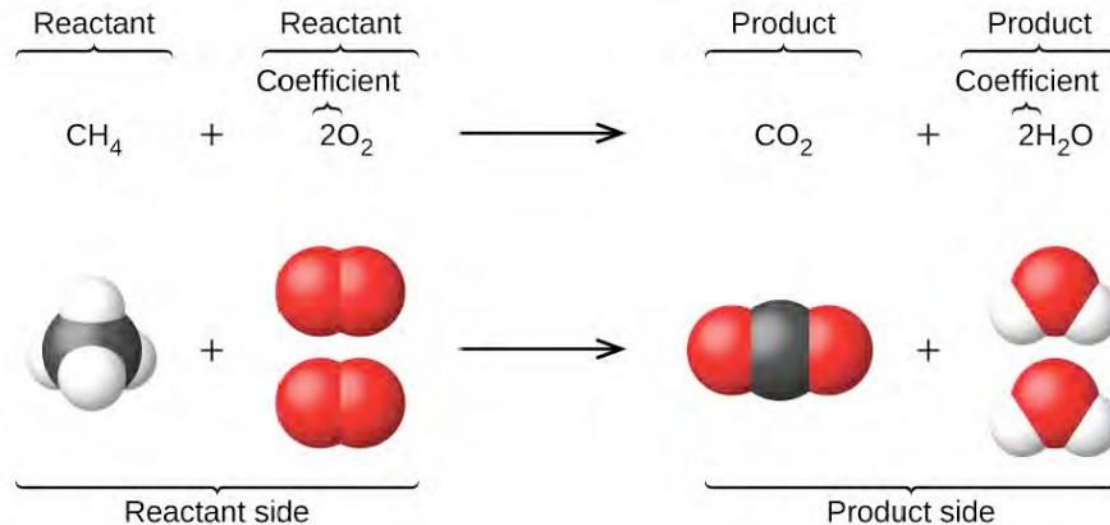
WRITING AND BALANCING CHEMICAL EQUATIONS

- Consider as an example the reaction between one methane molecule (CH_4) and two diatomic oxygen molecules (O_2) to produce one carbon dioxide molecule (CO_2) and two water molecules (H_2O).
- The chemical equation representing this process is provided in the upper half of [Figure 4.2](#), with space-filling molecular models shown in the lower half of the figure.

WRITING AND BALANCING CHEMICAL EQUATIONS

Figure 4.2

The reaction between methane and oxygen to yield carbon dioxide in water (shown at bottom) may be represented by a chemical equation using formulas (bottom).



WRITING AND BALANCING CHEMICAL EQUATIONS

This reaction between Methane and Oxygen in the previous slide illustrates the fundamental aspects of any chemical equation:

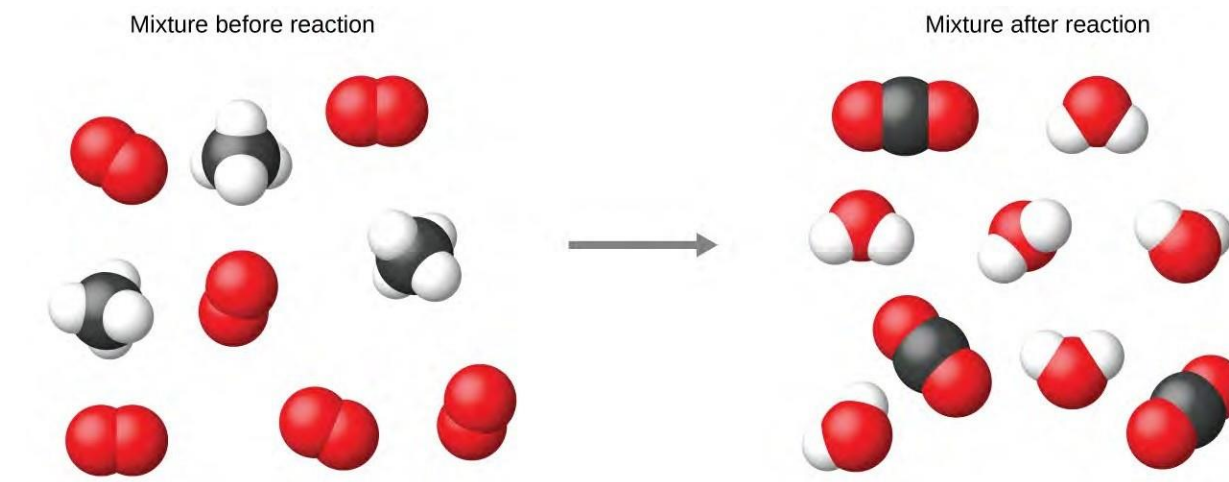
- 1) The substances undergoing reaction are called **reactants**, and their formulas are placed on the left side of the equation.
- 2) The substances generated by the reaction are called **products**, and their formulas are placed on the right side of the equation.
- 3) **Plus signs (+)** separate individual reactant and product formulas, and an **arrow (→)** separates the reactant and product (left and right) sides of the equation.
- 4) The relative numbers of reactant and product species are represented by **coefficients** (numbers placed immediately to the left of each formula). **A coefficient of 1 is typically omitted.**

WRITING AND BALANCING CHEMICAL EQUATIONS

- It is common practice to use the smallest possible whole-number coefficients in a chemical equation, as is done in this example.
- Realize, however, that these coefficients represent the *relative* numbers of reactants and products, and, therefore, they may be correctly interpreted as ratios.
- Methane and oxygen react to yield carbon dioxide and water in a 1:2:1:2 ratio.
- This ratio is satisfied if the numbers of these molecules are, respectively, 1-2-1-2, or 2-4-2-4, or 3-6-3-6, and so on (**Figure 4.3 next slide**).

Figure 4.3

Regardless of the absolute number of molecules involved, the ratios between numbers of molecules are the same as that given in the chemical equation.



WRITING AND BALANCING CHEMICAL EQUATIONS

Likewise, these coefficients may be interpreted with regard to any amount (number) unit, and so this equation may be correctly read in many ways, including:

- *One methane* molecule and *two oxygen* molecules react to yield *one carbon dioxide* molecule and *two water* molecules.
- *One dozen methane* molecules and *two dozen oxygen* molecules react to yield *one dozen carbon dioxide* molecules and *two dozen water* molecules.
- *One mole of methane* molecules and *2 moles of oxygen* molecules react to yield *1 mole of carbon dioxide* molecules and *2 moles of water* molecules.

Balancing Chemical Reactions

- The chemical equation between methane and oxygen described in the previous slide is **balanced**, meaning that equal numbers of atoms for each element involved in the reaction are represented on the reactant and product sides.
- This is a requirement the equation must satisfy to be consistent with the **law of conservation of matter**.
- It may be confirmed by simply summing the numbers of atoms on either side of the arrow and comparing these sums to ensure they are equal.
- Note that the number of atoms for a given element is calculated by multiplying the coefficient of any formula containing that element by the element's subscript in the formula.
- If an element appears in more than one formula on a given side of the equation, the number of atoms represented in each must be computed and then added together

CONSERVATION OF MATTER

As noted, the number and type of atoms in a chemical reaction doesn't change, nor does the mass of the system (if no material is able to escape. This gives us the ...

LAW OF THE CONSERVATION OF ATOMS AND MASS: In a chemical reaction, mass is neither created nor destroyed. In a closed system, the total mass is always conserved.

Take, as example,
the reaction:





Consider this reaction analysis: (# - number, mass = rel. atomic mass)

Atom Type	In Reactants		In Products		Equal?
	#	mass	#	mass	
calcium (Ca)	1	40,1	1 (CaO)	40,1	Yes
carbon (C)	1	12,0	1 (CO ₂)	12,0	Yes
oxygen (O)	3	16,0 x 3	3 (CaO + CO ₂)	16,0 x 3	Yes
Total Atoms	5		5		Yes
Total Mass		100,1		100,1	Yes

Note too though: the number of molecules is not conserved.

The *Law of the Cons. of Atoms/ Mass* holds for all chem. reaction, irrespective of the phase the reactants or products are in.

Another important law is that of **CONSTANT COMPOSITION**: for any particular compound, any samples of that compound will **always** have exactly the **same elements** in the **same ratio**.

e.g.: water (H₂O) has a H:O ratio of 2:1 (note the subscripts) - *this is always the same*. The composition of water does not change, ever.

The implication: when balancing chemical equations, never, never change the subscripts of the compounds

LAW OF CONSTANT COMPOSITION

Another important law is that of **CONSTANT COMPOSITION**: for any particular compound, any samples of that compound will **always** have exactly the **same elements** in the **same ratio**.

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Symbols and Formulae

- To speak a language, you have to know a fair amount of words and grammar.
- The same is true in the chemical sciences: you have to know the basic *elements* and their *symbols* (*the first 36 – hydrogen to krypton, plus a few others*), as well as the *formulae* of common *compounds / polyatomic ions*.

(See the information sheets and periodic table of elements)

Symbols and Formulae

A **brief review** of the rules for naming / writing the names of chemical compounds.

- The chemical formula of an **element** is simply its symbol (e.g.: iron – Fe, magnesium – Mg, neon – Ne). Noble gases and many metals are generally encountered as single element.
- Seven elements (H, N, O, F, Cl, Br and I) exist as **diatomic molecules**, i.e. as H_2 , F_2 , etc. At STP, these molecules are in the gas phase.
- Use **valency** to determine the formulae for simple compounds containing 2 elements.
- Write the symbols of the elements, with subscripts in the inverse ratio of their valencies. Use the ending –**ide**.
Valencies: Al - 3, S - 2, formula: Al_2S_3 , name: aluminium sulfide

Naming Rules ...

- When elements (transition metals mostly), have more than one valency, we use **Stock Notation** (Roman numerals) to indicate the valency of the element in a particular compound. e.g.:
copper(II) chloride – CuCl_2 ,
manganese(VII) oxide – Mn_2O_7
- In covalently bonded molecules, the number of atoms of an element may be indicated by a **prefix**, e.g.:
*carbon **mon**oxide (CO),*
***dinitrogen hexa**fluoride (N_2F_6)*

Naming Rules ...

- Many compounds contain **complex or polyatomic ions**. Their valency is the same as their charge. With 2 or more of an ion, the ion is placed in brackets, e.g.

$NH_4^+, NO_3^- \rightarrow NH_4NO_3$ ammonium nitrate; $Ca, OH \rightarrow Ca(OH)_2$
calcium hydroxide

NB: the brackets are very important: $Ca(OH)_2$ is not the same as $CaOH_2$.

- Ionic compounds (between metals & non-metals): Ions combine to form **a neutral formula unit** - in the inverse ratio to their charges. Sodium sulfate: $Na +1$, sulfate 2^- thus Na_2SO_4 , ammonium carbonate: $NH_4^+ +1$, $CO_3^{2-} 2^-$ thus $(NH_4)_2CO_3$

Balancing Chemical Reactions

- Before working with any chemical equation, you must check that it is balanced.
- Do not assume that it is, unless specifically stated.
- As a 1st step: make sure that you have check that it lists *all reactants and products*, with *correct formulae* used.
- As a 2nd step: make sure that you have an *equal number* of *each type* of atom on *both sides* of the arrow

Balancing Chemical Reactions

- If that is not the case, **add or change the coefficients** – *the numbers in front of the formulae – a 1 is assumed, and not written down.*
- Never, never ever change the subscripts within a formula.

For example, let's balance the reaction $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$

- the formulae are correct, but the oxygens are not balanced
- try adding a coefficient to H_2O : $\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$...
- now the oxygens are balanced, but not the hydrogens, so add an appropriate co-efficient to H_2 : $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$
- a quick inspection shows that the equation is now balanced.

Overview

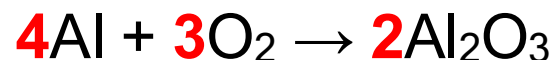
A quick overview of how to balance a chemical equation.

- begin balancing by *determining the number* of each type of atom both on the left (reactants) and on the right (products) - take polyatomic ions as single units
- *start* by balancing an *element* that appears *in only one reactant and one product*
- balance by changing the coefficients of the substances in appropriate ways
- *next* balance *more complicated* compounds
- generally, *leave oxygen and hydrogen* for last
- *single atoms / molecules* are the *easiest to balance* and don't affect the rest of the equation - use these to get the final balance
- always *double-check* that your balancing is correct

A Methodical Approach

Many equations can be balanced by inspection. For example, balance the equation $\text{Al} + \text{O}_2 \rightarrow \text{Al}_2\text{O}_3$.

- balance the more complex elements first, here O_2
- multiply O_2 by 3, and Al_2O_3 by 2: $\text{Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3$
- now the oxygen is balanced ...
- to balance Al, simply multiply the element Al by 4, thus



Other reactions might require a **more methodical approach** ...

Balance this equation: $\text{Mg}_3\text{N}_2 + \text{H}_2\text{O} \rightarrow \text{MgO} + \text{NH}_3$

	Left	x	Rht	x	Equation
Mg	3		1	x 3	$a\text{Mg}_3\text{N}_2 + b\text{H}_2\text{O} \rightarrow 3\text{MgO} + d\text{NH}_3$
N	2		1		
H	2		3		
O	1		1		

- the equation is balanced: $\text{Mg}_3\text{N}_2 + 3\text{H}_2\text{O} \rightarrow 3\text{MgO} + 2\text{NH}_3$

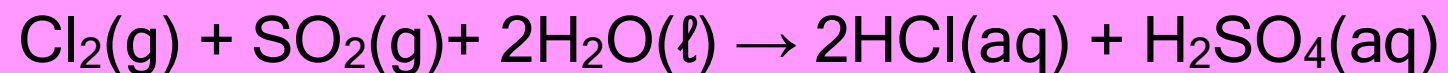
Phase Notation

Reactants and products exist in different phases (different states), as gas, liquid and as solution.

Because it is important to know in what phase a substance exists (it plays a significant role in determining how reactive a substance might be), chemists have developed a short-hand notation that is included in a fully balanced chemical ...

