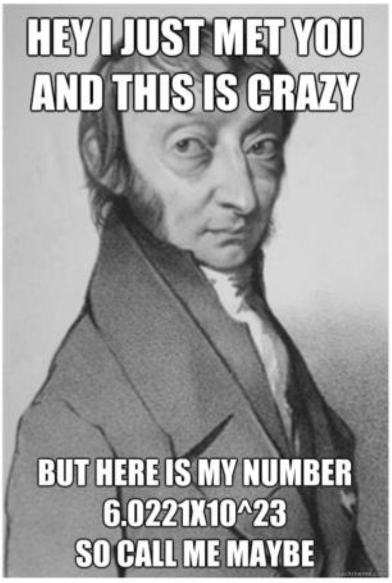
Introducing Molar Mass

January 23, 2018 12:04 PM

Chemistry 11

Book 1 : Introduction to The Mole



Name:__________ **Block:_____**

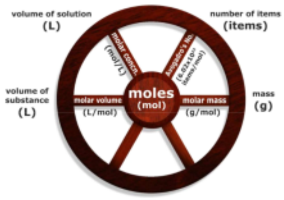
The Mole — The Central Unit of Chemistry

What mass of oxygen has the same number of atoms as 1 g of hydrogen? An oxygen atom (16 u) weighs 16 times as much as a hydrogen atom (1 u). Therefore, it would require 16 g of oxygen to have the same number of atoms as 1 g of hydrogen. Chemists extended this reasoning to all the elements. For example, 55.8 g Fe, 35.5 g Cl, 23.0 g Na, and 12.0 g C all contain the same number of atoms since these masses are in the same ratios as their individual atomic masses.

How many atoms are there in the atomic mass of any element expressed in grams?

Originally chemists didn't know and even now they only have a very rough estimate but they nevertheless gave a name to that number.

They called this number a "mole."



The mole is at the centre of the chemical measurement.

The Mole Concept

A **mole** is ... a quantity equal to the number of atoms in the atomic mass of any element when it is expressed in grams.

(e.g., the number of atoms in 1.0 g H, 16.0 g O, 63.5 g Cu).

NOTE: 1 mole ≠ 1 gram

1 mole = the number of particles in the atomic mass of an element

"How much is a mole?", you ask.... THE GREEN PEA ANALOGY

If you were to select one hundred (102) average-size peas, you would find that they occupy roughly a volume of 20 cm3. One million peas (106) are just enough to fill an ordinary household refrigerator and a billion (109) peas will fill a three bedroom house from basement to attic. A trillion (1012) peas will fill a thousand houses, the number you might find in a small town. A quadrillion (1015) peas will fill all of the buildings in a city the size of Victoria.

Obviously you will run out of buildings very soon. Let us try a larger measure. Say there is a blizzard over all the western provinces, except that instead of snowing snow, it snows peas. All of British Columbia, Alberta, and Saskatchewan lie covered to a depth of 1 metre. The blanket of peas drifts across roads, banks up against the sides of houses, and covers all the fields and forests. Think of flying across the province with this blanket of peas extending as far as you can see. This gives you an idea of our next number. In the entire blanket there are about a quintillion (1018) peas.

Imagine that this blizzard falls over the entire land surface of the planet! North America, South America, Africa, Europe, Asia, Australia and Antarctica are all buried one metre deep. This global blanket contains about one sextillion (1021) peas. Then imagine that the oceans are frozen over and the blanket now covers the entire land and sea area of the Earth to a one metre depth. Go out among the neighbouring stars and collect 250 planets the size of Earth and cover each of them with a blanket of peas one metre deep. Then you will have a mole of peas.

Furthermore, go out into the farthest reaches of the Milky Way and collect 250 000 planets, each the size of the Earth, and cover them with a blanket of peas one metre deep. You now have about one octillion (1027) peas – which is roughly the number of atoms which make up your body.

– adapted from the original Green Pea Analogy (Author unknown).

Introducing Molar Mass

Experimental work by the English chemist John Dalton (1766–1844) was concerned with how much of one element could combine with a given amount of another element. He put forth the following hypotheses.

- Molecules are made up of " atoms " of various elements.
- If compound B contains twice the mass of element X as does compound A, then compound B must contain twice as many atoms of X.

Dalton did not attempt to figure out the mass of an individual atom of any element. Instead he simply assigned an arbitrary mass to each element, assuming that hydrogen was the lightest element and therefore could be assigned a mass of "1".

Dalton's experiments found that Carbon was 6 times heavier than Hydrogen, so C was given the mass 6 (we know C = 12). Similarly, Oxygen was 16 times heavier than Hydrogen, and was assigned a mass of 16.

In this way Dalton was able to calculate relative masses (relative to hydrogen) for several different elements.

Figure 3.1.2 *The mass of an oxygen atom is equal to the mass of 16 hydrogen atoms.*

(* atomic mass = "u")

Molar Mass (g) grams

The mass of one mole of an element's atoms is called that element's "molar mass". It follows from simply restating the definition of a mole that the molar mass of an element is its atomic mass expressed in grams.

For example, "one mole is the number of atoms in 16 g of oxygen" can be restated as "one mole of oxygen atoms weighs 16 g."

The atomic mass of the elements can be found in the Periodic Table.

