Chapter 2
A quantity of matter:
the mole concept
from microscopic to macroscopic

The concept of Mole is fundamental in chemistry and **links macroscopic world of substances** with **microscopic world of molecules and atoms**, permitting to easily determinate stoichiometric rates in reactions.
This concept has a **high degree of complexity** and students have often difficulty in understanding it properly.
The use of a **problem** connect to **everyday life** can ease the challenge

Objective:
understand Mole concept and its practical implications

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Real life

Counting great amount of small objects can be difficult and in everyday life some trick can be useful: to weigh them.

Example: in hardware store
bolts, nails and ***screws*** are sell by number
but are weighed to be sold.

But how can we do if the weight of each object is unknown?

How can we prepare packs of bolts and screws to assemble a piece of furniture, in order to have 2 screws per each bolt?

Let's think about it!!

Problem solving

The class is divided in groups
We propose to the class this problem:

How could we obtain 4 packages of the same number of different bolts without counting them neither weighing each, using only a 2 plates balance and a technical scale?

Brainstorming

During the brainstorming students will be invited to analyze the problem within each group and to propose solutions. The teacher have the task to direct discussion to the right way:

Q. Could we put on the plates the same number of different objects?
A. The stale will be not balanced!
Q. When the stale will be balanced?
A. When we will have a different number of object

Observation: If we try to balance bolts of different size over two scale plates, their number will be surely different.

The crucial step is to find bolt mass rates!

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Balancing masses

As an example to ease comprehension, let’s consider 4 different bolts A, B, C, D of different size. The teacher knows their average masses, students do not.

A = 13,1 g
B = 5,8 g
C = 1,7 g
D = 3,6 g

Probably student will try to **equalize the mass of different bolts adding or taking away bolts from the plates of the scale.**

Obviously it is important to choose 1 bolt as reference. C for instance.

Example:

10 D = 21 C
D = 2,1 C

Balancing masses

As bolts have discrete masses sometimes it could be difficult to balance the plates.

It can be easier to take a medium value.

Example: 2A bolts are heavier than 15C bolts but lighter that 16C.

$$15C<2A<16C$$

So we could help students to consider the medium value as the better one:

$$2A = C(15+16)/2$$

$$A=7,7\ C$$

Exercise for teacher: Knowing the real mass of B and C calculate B/C rate?

Is an irresoluble problem?

At the end of the work students can **connect all masses to one taken as reference (C).**

A = 7,7 C
B = 3,5 C
D = 2,1 C

We can help students to reflect that:

a) these are 3 equations with 4 unknown data so the system is insoluble

b) if we give a fictitious value to one unknown element we can solve the problem

c) using a **small conventional mass unit** it could be easier to quantify all bolt masses.

Every group of students can choose their **Bolt Mass Unit** (**BMU**) to solve the mathematical system**.**

Define a "bolt mass unit"

For instance: **C = 12 BMU**

So the BMU corresponds to

BMU = C/12

Exercise for students: Calculate the mass of A, B and D using your BMU definition.

From the definition, **C = 12 BMU**

follows that:

A = 92,4 BMU
B = 42,0 BMU
D = 25,2 BMU

Remember: ***Rates between different bolts remain unchanged!***

This solution is only theoretical because student do not know how much a BMU weighs and how many bolts are contained in 1 BMU.

Activities goes here

Students do not know how much a BMU weighs but teacher can calculate it.

Exercise for teacher: How many grams is your BMU?

Knowing that the mass of a C bolt is 1,69 g

C= 1,7 g = 12 BMU -> 1 BMU = 1,7/12 = 0,14 g

The BMU is 0,14 g

Mole of Bolts

Ask to students to weigh as much grams of C as the BMU they have choose, using a technical scale.

In our example as **C = 12 BMU →12 g of C**

Now we are ready to introduce the definition of **Mole of bolts** as:

A Mole of bolts is the quantity of objects that are present in as many grams as 1 BMU

In our example as **C = 12 BMU**

1 Mole of C = 12 g of C

Weight of n bolts

Consider to have only C and D

C = 12 BMU and B = 42 BMU

We want to calculate the masses of C and D that contain the same number of bolts.

If **x** is the mass of C expressed in grams, and **y** the mass of B, we can write:

x = nC = n12BMU and **y = nB = n42BMU**

Now consider mass **x** equal to **a Mole of C** i.e. 12 grams
We will have:

12 = n12BMU so **n = 1/BMU**

Now replacing the value of **n** in the **y** equation we have:

y = (1/BMU) 42 BMU = 42 g

Solution of the problem

Thanks to this calculation, it's now easy to understand that 1 Mole of different objects has the same quantity of objects inside.

So weighing **equal number of Moles** of each kind of bolt, we will have the **same number of bolts** in each package.
Knowing the number of bolts present in 1 Mole we will be able to know also the number of bolts present in all the packages.

Bolt Number

Exercise 1: how many bolts are present in 1 mole?

Students can answear by counting bolts present in 1 mole

In our example , as we know the mass of C, we can calculate:

C = 12 BMU **1 mole of C = 12g** **C = 1,7 g**
~7 C bolts in 12 g.

A = 93 BMU **1 mole of A = 93g** **A= 13,1 g**
~7 A bolts in 93 g of A.

B= 42 BMU **1 mole of B = 42 g** **B = 5,8 g**
~7 B bolts in 93 g of B.

the Bolt Number (BN) is the number of bolts present in 1 Mole

Activities goes here

Exercise : How many grams of screws have we to weigh to have 2 screws for each C bolt?

We balance the screws (**S**) with C bolts in the scale.

S = 0,65C = 0,65 x 12BMU

S = 7,8BMU

1 Mole of S = 7,8 g

Knowing that 1 Mole of screws contains the same number of bolts of 1 Mole of bolts.

To have 2 screw for each bolt we will have to weigh 2 Moles of screw for each Mole of Bolts

2 Mole of S = 7,8g x2

So we have to weigh 7,8 g of S for 12 g of C Bolt