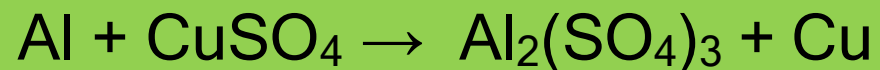
- solid (s)
- liquid (l) or (ℓ)
- gas (g)
- solution (aq) (aq - aqueous)

Once you've balanced a chemical equation, you should, if possible, include phase notation, e.g.:



Learning to Read Equations

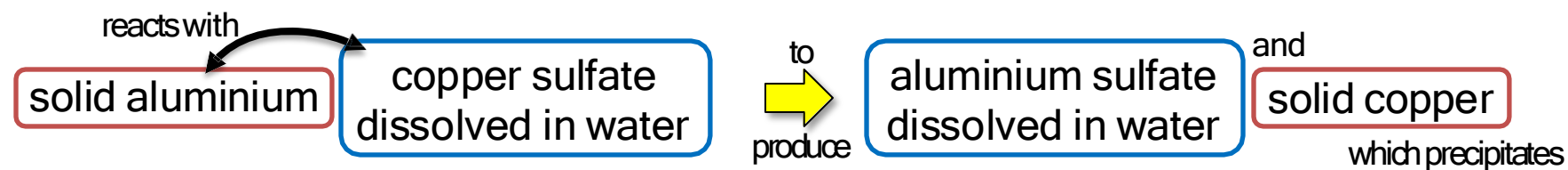
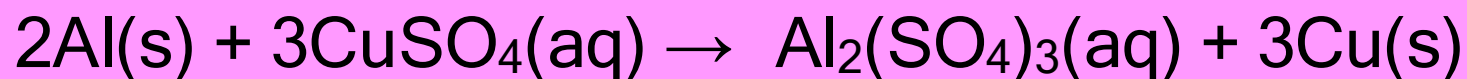
Let's take another chemical equation ...



- this equation is *unbalanced* (in the so-called *skeletal form*).
Balancing it, we get ... and adding phase notation gives ...



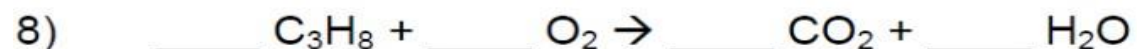
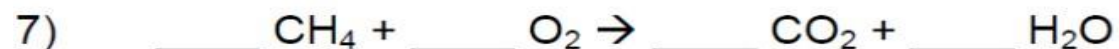
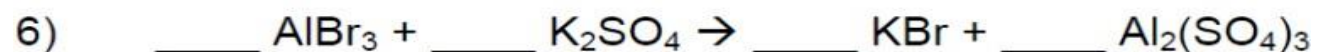
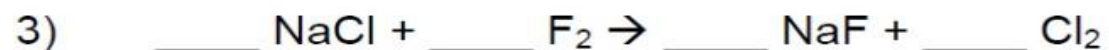
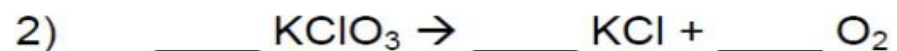
Reading
the equation ...



Dissolved in water, CuSO_4 dissociates into Cu^{2+} and SO_4^{2-} ions. The Cu^{2+} ions gives the solution a lovely blue colour. As the Cu^{2+} ions take up electrons from the aluminium, copper metal (Cu) is formed. This precipitates (drops out of the solution) and settles at the bottom as a reddish-brown deposit. The blue colour of the solution slowly disappears.

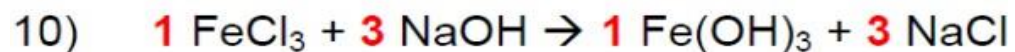
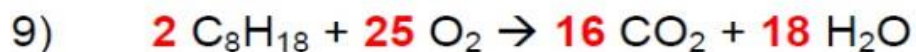
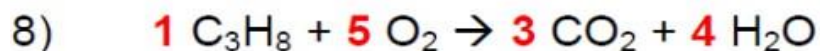
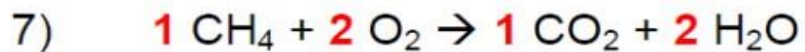
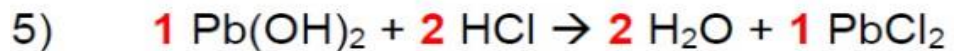
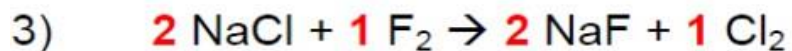
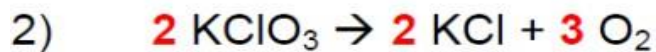
Practice Exercise 1

Balance the equations below:



Practice Exercise 1

Balance the equations below:



Practice Exercise 4

Word Equations

Write the word equations below as chemical equations and balance:

- 1) Zinc and lead (II) nitrate react to form zinc nitrate and lead.
- 2) Aluminum bromide and chlorine gas react to form aluminum chloride and bromine gas.
- 3) Sodium phosphate and calcium chloride react to form calcium phosphate and sodium chloride.
- 4) Potassium metal and chlorine gas combine to form potassium chloride.
- 5) Aluminum and hydrochloric acid react to form aluminum chloride and hydrogen gas.
- 6) Calcium hydroxide and phosphoric acid react to form calcium phosphate and water.
- 7) Copper and sulfuric acid react to form copper (II) sulfate and water and sulfur dioxide.
- 8) Hydrogen gas and nitrogen monoxide react to form water and nitrogen gas.

Practice Exercise 4

- 1) Zinc and lead (II) nitrate react to form zinc nitrate and lead.



- 2) Aluminum bromide and chlorine gas react to form aluminum chloride and bromine gas.



- 3) Sodium phosphate and calcium chloride react to form calcium phosphate and sodium chloride.



- 4) Potassium metal and chlorine gas combine to form potassium chloride.



- 5) Aluminum and hydrochloric acid react to form aluminum chloride and hydrogen gas.



- 6) Calcium hydroxide and phosphoric acid react to form calcium phosphate and water.



- 7) Copper and sulfuric acid react to form copper (II) sulfate and water and sulfur dioxide.



- 8) Hydrogen gas and nitrogen monoxide react to form water and nitrogen gas.



- Once a chemical equation has been fully specified, it can be used to do calculations of quantities of the various substances that are required, or may be produced.
- This is known as **STOICHIOMETRY**, and you'll be doing quite a bit of this in due course.

Periodic Table of Elements

Physical Sciences

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Examination Guidelines

DBE/2017

TABLE 3: THE PERIODIC TABLE OF ELEMENTS

1 (I)	2 (II)	3	4	5	6	7	8	9	10	11	12	13 (III)	14 (IV)	15 (V)	16 (VI)	17 (VII)	18 (VIII)
1 2,1 H 1																	2 He 4
3 1,0 Li 7	4 1,5 Be 9											5 2,0 B 11	6 2,5 C 12	7 3,0 N 14	8 3,5 O 16	9 4,0 F 19	10 20 Ne
11 0,9 Na 23	12 1,2 Mg 24											13 1,5 Al 27	14 1,8 Si 28	15 2,1 P 31	16 2,5 S 32	17 3,0 Cl 35,5	18 40 Ar
19 0,8 K 39	20 1,0 Ca 40	21 1,3 Sc 45	22 1,5 Ti 48	23 1,6 V 51	24 1,6 Cr 52	25 1,5 Mn 55	26 1,8 Fe 56	27 1,8 Co 59	28 1,8 Ni 59	29 1,9 Cu 63,5	30 1,6 Zn 65	31 1,6 Ga 70	32 1,8 Ge 73	33 2,0 As 75	34 2,4 Se 79	35 2,8 Br 80	36 84 Kr
37 0,8 Rb 86	38 1,0 Sr 88	39 1,2 Y 89	40 1,4 Zr 91	41 Nb 92	42 1,8 Mo 96	43 1,9 Tc	44 2,2 Ru 101	45 2,2 Rh 103	46 2,2 Pd 106	47 1,9 Ag 108	48 1,7 Cd 112	49 1,7 In 115	50 1,8 Sn 119	51 1,9 Sb 122	52 2,1 Te 128	53 2,5 I 127	54 131 Xe
55 0,7 Cs 133	56 0,9 Ba 137	57 La 139	72 1,6 Hf 179	73 Ta 181	74 W 184	75 Re 186	76 Os 190	77 Ir 192	78 Pt 195	79 Au 197	80 Hg 201	81 1,8 Tl 204	82 1,8 Pb 207	83 1,9 Bi 209	84 2,0 Po	85 2,5 At	86 Rn
87 0,7 Fr	88 0,9 Ra 226	89 Ac															
58 Ce 140	59 Pr 141	60 Nd 144	61 Pm	62 Sm 150	63 Eu 152	64 Gd 157	65 Tb 159	66 Dy 163	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173	71 Lu 175				
90 Th 232	91 Pa	92 U 238	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr				

KEY/SLEUTEL

Atomic number
Atoomgetal

Electronegativity
Elektronegatiwiteit

Symbol
Simbool

Approximate relative atomic mass
Benaderde relatiewe atoommassa



Thank you



PHYSICAL SCIENCES GRADE 11

(CHEMICAL CHANGE)

LESSON 2

28 JUNE 2025

THE MOLE CONCEPT AND MOLE
RELATIONSHIPS

Quantitative Aspects of Chemical Change

Physical Sciences Grade 11 examinable materials

on ***Quantitative Aspects***

- Quantitative Aspects
- Stoichiometric Calculations
- Some More Stoichiometry
- Balancing Chemical Equations

Quantitative Aspects of Chemical Change

Quantitative aspects of chemical change

(This section must be read in conjunction with the CAPS, p. 50-52 & 82-83.)

The mole concept

- Describe the mole as the SI unit for amount of substance.
- Define one mole as the amount of substance having the same number of particles as there are atoms in 12 g carbon-12.
- Describe Avogadro's number, N_A , as the number of particles (atoms, molecules, formula-units) present in one mole ($N_A = 6,023 \times 10^{23} \text{ particles} \cdot \text{mol}^{-1}$).
- Define molar mass as the mass of one mole of a substance measured in $\text{g} \cdot \text{mol}^{-1}$.
- Calculate the molar mass of a substance given its formula.

Molar volume of gases

- State Avogadro's Law i.e. one mole of any gas occupies the same volume at the same temperature and pressure.
- At STP: 1 mole of any gas occupies $22,4 \text{ dm}^3$ at 0°C (273 K) and 1 atmosphere (101,3 kPa). Thus the molar gas volume, V_M , at STP = $22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$.

Volume relationships in gaseous reactions

- Interpret balanced equations in terms of volume relationships for gases, i.e. under the same conditions of temperature and pressure, equal amounts (in mole) of all gases occupy the same volume.

Quantitative Aspects of Chemical Change

Concentration of solutions

- Define concentration as the amount of solute per litre of solution.
- Calculate concentration in $\text{mol}\cdot\ell^{-1}$ (or $\text{mol}\cdot\text{dm}^{-3}$) using $c = \frac{n}{V}$.

More complex stoichiometric calculations

- Determine the empirical formula and molecular formula of compounds.
- Determine the percentage yield of a chemical reaction.
- Determine percentage purity or percentage composition, e.g. the percentage CaCO_3 in an impure sample of seashells.
- Perform stoichiometric calculations based on balanced equations that may include limiting reagents.

The mole concept

Definitions:

The amount of substance that contains as many particles as there are atoms of carbon in 12g of carbon

Avogadro's constants (N_A):

$$N_A = 6,023 \times 10^{23} \text{ mol}^{-1}$$

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

1 mol of matter contains $6,023 \times 10^{23}$ elementary particles.

CHEMICAL FORMULA OF SUBSTANCES	NATURE OF SUBSTANCES	Type of elementary particles	Number of elementary particle per mol.
He	Noble gas/Unreactive	atoms	$6,023 \times 10^{23}$
N_2	Covalent molecular substances	molecules	$6,023 \times 10^{23}$
$NaCl$	Ionic substances	Formula units	$6,023 \times 10^{23}$

Molecular atomic mass (A), molar molecular mass and molar formula mass (M)

	Description	Measured in:
Atomic mass (A)	Mass of one atom	atomic mass-unit (amu)
Molar mass	Mass of 1 mole of a substance	$\text{g}\cdot\text{mol}^{-1}$
Relative mass (M_r)		no unit

The Mole & Molar Mass

The **MOLE** (abbr: *mol*)

- is the *SI unit* for *amount of substance*.
- 1 mole is the amount of a substance that has the *same number of particles* (atoms, molecules, ions, etc.) as there are atoms in 12 g of carbon-12
- **Avogadro's number**: N_A - the number of particles present in one mole
- $N_A = 6,022 \times 10^{23} \text{ mol}^{-1}$
- **MOLAR MASS** (**M**): the mass (in g) of one mole of a substance measured in grams per mole ($\text{g} \cdot \text{mol}^{-1}$)
e.g.: the molar mass of NaHCO_3

$$M_r(\text{NaHCO}_3) = 23 + 1 + (3 \times 16) = 84$$

$$\text{therefore } \mathbf{M(\text{NaHCO}_3) = 84 \text{ g} \cdot \text{mol}^{-1}}$$

$$M_r(\text{AgNO}_3) = 108 + 14 + (3 \times 16) = 170$$

$$\text{therefore } \mathbf{M(\text{AgNO}_3) = 170 \text{ g} \cdot \text{mol}^{-1}}$$

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

Substance	Number of moles	Mass in gram	Particles	Number of particles
Carbon	1	12	Atoms	$6,02 \times 10^{23}$
Silver	1	108	Atoms	$6,02 \times 10^{23}$
Water	1	18	Molecules	$6,02 \times 10^{23}$
Sodium Chloride	1	58,50	Formula units.	$6,02 \times 10^{23}$

Examples:

What is the relative atomic mass of Mg (element)?

$$M_r(\text{Mg}) = 24$$

What is the molar atomic mass of Mg?

$$M(\text{Mg}) = 24 \text{ g}\cdot\text{mol}^{-1}$$

What is the relative molecular mass of H_2O (covalent molecule)?

$$M_r(\text{H}_2\text{O}) = (1 \times 2) + 16 = 18$$

What is molar molecular mass of H_2O ?

$$M(\text{H}_2\text{O}) = 18 \text{ g}\cdot\text{mol}^{-1}$$

What is the relative formula mass of NaCl (ionic compound)?

$$M(\text{NaCl}) = 23 + 35,5 = 58,5$$

What is the molar formula mass of NaCl ?

$$M(\text{NaCl}) = 58,5 \text{ g} \cdot \text{mol}^{-1}$$

What is the relative molecular mass of HCl (covalent molecule)?

$$M_r(\text{HCl}) = 1 + 35,5 = 36,5$$

What is the molecular formula mass of MgSO_4 (ionic compound)?

$$M(\text{MgSO}_4) = 24 + 32 + (16 \times 4) = 120 \text{ g} \cdot \text{mol}^{-1}$$

Relative atomic /molecular /formula mass, in grams, of any element will always contain 1 mole of that element's atoms'.