The atomic mass of oxygen is 16 u and thus the molar mass of oxygen is 16.0 g ← if I have 1 oxygen

This is better expressed as a conversion factor for calculation purposes:

16 g per mole of oxygen or $\frac{16\,g}{1\,mol}$ or $\frac{1\,mol}{16\,g}$

The molecular mass or "**formula mass**" of a compound is the sum (+) of its constituent atomic masses

For Example: H_2O: 2 × H and 1 × O

One mole of water molecules consists of 1 mol of oxygen atoms (16 g) and 2 mol of hydrogen atoms (2 g) and therefore weighs 18 g.

O_2: 16u – 16u — molecular mass (molecule): 2 × (16) = 32.0 g

O: 16u — molar mass: 1 × (16u) = 16.0 g #1

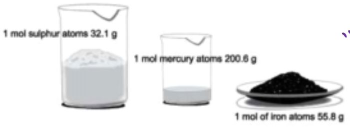


Figure 3.2.3 *The mass of 1 mol of a chemical depends on the atoms that make it up.*

~~1 mole of molecules consists of ___ of oxygen atoms (___) and ___ of hydrogen atoms (2 g) and therefore has a mass of 18 g.~~

1 mol of NaCl formula units consists of 1 mol of sodium atoms (23.0 g) and 1 mol of chlorine atoms (35.5 g) for a total mass of 58.5 g molecular mass

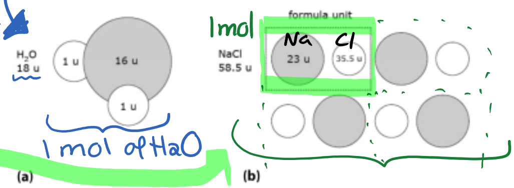


Figure 3.2.4 *(a) The molecular mass of water is the sum of the masses of the oxygen and hydrogen atoms. (b) The formula mass of NaCl is the sum of the masses of sodium and chlorine atoms.*

Just as the molar mass of an element is simply its atomic mass expressed in grams, the **molar mass** of a compound is simply its molecular or formula mass expressed in grams.

1 mol of H = 1.0 g = 6.0221×10^{23} H atoms

1 mol of H_2O = 18.0 g = 6.0221×10^{23} H_2O molecules

1 mol = 6.0221×10^{23} of something

The **MOLAR MASS** is the mass of ONE MOLE of particles.

This definition leads to the following statement.

The molar mass of an element is the mass shown in the periodic table, expressed in grams (g)

EXAMPLES:

Element	Atomic mass shown on periodic table ("u")	Molar mass of element (g) = (1 mol) = 6.0221×10^{23} carbon atoms
C	12.0 u	12.0 g
Fe	55.8 u	55.8 g
S	32.1 u	32.1 g

IMPORTANT: Unless specifically asked to use more precise values, always use masses rounded off to one decimal place. The masses of the elements are given in the ***Periodic Table of the Elements*** and the table ***Atomic Masses of the Elements*** at the back of this book.

Sample Problem — Determining a Compound's Molar Mass

What are the **atomic mass** and **molar mass** of $Al_2(SO_4)_3$?

What to Think About	How to Do It
1. 1 $Al_2(SO_4)_3$ consists of 2 Al's, 3 S's, and 12 O's.	atomic mass (u) 2 × Al 2×(27.0u) 3 × S 3×(32.1u) 12 × O + 12×(16.0u) 342.3u
2. 1 mol $Al_2(SO_4)_3$ consists of 2 mol Al, 3 mol S and 12 mol O.	1 mol of $Al_2(SO_4)_3$ = molar mass molar mass = atomic mass = 342.3 g

NOTE: **Molecular mass** is the mass of a molecule: the sum of the atomic weights of each element multiplied by the number of atoms of that element in the molecular formula.

Practice Problems — Determining a Compound's Molar Mass

1. What is the molecular mass of nitrogen dioxide? NO_2
2. What is the molar mass of $Na_2Cr_2O_7$?

1. What is the molecular mass of nitrogen dioxide?

NO_2

2. What is the molar mass of $Na_2Cr_2O_7$?

3. What is the molar mass of iron(III) sulphide?

Fe^{3+} S^{2-} = Fe_2S_3

ASSIGNMENT #1: questions # 6 (a,e,i,m,c,g,k,o) #7 a + c

Complete ALL assignments on a **seperate piece of paper** and attach to your booklet when handing in at the end of the unit.

6. Calculate the molar mass of each of the following.

(a) NO	(e) CH_4	(i) $FeCl_3$	(m) CH_3COOH
(b) H_2O	(f) $AgNO_3$	(j) SnC_2O_4	(n) $CH_3CH_2CH_2CH_3$
(c) NH_3	(g) $Ca(OH)_2$	(k) $Sn(C_2O_4)_2$	(o) $Ni(H_2O)_2(NH_3)_4Cl_2$
(d) CO_2	(h) $Al(NO_3)_3$	(l) $(NH_4)_3PO_4$	(p) $Al_2(SO_4)_3$

7. Calculate the molar mass of each of the following.

(a) $Co_3(AsO_4)_2 \cdot 8H_2O$ (b) $Pb(C_2H_3O_2)_2 \cdot 3H_2O$ (c) $MgSO_4 \cdot 7H_2O$ (d) $KAl(SO_4)_2 \cdot 12H_2O$