- 1 mol C = 12 g C = $6,02 \times 10^{23}$ C atoms
- 1 mol Na = 23 g Na = $6,02 \times 10^{23}$ Na atoms
- 1 mol NaCl = 58,5g = $6,02 \times 10^{23}$ formula units.
- 1 mol of O₂ = 32g = $6,02 \times 10^{23}$ molecules.
- 1 mol of NH₃ = 17g = $6,02 \times 10^{23}$ molecules

Substance	Number of moles	Mass in gram	Particles	Number of particles
Carbon	1	12	Atoms	$6,02 \times 10^{23}$
Silver	1	108	Atoms	$6,02 \times 10^{23}$
Water	1	18	Molecules	$6,02 \times 10^{23}$
Calcium	1	40	Atoms	$6,02 \times 10^{23}$

Exercise 1

1 Give the relative atomic mass of:

1. Mg

$$M_r(\text{Mg}) = 24$$

2 Al

$$M_r(\text{Al}) = 27$$

2 Calculate the relative formula mass of:

1. NaCl

$$M_r(\text{NaCl}) = 23 + 35,5 = 58,5$$

2.2 MgO

$$M_r(\text{MgO}) = (24) + (16) = 40$$

3 Calculate the molar mass of:

1. H₂O

$$M(\text{H}_2\text{O}) = (1 \times 2) + (16) = 18 \text{ g}\cdot\text{mol}^{-1}$$

3.2 HCl

$$M(\text{HCl}) = 1 + 35,5 = 36,5 \text{ g}\cdot\text{mol}^{-1}$$

4 Calculate the molar mass of:

1. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$

$$M(\text{CuSO}_4 \cdot 5\text{H}_2\text{O})$$

$$= 63,5 + 32 + (16 \times 4) + (1 \times 10) + (16 \times 5)$$

$$= 249,5 \text{ g}\cdot\text{mol}^{-1}$$



$$\begin{aligned} M(\text{MgCl}_2) &= 24 + (35,5 \times 2) \\ &= 95 \text{ g}\cdot\text{mol}^{-1} \end{aligned}$$



$$\begin{aligned} M(\text{NH}_4\text{NO}_3) &= 14 + (1 \times 4) + 14 + (16 \times 3) \\ &= 80 \text{ g}\cdot\text{mol}^{-1} \end{aligned}$$

4. Na_2SO_4
 $M(\text{Na}_2\text{SO}_4)$
 $= (23 \times 2) + 32 + (16 \times 4)$
 $= 142 \text{ g}\cdot\text{mol}^{-1}$

5. $\text{Ca}(\text{OH})_2$
 $M \text{ Ca}(\text{OH})_2 = 40 + (16 \times 2) + (1 \times 2)$
 $= 74 \text{ g}\cdot\text{mol}^{-1}$

4.6 Al_2O_3

$$\begin{aligned} M(\text{Al}_2\text{O}_3) &= (27 \times 2) + (16 \times 3) \\ &= 102 \text{ g}\cdot\text{mol}^{-1} \end{aligned}$$

5 How many particles do the following contain:

- 1. 2 mol Na (atoms)?**
 $\therefore 2(6,02 \times 10^{23})$
 $= 12,04 \times 10^{23}$ atoms
 $= 1,204 \times 10^{24}$ atoms

5.2 36 g water (atoms)?

$$36 \text{ g H}_2\text{O} = 2 \text{ mol H}_2\text{O}$$

$$\therefore 2(6,02 \times 10^{23})$$

$$= 1,204 \times 10^{24} \text{ molecule}$$

$$= 3 \times 1,204 \times 10^{24}$$

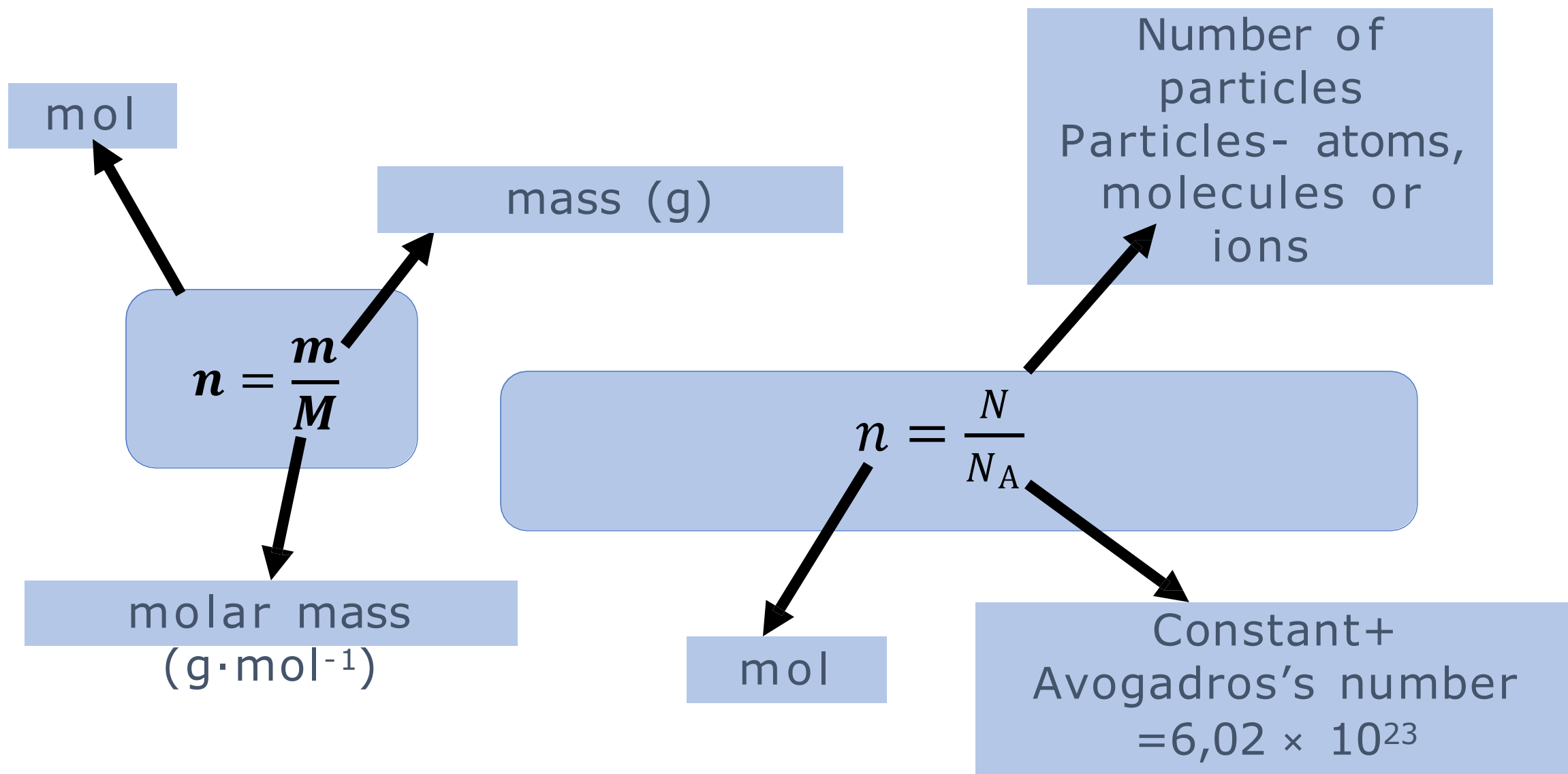
$$\therefore 3,612 \times 10^{24} \text{ atoms}$$

3. 3 mol NaCl has how many ions?
 $\therefore 3(6,02 \times 10^{23})$ formula units
 $= 1,806 \times 10^{24}$ formula units $\times 2$
 $\therefore 3,612 \times 10^{24}$ ions
4. 80 g calcium has how many atoms?
 $80 \text{ g Ca} = 2 \text{ mol Ca}$
 $\therefore 2(6,02 \times 10^{23})$
 $= 1,204 \times 10^{24}$ atoms Ca

Which of the following represents a mole?

- A 18,02 g of water
- B 22,4 g of nitrogen gas at STP
- C 22,4 dm³ of water at STP
- D 3,2 g of oxygen gas

The relationship between moles, mass and molar mass



Examples:

1. Calculate the number of moles of atoms in 96 g of sulphur.

$$A_r(\text{S}) = 32$$

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

$$= \frac{96}{32}$$

$$= 3$$

$$= 3 \text{ mol sulphur atoms}$$

2. Calculate the mass of 0,5 mol of H_2SO_4 .

$$M(\text{H}_2\text{SO}_4) = 2(1) + 32 + 4(16) = 98 \text{ g}\cdot\text{mol}^{-1}$$

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

$$\begin{aligned} 0,5 &= \frac{m}{98} \\ &= 49 \text{ g} \end{aligned}$$

3. The mass of 2 mol of an ionic substance is 80 g. Calculate the formula mass of the substance.

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

$$2 = \frac{80}{M}$$

$$M = 40 \text{ g} \cdot \text{mol}^{-1}$$

Can you identify the ionic substance?

4 Determine the number of molecules in 245 g of iodine (I_2).

$$n = \frac{m}{M} = \frac{245}{2(127)} = 0,96457 \text{ mol } I_2$$

$$\begin{aligned} 0,96457 \text{ mol } I_2 &= 0,96457 \times 6,02 \times 10^{23} \\ &= 5,8067 \times 10^{23} \text{ molecules of } I_2 \end{aligned}$$

4.2 Determine the number of atoms in 245 g of iodine (I_2).

$$\begin{aligned} 1 \text{ mol } I_2 &= 1 \text{ mol molecules} = 2 \text{ mol atoms} \\ &= 2 \times 6,02 \times 10^{23} \\ &= 1,2 \times 10^{24} \text{ atoms} \end{aligned}$$

4.3 Determine the number of ions in solution when 117 g of $NaCl(s)$ dissolves in water.



$$n_{NaCl} = \frac{m}{M} = \frac{117}{58,5} = 2 \text{ mol}$$

$$1 \text{ mol} \rightarrow 1 \text{ mol} + 1 \text{ mol}$$

$\therefore 1 \text{ mol } NaCl$ **2 mol ions** in $NaCl$

$$\therefore 2 \times 6,02 \times 10^{23} = 1,2 \times 10^{24} \text{ ions}$$

4.4 How many atoms are there in 4 mol of Mg?

number of atoms

$$n = \frac{N_A}{\text{number of atoms}}$$

$$\begin{aligned} 4 &= \frac{6,02 \times 10^{22}}{\text{number of atoms}} \\ &= 24,08 \times 10^{23} \end{aligned}$$

1 Calculate the number of moles of atoms in:

1.1 120 g Ca.

$$A(\text{Ca}) = \underline{40} \text{ g}\cdot\text{mol}^{-1}$$

m

$$n = \frac{M}{120}$$

$$= 40$$

1.2 128 g O₂.

M(O₂)

$$= 2(16) = 32 \text{ g}\cdot\text{mol}^{-1}$$

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

$$= \frac{128}{32}$$

$$= 4 \text{ mol O}_2 \text{ molecules}$$

∴ 8 mol O atoms

2 Calculate the mass of:

2.1 4 mol HCl

$$\mathbf{M(HCl) = 1 + 35,5 = 36,5 \text{ g} \cdot \text{mol}^{-1}}$$

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

$$\mathbf{4 = \frac{m}{36,5}}$$

$$\mathbf{m = 146 \text{ g}}$$

2.2 0,6 mol MgO.

$$M(\text{MgO}) = 24 + 16 = 40 \text{ g}\cdot\text{mol}^{-1}$$

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

$$0,6 = \frac{m}{40}$$

$$m = 24 \text{ g}$$

- 3 Calculate the molar mass of a substance if:
1. the mass of 4 mol of an ionic substance is 234 g.

$$n = \frac{m}{M}$$
$$4 = \frac{234}{M}$$

$$M = \frac{234}{4}$$

$$M = 58,5 \text{ g} \cdot \text{mol}^{-1}$$

3.2 the mass of 0,5 mol of a covalent substance is 49 g.

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

$$0,5 = \frac{49}{M}$$

$$M = 98 \text{ g}\cdot\text{mol}^{-1}$$

4. Calculate the number of particles in:

4.1. 2,3 mol NaCl (formula units).

$$n = \frac{\text{number of particles}}{N_A}$$

number of particles

$$2,3 = 6,02 \times 10^{23}$$

$$\text{number of particles} = (2,3)(6,02 \times 10^{23})$$

$$= 1,39 \times 10^{24} \text{ formula units}$$

4.2 2,6 g SO₂ (molecules).

$$\begin{aligned} M(\text{SO}_2) &= 32 + (16 \times 2) \\ &= 64 \text{ g} \cdot \text{mol}^{-1} \end{aligned}$$

$$\begin{aligned} n &= \frac{m}{M} \\ &= \frac{2,6}{64} \\ &= 0,04 \text{ mol} \end{aligned}$$

$$\begin{aligned} n &= \frac{\text{number of particles}}{N_A} \\ 0,04 &= \frac{\text{number of particles}}{6,02 \times 10^{23}} \end{aligned}$$

$$\begin{aligned} \text{number of particles} &= 0,04 (6,02 \times 10^{23}) \\ &= 2,45 \times 10^{22} \text{ molecules} \end{aligned}$$

5 Calculate the number of cations and anions in:

5.1 60 g calcium nitrate.

$$M(\text{Ca}(\text{NO}_3)_2) = 40 + 2(14 + (16 \times 3)) = 164 \text{ g} \cdot \text{mol}^{-1}$$

$$\begin{aligned} n &= \frac{m}{M} \\ &= \frac{60}{164} \\ &= 0,37 \text{ mol} \end{aligned}$$

$$\text{number of formula units} = n \cdot N_A$$

$$\begin{aligned} &= (0,37)(6,02 \times 10^{23}) \\ &= 2,23 \times 10^{23} \end{aligned}$$

$$\begin{aligned} \therefore \text{amount of } \text{Ca}^{2+} &= 1(2,23 \times 10^{23}) \\ &= 2,23 \times 10^{23} \text{ and} \end{aligned}$$

$$\begin{aligned} \text{amount of } \text{NO}_3^- &= 2(2,23 \times 10^{23}) \\ &= 4,46 \times 10^{23} \end{aligned}$$

5.2 20 g ammonium sulphate.

$$M((\text{NH}_4)_2\text{SO}_4) = 2(14) + 8(1) + 32 + 4(16) = 132 \text{ g}\cdot\text{mol}^{-1}$$

$$\begin{aligned} n &= \frac{m}{M} \\ &= \frac{20}{132} \\ &= 0,15 \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{number of formula units} &= n \cdot N_A \\ &= (0,15)(6,02 \times 10^{23}) \\ &= 9,12 \times 10^{22} \end{aligned}$$

$$\begin{aligned} \therefore \text{amount of } \text{Ca}^{2+} &= 2(9,12 \times 10^{22}) \\ &= 1,82 \times 10^{23} \text{ and} \end{aligned}$$

$$\text{amount of } \text{NO}_3^- = 1(9,12 \times 10^{22}) = 9,12 \times 10^{22}$$

THE REALTIONSHIP BETWEEN MOLES AND VOLUME OF GAS

- According Avogadro's Law, i.e. one mole of any gas occupies the same volume at the same temperature and pressure.
- For example at Standard Temperature and Pressure (STP) 1 mole of any gas occupies 22,4 dm³
- Standard Temperature is = 0 °C (273 K)
- Standard Pressure is = 1 atmosphere (101,3 kPa).
- The the molar gas volume, V_m , at STP = 22,4 dm³·mol⁻¹
- The relationship between volume of gas and number of moles of gas is a s follows

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

THE REALTIONSHIP BETWEEN MOLES ,CONCENTRATION AND VOLUME OF SOLUTION

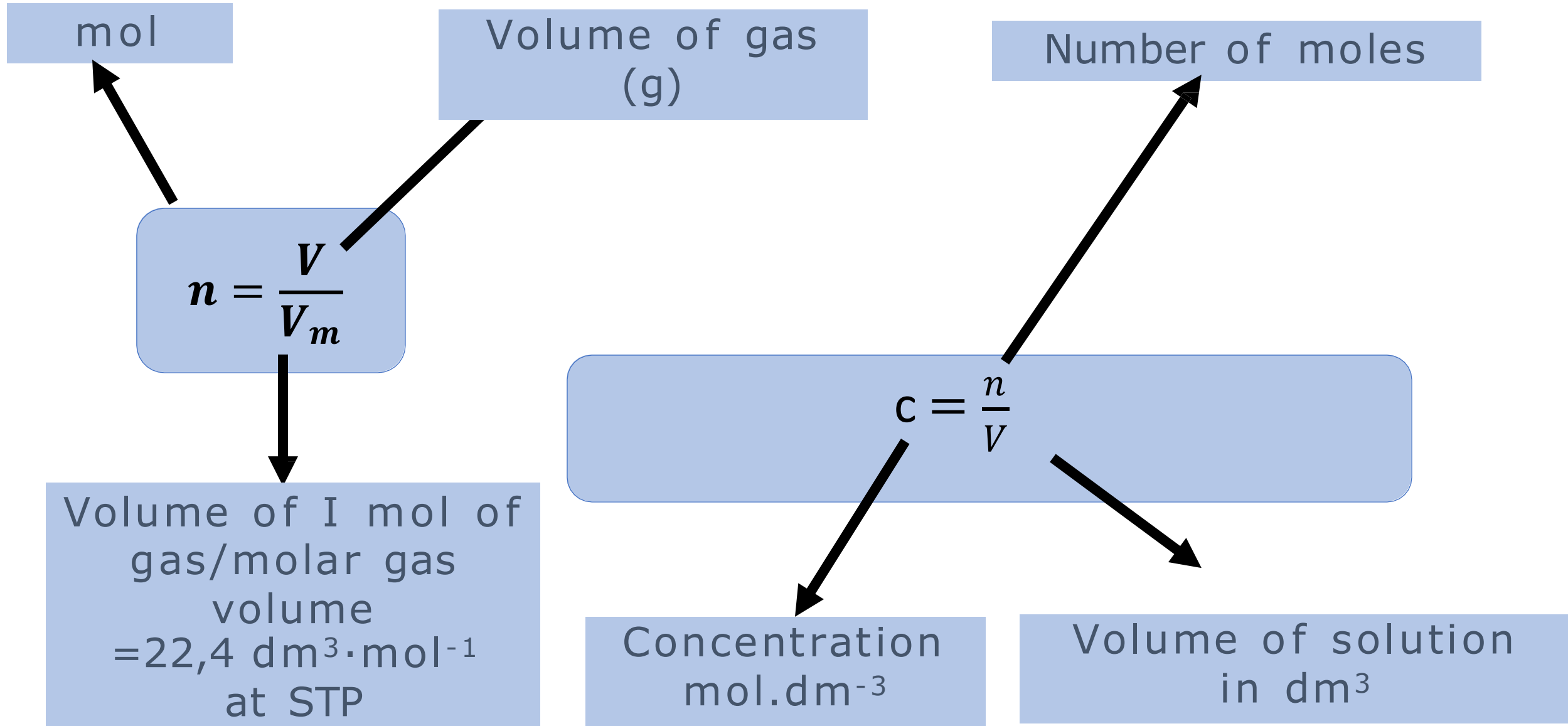
- Define concentration as the number of moles of solute per cubic decimetre of solution.
- It is calculated using : $c = \frac{n}{v}$
- The unit of concentration is mol.dm⁻³ using

$$c = \frac{n}{v}$$

Concentration of solutions

- Define concentration as the amount of solute per litre of solution.
- Calculate concentration in $\text{mol}\cdot\text{l}^{-1}$ (or $\text{mol}\cdot\text{dm}^{-3}$) using $c = \frac{n}{V}$.

The relationship between moles, volume of gas and concentration



ACTIVITY : Mass, concentration and volume of solution

1. The concentration of sodium chloride is $0,5\text{mol.dm}^{-3}$

Calculate the number of moles of solute dissolved in :

1. 2dm^3 of the solution.
2. 20cm^3 of the solution.

2. Calculate the concentration in (mol.dm^{-3}) of each of the following aqueous solutions:

1. $3,65\text{g}$ of HCl in 1dm^3 of solution
2. 98g of sulphuric acid in 1000cm^3 .
3. $249,5\text{g}$ of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in 250cm^3
- 2.4. $0,04\text{kg}$ of NaOH in 1 dm^3 of solution

3. Calculate in each case the mass (in g) of solute needed to prepare the following solutions :

1. 200cm^3 of a $0,1\text{mol.dm}^{-3}$ NaCl solution.
- 3.2. 100cm^3 in $0,5\text{mol.dm}^{-3}$ of KOH solution.
- 3.3 1dm^3 of a $0,01\text{mol.dm}^{-3}$ of oxalic acid[$(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$ solution.

ACTIVITY : MOLES AND VOLUME OF GAS

1. Calculate the number of moles of gas in

1. 44,8 dm³ of oxygen gas at STP
2. 11,2 dm³ of nitrogen gas at STP
3. 800cm³ of argon at STP

ACTIVITY MOLES, CONCENTRATION AND VOLUME OF GAS

6.2 Learners prepare a solution of sodium hydroxide (NaOH) in water by placing 8 g of sodium hydroxide (NaOH) in a volumetric flask and adding water to produce 250 cm³ of solution after stirring.

6.2.1 Define *concentration* in words. (2)

6.2.2 Calculate the concentration of the sodium hydroxide (NaOH) solution. (4)

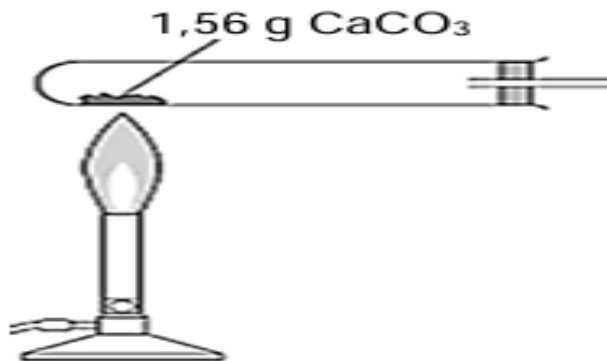
6.3 Sodium azide (NaN₃) is used in car airbags. For the airbag to inflate the following reaction must take place:



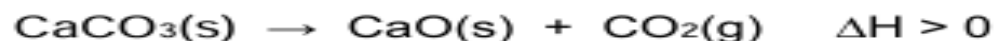
Calculate the volume of nitrogen gas (N₂) that would be produced at STP if 55 g of sodium azide reacts completely. (5)

ACTIVITY MOLES, CONCENTRATION AND VOLUME OF GAS

5.1 1,56 g of calcium carbonate is heated as shown in diagram below.



The calcium carbonate decomposes according to the balanced equation:



0,163 g of CO₂ is produced during this decomposition.

5.1.1 Is this reaction ENDOTHERMIC or EXOTHERMIC? (1)

5.1.2 Give a reason for your answer in QUESTION 5.1.1. (2)

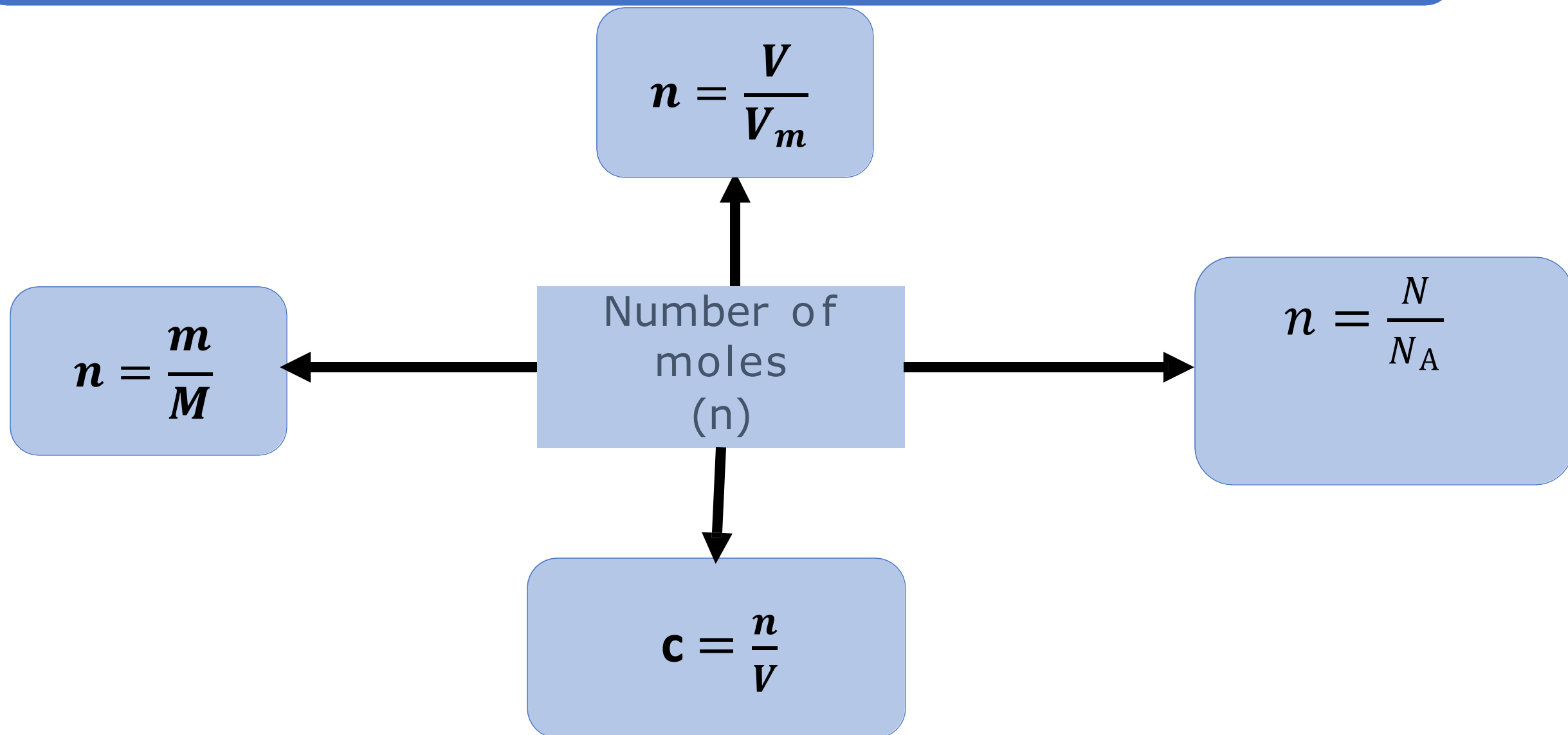
5.1.3 Describe *Avogadro's number*. (1)

5.1.4 Calculate the:

(a) Number of CO₂ molecules produced (4)

(b) Mass of CaCO₃ that remains unreacted in the flask at the completion of the reaction (5)

FORMULAE FOR CALCULATIONS BASED ON NUMBER OF MOLES



Concluding Remarks

Following our today lesson, I want you to do the following:

Read through what the learner **need to understand and master** in your learner material.

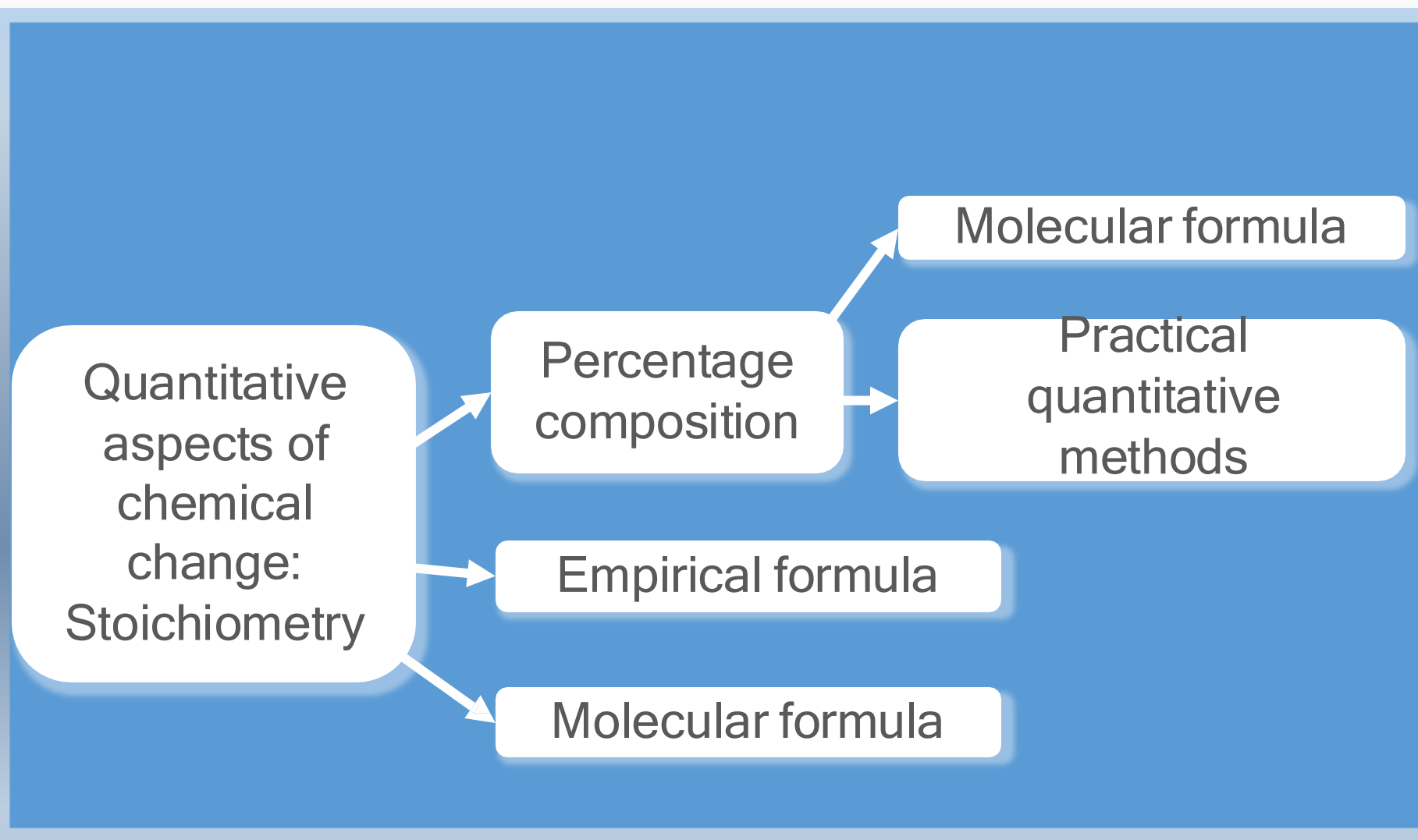
Complete all prescribed activities/exercises

Work through as many of the associated exercises as possible on your own from the **Text-Book and the Past Exam Papers**.

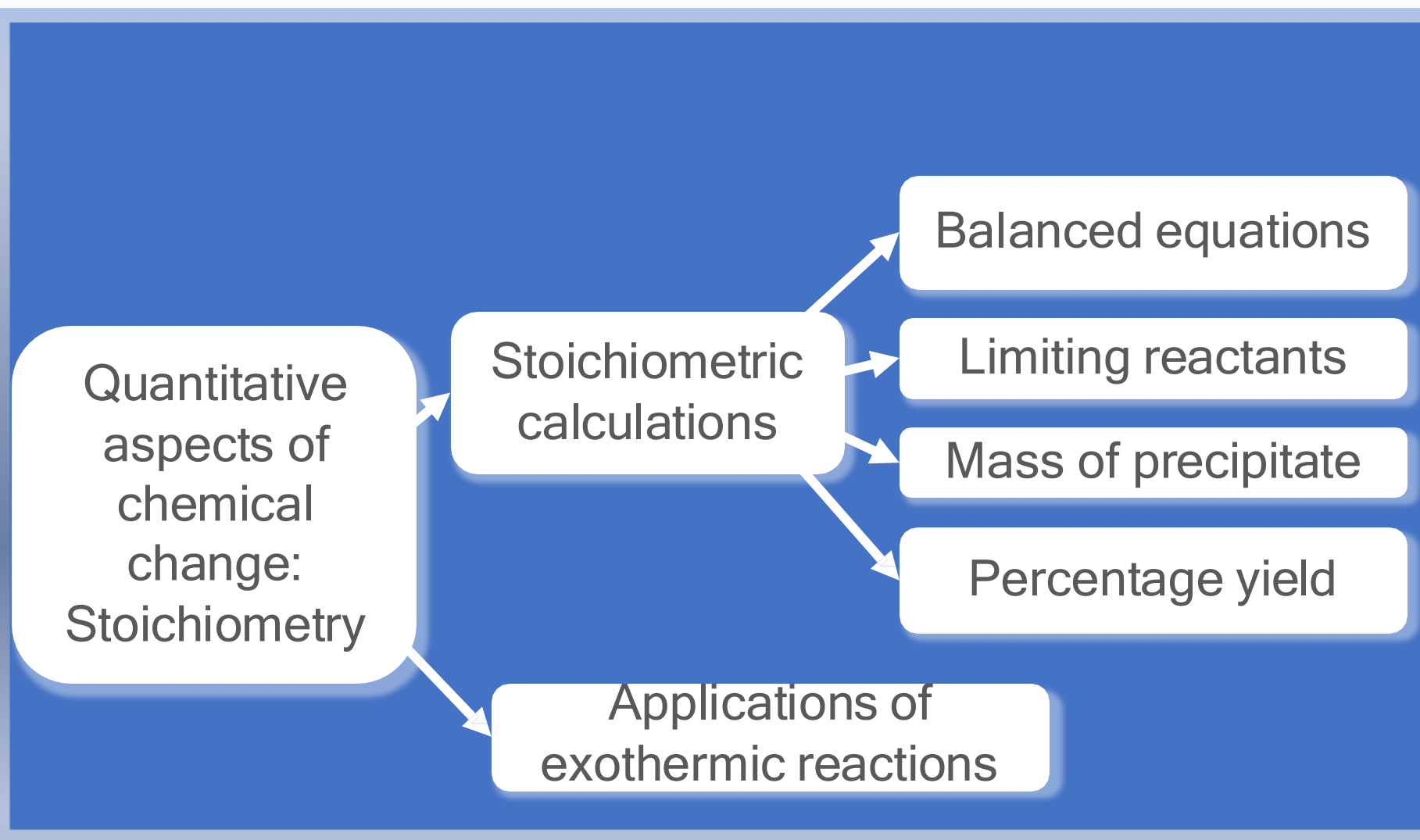
Repeat this procedure until you are **confident**.

Do not forget: **Practice makes perfect!**

Quantitative aspects of chemical change: stoichiometry



Quantitative aspects of chemical change: stoichiometry





PHYSICAL SCIENCES GRADE 11

(CHEMICAL CHANGE)

LESSON 3

30 JUNE 2025

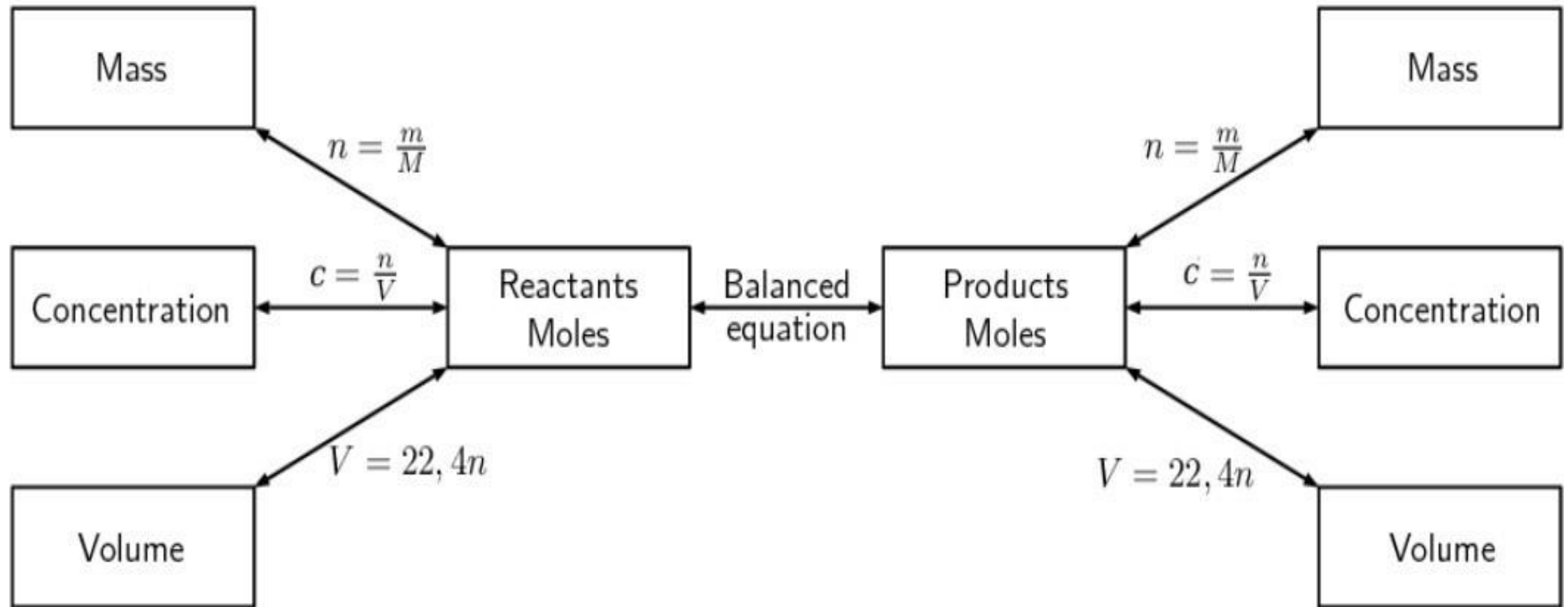
LIMITING REAGENT
PERCENTAGE YIELD
PERCENTAGE PURITY

STOICHIOMETRIC FLOW DIAGRAM

More complex stoichiometric calculations

- Determine the empirical formula and molecular formula of compounds.
- Determine the percentage yield of a chemical reaction.
- Determine percentage purity or percentage composition, e.g. the percentage CaCO_3 in an impure sample of seashells.
- Perform stoichiometric calculations based on balanced equations that may include limiting reagents.

STOICHIOMETRIC FLOW DIAGRAM



LIMITING REAGENT

The limiting reagent is the reactant that is used up(finished /exhausted) first during a chemical reactions.

What does it LIMIT?

It limits

- 1.The final amount of product(yield)*
- 2.Extent of reaction.*

CONSIDER THE SANDWICH ANALOGY

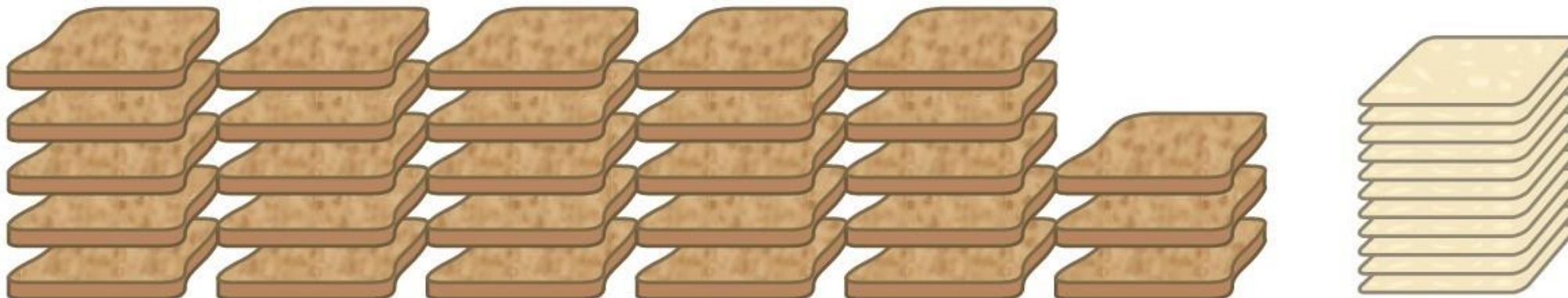
1 sandwich = 2 slices of bread + 1 slice of cheese



NOTE : CHEESE WAS FINISHED FIRST-IT LIMITED THE MAXIMUM NUMBER OF SANDWICHES THAT COULD BE MADE IT IS THE "LIMITING REACTANT" . SOME SLICES OF BREAD ARE LEFT UNUSED.BREAD IS IN EXCESS

Provided with:

28 slices of bread



We can make:

11 sandwiches

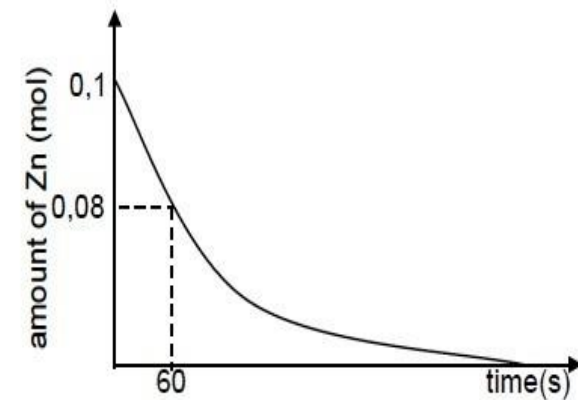
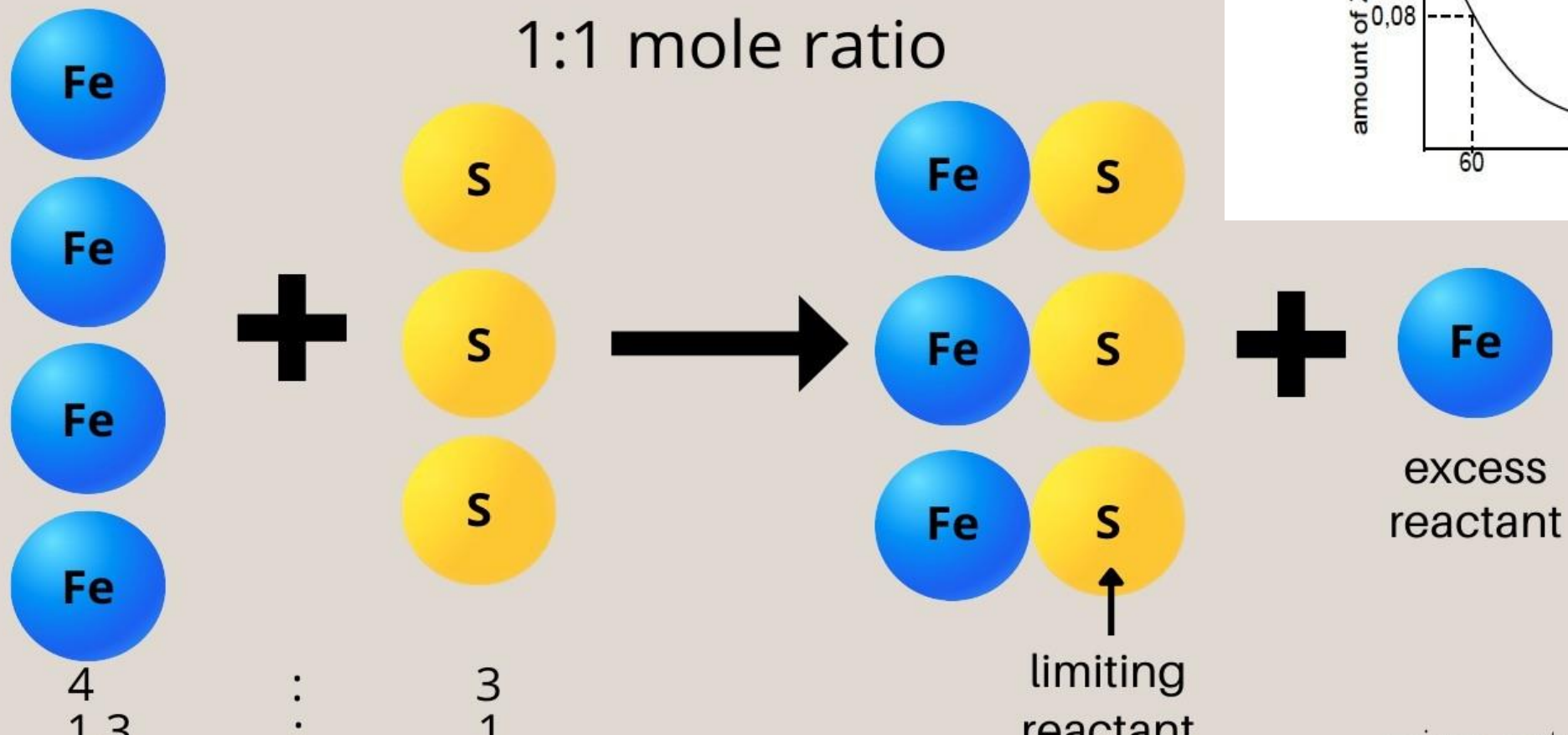
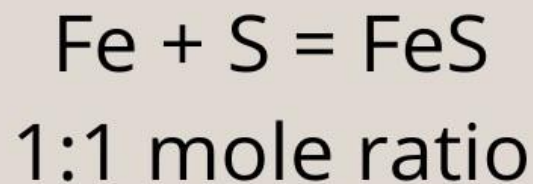
+ 6 slices bread left over



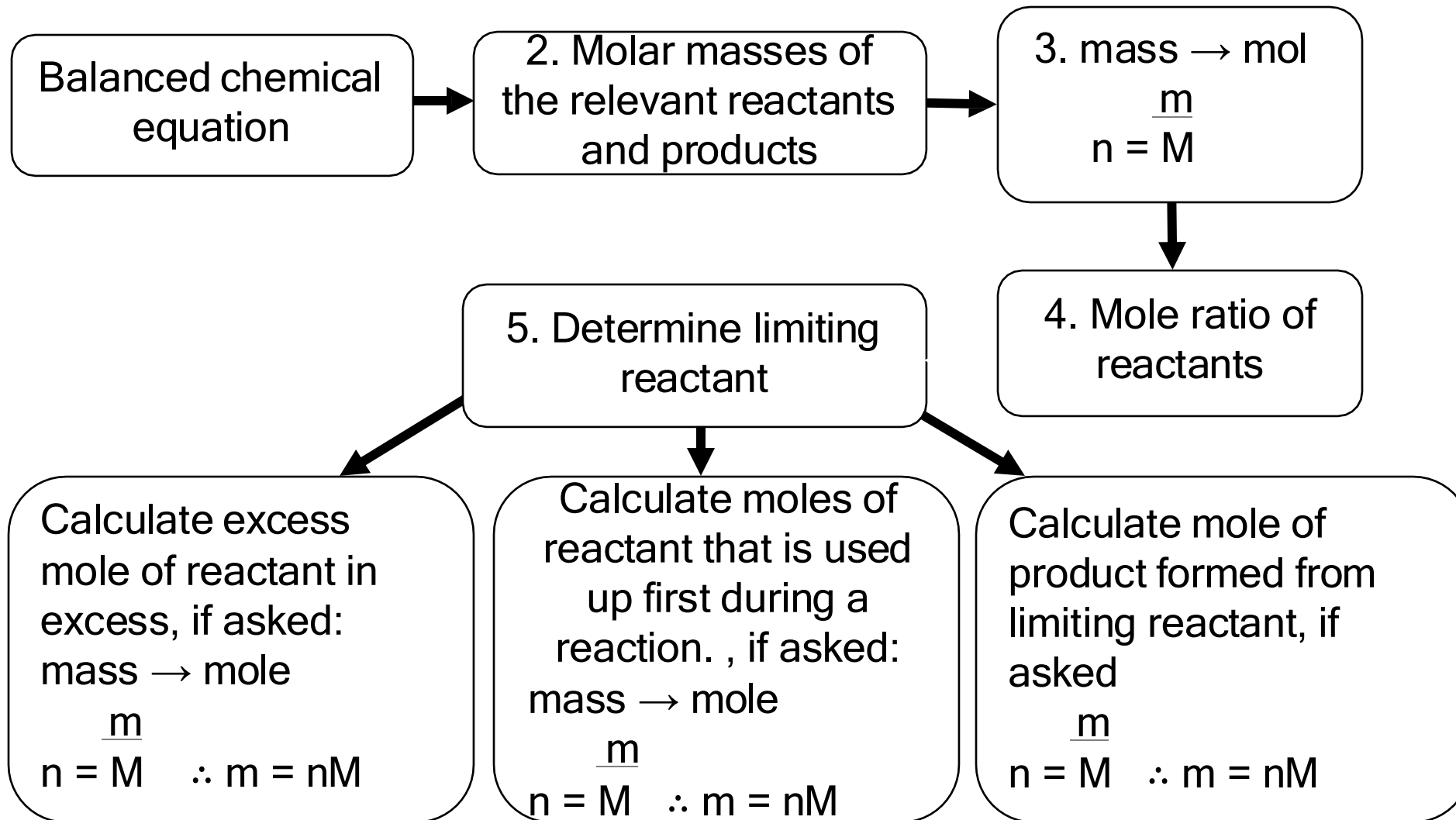
Limiting Reactant

The limiting reactant is the reactant that is completely consumed in a chemical reaction.

Find it using the mole ratio in the balanced chemical equation



Procedure on Determining Limiting Reagent



ACTIVITY :Limiting Reagent

1. Consider the following balanced equation :

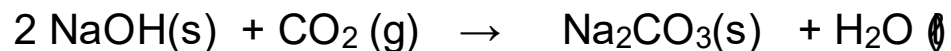


A mixture of 1,5 mol of Al and 3 mol of Cl_2 is allowed to react with each other.

Determine the:

1. limiting reagent.
2. mass of $\text{AlCl}_3(\text{s})$ formed
- 1.3. number of moles of the EXCESS reagent that remain unused. (3

2.Sodium hydroxide reacts with carbon dioxide as follows :



1.85 mol of NaOH and 1mol CO_2 are allowed to react.

Determine :

1. the reagent in excess
2. the mass of the EXCESS reagent that remained unused.
- 2.3. the mass of Na_2CO_3 FORMED.

Consider the following balanced equation ;



60g NH_4NO_3 is allowed to react with 100g of Na_3PO_4

ACTIVITY :Empirical Formula.

3.Consider the following balanced equation ;

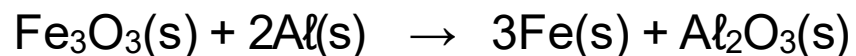


60g NH_4NO_3 is allowed to react with 100g of Na_3PO_4

Determine the :

1. limiting reagent.
2. mass of $(\text{NH}_4)_3\text{PO}_4$ produced .
3. mass of NaNO_3 produced.
4. the mass of the EXCESS reactant that remains unused.

4.The thermal reaction involves the preparation of iron metal from a mixture of aluminium powder and iron (III) oxide. A mixture of 50g iron (III) oxide and 50g aluminium is used. The chemical equation for the reaction is as follows :

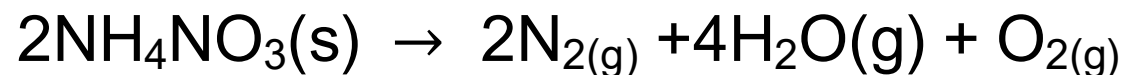


Determine

- 4.1 the limiting reagent..
- 4.2 the mass of iron formed.
- 4.3 mass of the EXCESS reagent that remains unused.

ACTIVITY :VOLUME OF GAS MOLE RELATIONSHIP.

1. Ammonium nitrate undergoes thermal decomposition to only produce gas

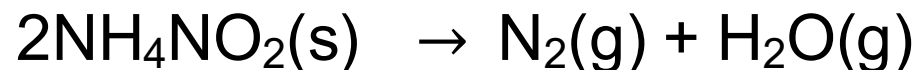


1. Calculate the total volume (in dm^3) of gas that is produced by the decomposition of 70g of ammonium nitrate at STP.

2. temperature of 400K and a pressure of 150kpa

3. temperature of 100°C and a pressure of 2atmospheres.

2. Ammonium nitrite (NH_4NO_2) decomposes during heating to deliver nitrogen gas and water vapour .



Calculate the volume of nitrogen gas produced during decomposition of 128g of ammonium nitrate at 819K and a pressure of 1atm.

3. Since the introduction of air bags in the 1980s, many lives have been saved in car accidents. Most modern cars are fitted with airbags for the driver and the front passenger. It takes approximately 30-40-milliseconds for an airbag to inflate while a typical accident lasts approximately 0,125s.

1. During an accident, an electrical signal is sent to a sodium azide capsule (found inside airbag) which decomposes rapidly to form a large quantity of nitrogen gas according to the equation below



Assume the temperature of nitrogen remains constant during the collision.

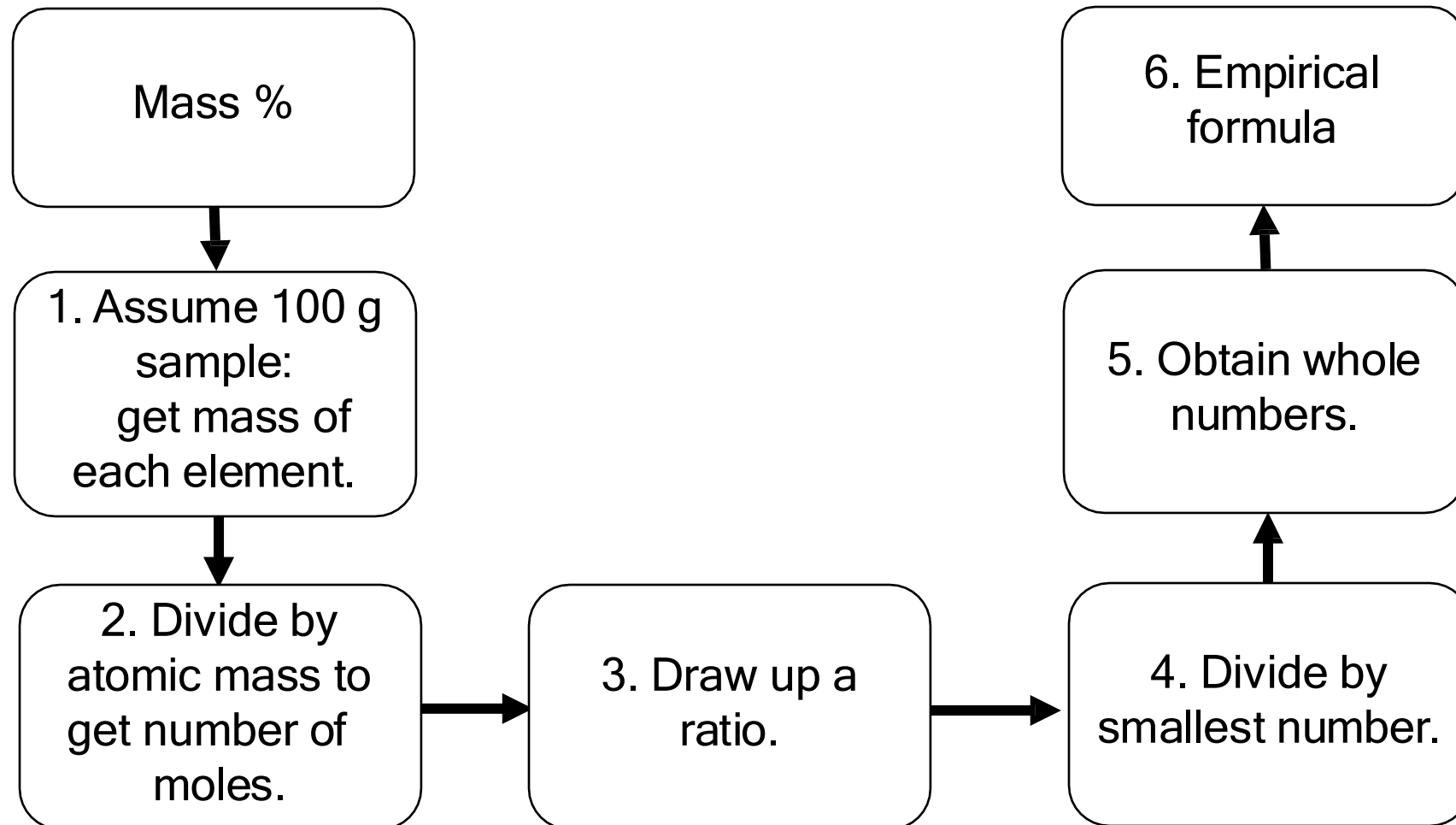
Calculate :

1. the mass of $\text{N}_2(\text{g})$ that will be needed to inflate an airbag to a volume of 70dm^3 and 10,5kPa and 25°C .
2. the mass of NaN_3 required to produce this mass of nitrogen.

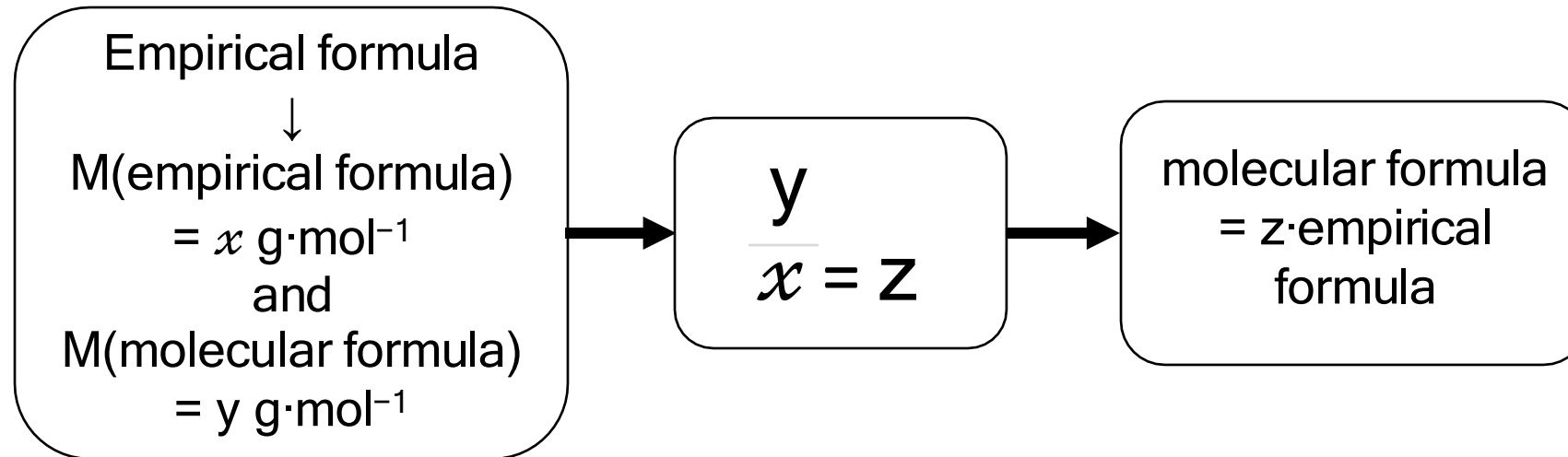
3.2 In **another** airbag 300g of NaN_3 decomposes at 85°C and 108,25kPa .

Calculate the volume of nitrogen gas that will be formed

Procedure to determine the Empirical Formula.

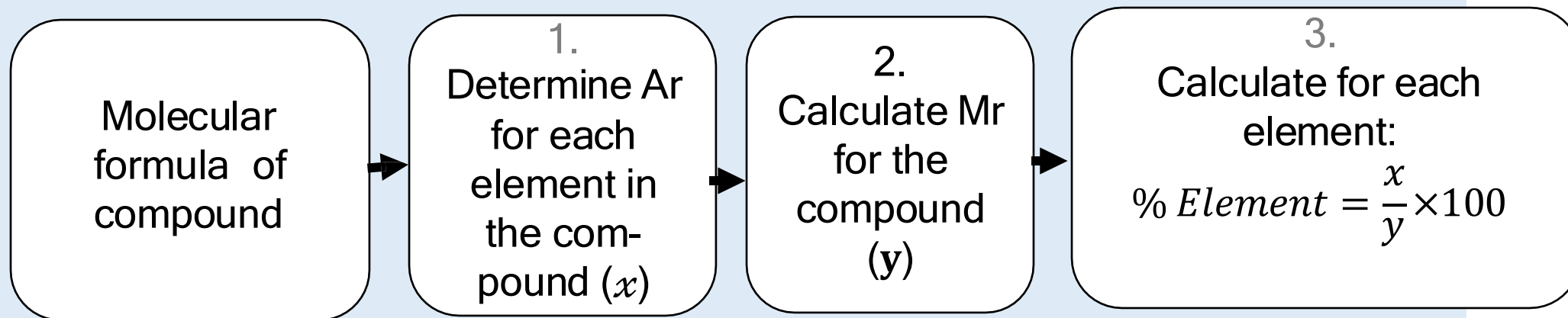


Molecular formula



Calculated from the molecular formula

Procedure to follow to determine the percentage composition of a compound:



ACTIVITY :EMPIRICAL FORMULA.

1. Write down the empirical formula of :

1. C_3H_8

2. C_5H_{10}

3. $C_2H_4O_2$

2. Determine the empirical formula in each of the following cases :

1. .Caffeine is a stimulant found in coffee and many beverages.

Caffeine is composed of 49.5% C; 5,2% H;28,8% N and 16,6% O.

2. Nitrogen and oxygen form a series of oxides with the general formula N_xO_y .One of the oxides ,a blue solid contains 36,8% N

3. A hydrocarbon is a compound that consists of carbon and hydrogen only.20g of the hydrocarbon combusts(burns in oxygen) to produce 67,69g CO and 3,85g of H_2O .

ACTIVITY :EMPIRICAL FORMULA & MOLECULAR FORMUAL.

3. Determine the molecular formula in each of the following cases :

1. Vinegar ,which we use in our homes, is a diluted form of ethanoic acid.

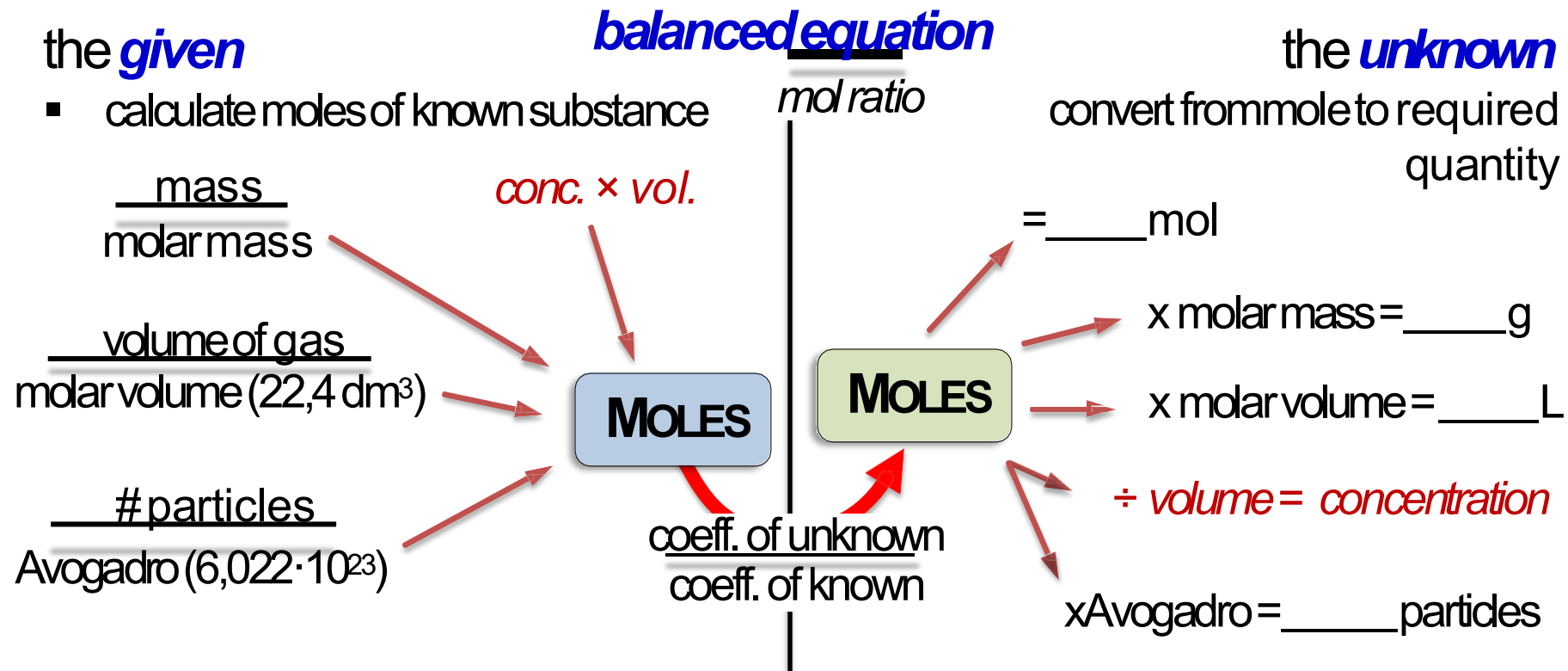
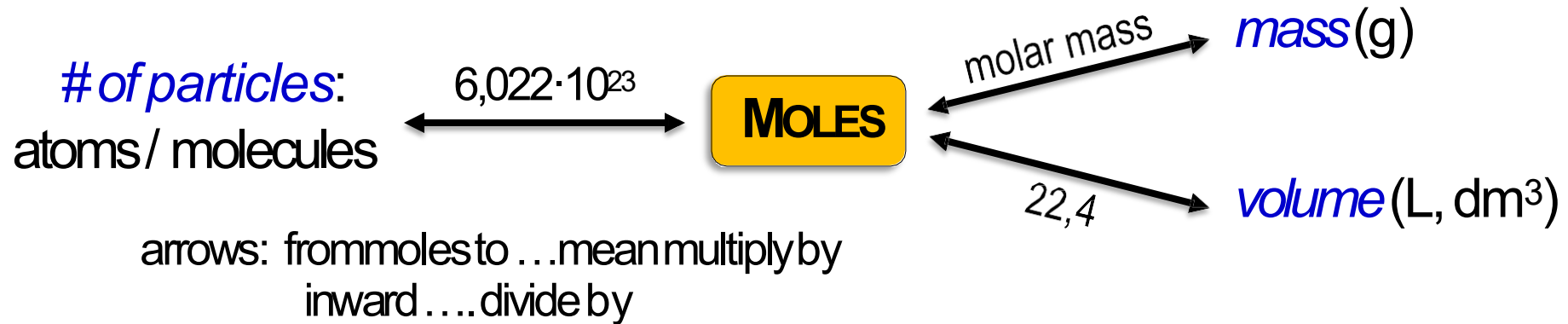
A sample of ethanoic acid has the following composition :

39,9% carbon;6,7% hydrogen and 53,4% oxygen . The molar mass of ethanoic acid s $60\text{g}\cdot\text{mol}^{-1}$

2. Nicotine is a toxic compound found in tobacco leaves, containing 74,0% carbon;8,65% hydrogen and 17,35% nitrogen. The molar mass of nicotine is $162\text{g}\cdot\text{mol}^{-1}$

3. Aspirin is known by the chemical name acetylsalicylic acid. Aspirin consists of 58,065 % carbon ad 7,527% hydrogen and oxygen. The molar mass of of aspirin is $186\text{g}\cdot\text{mol}^{-1}$.

'Roadmaps'



Percent Yield

Chemists distinguish between

- the amount of product a chemical reaction should yield based on a balanced chemical equation (the **theoretical yield**)
- and the amount that is physically produced (the **actual yield**) which is often less.

The **PERCENT YIELD** is calculated using the formula ...

$$\text{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

For example: In a certain reaction, 49,32 g of NaCl are expected to be formed. When actually weighed in a sensitive mass balance, it turns out only 47,23 g of NaCl are formed.

The percent yield is $\frac{47,23}{49,32} \times 100 = 95,76\%$

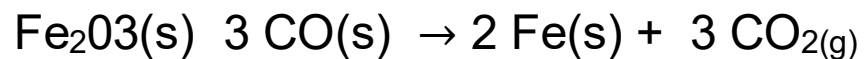
ACTIVITY : PERCENTAGE YIELD

1. Methanol , CH_3OH , can combust in oxygen to deliver energy. Otherwise it can decompose to form hydrogen gas that can be used as a fuel. 13.6g of hydrogen gas forms during decomposition of 125g methanol. Determine the percentage yield of the hydrogen gas. The decomposition of Methanol is as follows :



1. Determine the number of moles of methanol.
2. Calculate the theoretical number of moles that can be formed.
3. The theoretical yield (mass) of hydrogen that can be formed.
4. Determine the percentage yield of hydrogen.

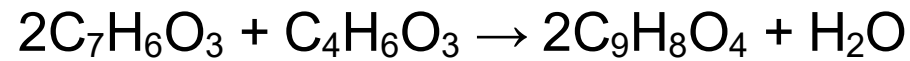
2. In an investigation to improve the process from which iron is obtained from Fe_2O_3 . In your investigation you carry out the following reaction.



150g Fe_2O_3 is reacted.

1. Determine the percentage yield if 87,9g of Fe was formed.

3. The chemical reaction for the production of the drug, aspirin, from two compounds, X and Y, is represented by the balanced equation below.



X Y

A chemist reacts 14 g of compound X with 10 g of compound Y.

1. Define the term limiting reactant in a chemical reaction.
2. Perform the necessary calculations to determine which one of compound X or compound Y is the limiting reactant.

The actual mass of aspirin obtained is 11,5 g.

3.3 Calculate the percentage yield of the aspirin.

Percentage Purity

Many chemical compounds contain impurities. To determine the percent purity of a compound, we use the following formula ...

$$\% \text{ purity} = \frac{\text{mass of compound}}{\text{mass of sample}} \times 100$$

Percent Purity Problem 1

You've been given a bag filled with 45,3 g of sea shells, made mostly of calcium carbonate (CaCO_3). Upon processing them, you can filter out 19,2 g of impurities.

What is the percent purity of these seashells?

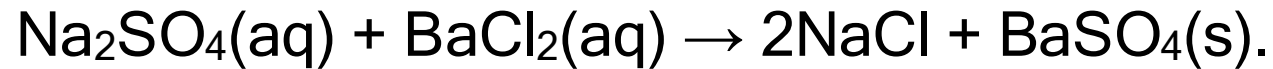
$$\begin{aligned} \text{mass of CaCO}_3 &= \text{mass of seashells} - \text{mass of impurities} \\ &= 45,3 - 19,2 = 26,1 \text{ g.} \end{aligned}$$

$$\% \text{ purity} = \frac{\text{mass of compound}}{\text{mass of sample}} \times 100$$

$$\begin{aligned} &= \frac{26,1}{45,3} \times 100 \\ &= 57,62 \% \end{aligned}$$

Percent Purity Problem 2

An impure sample of Na_2SO_4 has a mass of 1,56 g. The sample is dissolved and allowed to react with BaCl_2 solution.



The precipitate, BaSO_4 , has a mass of 2,15 g.

Calculate the percent purity of the sample.

$$M(\text{BaSO}_4) = 233 \text{ g}\cdot\text{mol}^{-1},$$

$$M(\text{Na}_2\text{SO}_4) = 142 \text{ g}\cdot\text{mol}^{-1}$$

$$n(\text{BaSO}_4) = m/M$$

$$= 2,15 / 233$$

$$= 9,228 \cdot 10^{-3} \text{ mol}$$

ACTIVITY : PERCENTAGE PURITY

1. In a certain reaction, 10g of Calcium carbonate reacts with EXCESS hydrochloric acid according to the equation



4g of carbon dioxide is produced.

1. Calculate percentage purity of the calcium carbonate .
 2. Calculate percentage yield of the carbon dioxide.
 3. Compare percentage purity and percentage yield . What do you observe ?
2. Limestone is mostly calcium carbonate .Jake wants to know how much calcium carbonate is in a sample of limestone. He finds that the sample weighs 3,53,5 gg. He then adds concentrated hydrochloric acid to the sample. The equation for this reaction is:



If the mass of calcium chloride produced is 3,63,6 gg, what is the percent purity of the limestone sample?

Concluding

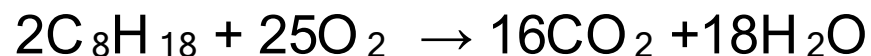
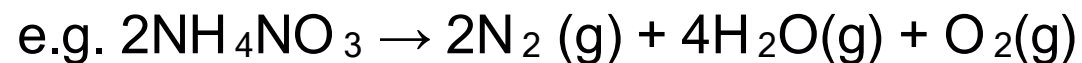
*mol ratio $\text{Na}_2\text{SO}_4 : \text{BaSO}_4$ is 1:1,
thus $9,228 \cdot 10^{-3}$ mol Na_2SO_4 are present in sample*

$$m(\text{Na}_2\text{SO}_4) = n \cdot M = 9,228 \cdot 10^{-3} \times 142 = 1,31 \text{ g}$$

$$\% \text{ purity} = 1,31 / 1,56 \times 100 = 83,97 \text{ or } 84\%$$

Quantity	Unit name / Symbol	Value / Equivalent ...
N _A (Avogadro's number)	mol ⁻¹	6,022×10 ²³
molar mass (M)	gram per mole (g·mol ⁻¹)	
moles (n)	moles (mol) →	22,4 dm ³ _A (at STP) $V = \frac{n}{c} V_A$
molar volume (V _M)	dm ³ ·mol ⁻¹	
concentration (c)	moles per cubic cm (mol·dm ⁻³)	
Formulae		
$n = V / V_M$	$\% \text{ yield} = \frac{\text{actual}}{\text{theor.}} \times 100$	$\% \text{ purity} = \frac{\text{mass compound}}{\text{mass sample}} \times 100$
$c = n / V$		

- Stoichiometric calculations with explosions as reactions



- Stoichiometric calculations using reaction in airbags (sodium azide):

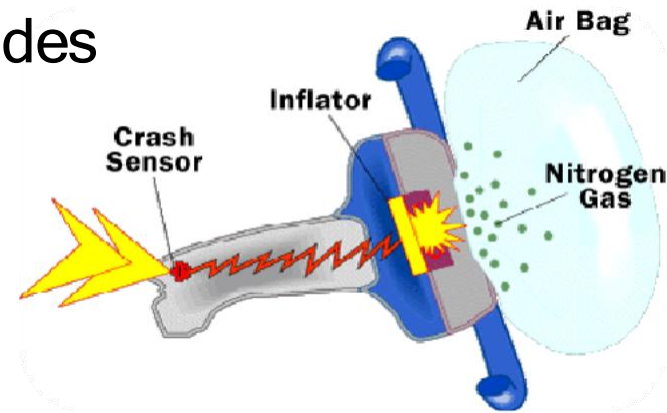


Gas Explosions

Airbags contain sodium azide, which explodes when triggered according to the following equation:



Calculate the volume to which the airbag will inflate if 50 g of NaN_3 reacts.



$$M(\text{NaN}_3) = (23 + 3 \times 14) = 65 \text{ g} \cdot \text{mol}^{-1} \quad | \quad n(\text{NaN}_3) = 50/65 = 0,77 \text{ mol}$$

According to the balanced equation, 2 mol NaN_3 produce 3 mol N_2 gas, therefore 0,77 mol NaN_3 produce $0,77 \times \frac{3}{2} = 1,16 \text{ mol N}_2$

$$\text{Volume } \text{N}_2 = n \cdot V_M$$

$$= 1,16 \times 22,4$$

$$= \mathbf{25,98 \text{ dm}^3}$$

4.3 INFORMATION SHEETS – PAPER 2 (CHEMISTRY)

TABLE 1: PHYSICAL CONSTANTS

NAME	SYMBOL	VALUE
Avogadro's constant	N_A	$6,02 \times 10^{23} \text{ mol}^{-1}$
Standard pressure	p^θ	$1,01 \times 10^5 \text{ Pa}$
Molar gas volume at STP	V_m	$22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$
Standard temperature	T^θ	273 K

TABLE 2: FORMULAE

$n = \frac{m}{M}$	$n = \frac{N}{N_A}$
$c = \frac{n}{V}$ OR $c = \frac{m}{MV}$	$n = \frac{V}{V_m}$
$\frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b}$	$\text{pH} = -\log[\text{H}_3\text{O}^+]$
$K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$ at 298 K	
$E_{\text{cell}}^\theta = E_{\text{cathode}}^\theta - E_{\text{anode}}^\theta$ $E_{\text{cell}}^\theta = E_{\text{reduction}}^\theta - E_{\text{oxidation}}^\theta$ $E_{\text{cell}}^\theta = E_{\text{oxidising agent}}^\theta - E_{\text{reducing agent}}^\theta$	

6.1 Methyl propanoate is an organic compound with the following percentage composition:

54,55% C ; 9,09% H ; 36,36% O

The molar mass of the compound is $88 \text{ g}\cdot\text{mol}^{-1}$.

6.1.1 Define the term *empirical formula*. (2)

6.1.2 Determine, by calculation, the empirical formula. (6)

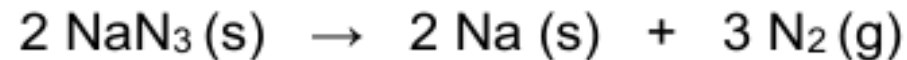
6.1.3 Determine the molecular formula. (2)

6.2 Learners prepare a solution of sodium hydroxide (NaOH) in water by placing 8 g of sodium hydroxide (NaOH) in a volumetric flask and adding water to produce 250 cm³ of solution after stirring.

6.2.1 Define *concentration* in words. (2)

6.2.2 Calculate the concentration of the sodium hydroxide (NaOH) solution. (4)

6.3 Sodium azide (NaN₃) is used in car airbags. For the airbag to inflate the following reaction must take place:



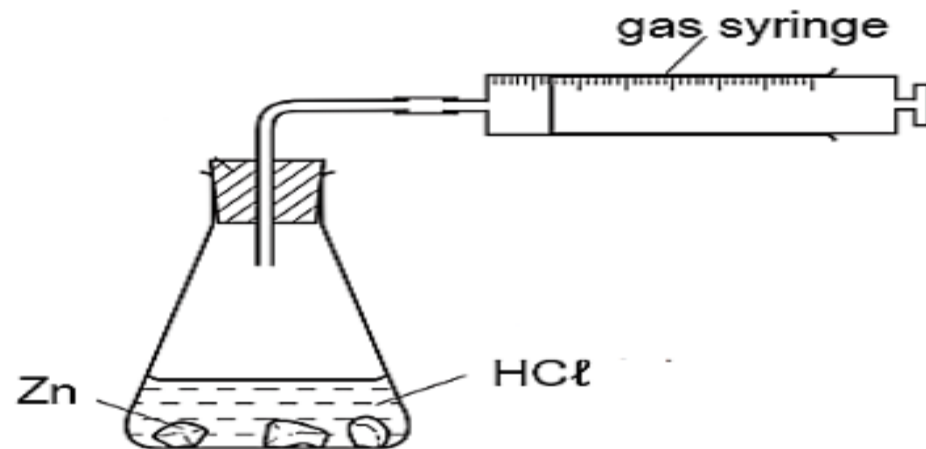
Calculate the volume of nitrogen gas (N₂) that would be produced at STP if 55 g of sodium azide reacts completely. (5)

- 5.2 A teacher demonstrates to a group of learners the impact that the limiting reagent have on the amount of product formed during a chemical reaction.

The teacher uses the following chemical equation:



The teacher uses the following set-up for this investigation:



Experiment 1	Experiment 2
7 g of Zn	3,27 g of Zn
1 mol of HCl	1 mol of HCl

5.2.1 Define the term *limiting reagent*. (2)

5.2.2 Determine, by calculation, the limiting reagent in **experiment 1**. (5)

Periodic Table of Elements

Physical Sciences

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Examination Guidelines

DBE/2017

TABLE 3: THE PERIODIC TABLE OF ELEMENTS

1 (I)	2 (II)	3	4	5	6	7	8	9	10	11	12	13 (III)	14 (IV)	15 (V)	16 (VI)	17 (VII)	18 (VIII)
1 2,1 H 1																	2 He 4
3 1,0 Li 7	4 1,5 Be 9											5 2,0 B 11	6 2,5 C 12	7 3,0 N 14	8 3,5 O 16	9 4,0 F 19	10 Ne 20
11 0,9 Na 23	12 1,2 Mg 24											13 1,5 Al 27	14 1,8 Si 28	15 2,1 P 31	16 2,5 S 32	17 3,0 Cl 35,5	18 Ar 40
19 0,8 K 39	20 1,0 Ca 40	21 1,3 Sc 45	22 1,5 Ti 48	23 1,6 V 51	24 1,6 Cr 52	25 1,5 Mn 55	26 1,8 Fe 56	27 1,8 Co 59	28 1,8 Ni 59	29 1,9 Cu 63,5	30 1,6 Zn 65	31 1,6 Ga 70	32 1,8 Ge 73	33 2,0 As 75	34 2,4 Se 79	35 2,8 Br 80	36 Kr 84
37 0,8 Rb 86	38 1,0 Sr 88	39 1,2 Y 89	40 1,4 Zr 91	41 Nb 92	42 1,8 Mo 96	43 1,9 Tc	44 2,2 Ru 101	45 2,2 Rh 103	46 2,2 Pd 106	47 1,9 Ag 108	48 1,7 Cd 112	49 1,7 In 115	50 1,8 Sn 119	51 1,9 Sb 122	52 2,1 Te 128	53 2,5 I 127	54 Xe 131
55 0,7 Cs 133	56 0,9 Ba 137	57 La 139	72 1,6 Hf 179	73 Ta 181	74 W 184	75 Re 186	76 Os 190	77 Ir 192	78 Pt 195	79 Au 197	80 Hg 201	81 1,8 Tl 204	82 1,8 Pb 207	83 1,9 Bi 209	84 2,0 Po	85 2,5 At	86 Rn
87 0,7 Fr	88 0,9 Ra 226	89 Ac															
			58 Ce 140	59 Pr 141	60 Nd 144	61 Pm	62 Sm 150	63 Eu 152	64 Gd 157	65 Tb 159	66 Dy 163	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173	71 Lu 175	
			90 Th 232	91 Pa	92 U 238	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

KEY/SLEUTEL

Atomic number
Atoomgetal

Electronegativity
Elektronegatiwiteit

Symbol
Simbool

Approximate relative atomic mass
Benaderde relatiewe atoommassa



Thank you