Name: ____ Period:______ Date:____________

The Mole and Molar Mass Guided Notes – Teacher Edition

Relative Atomic Mass (A_r)

Recall that an atom's mass depends on the number of protons and neutrons found its nucleus. Electrons have a much smaller mass by comparison and are therefore not included in the mass value. While it is not possible to weigh individual atoms, it is possible to determine the mass of one atom relative to another. This is done by assigning a value to the mass of an atom of a given element so that it can be used as a point of reference.

Relative Atomic Mass (A_r): Why Carbon?

Atoms were first measured relative to hydrogen, which was given the mass value 1. Soon after, the isotopes of hydrogen, deuterium and tritium were discovered which had mass values of 2 and 3 respectively. From here, oxygen was then chosen. However, it was then discovered that oxygen also had isotopes, and so carbon was finally chosen. Eventually, carbon was also found to have isotopes, but rather than opting for yet another element, the carbon isotope with the mass number 12 was chosen. Its mass is defined as 12 atomic mass units (amu). The relative atomic mass (A_r) of an atom is therefore defined as its mass related to carbon-12. A_r has no units.

Quantitative Chemistry

Quantitative chemistry is the study of the amounts of substances taking part in a chemical reaction. The amount (*n*) of particles (e.g. atoms, ions or molecules) is measured in units called moles (symbol mol). The mole allows scientists to calculate the number of atoms or molecules in a known mass of any given substance.

Defining the Mole

The mole is the "counting unit" used by chemists to indicate the number of particles present in a particular chemical sample. The mole is similar to other counting units, such as a pair (2), or a dozen (12).

The mole is defined as the amount of substance which contains the same number of particles (i.e. atoms, ions or molecules) as there are atoms in exactly 12g of carbon-12 (C-12 or ^{12}C).

Name: ____ Period:______ Date:____________

The Mole and Molar Mass Guided Notes – Teacher Edition

One mole of any substances contains 6.02×10^{23} atoms. This number is called Avogadro's number after the Italian chemist Amedeo Avogadro and is given the symbol N_0.

This means that...

- 12 grams of carbon is the same as 1 mole of carbon.
- 1 mole of carbon is equal to 6.02×10^{23} carbon atoms.
- 6.02×10^{23} carbon atoms have a mass of 12 grams.

Molar Mass

The mass (in grams) of one mole (6.02×10^{23} particles) of a substance (element or compound) is called its molar mass. It has the symbol *M* and the unit grams per mole or g mol^{-1}.

Molar masses are defined relative to that of carbon-12 (the isotope of carbon with 6 protons and 6 neutrons), which is given a molar mass of 12.0 g mol^{-1} (i.e. 12g of C-12 contains 1 mole or 6.02×10^{23} C-12 atoms).

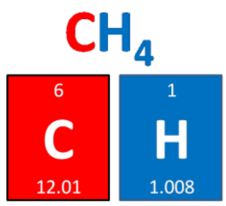
By comparing the mass of each element and compound with carbon-12, the masses of all elements and compounds can be compared with each other (e.g. atomic hydrogen, H-1, has a molar mass of 1.00 g mol^{-1}, so hydrogen atoms are 12 times lighter than C-12 atoms).

Steps for Calculating the Molar Mass (*M*)

Recall that the molar masses for a compound can be calculated by adding together the molar masses for each atom in the compound.

The following steps review the process:

Calculating Molar Mass



$$
\begin{array}{r}
12.01 \text{ g mol}^{-1} \\
\underline{+ (1.008 \text{ g mol}^{-1}) \times 4} \\
16.042 \text{ g mol}^{-1}
\end{array}
$$

Step 1: From the formula of the compound, determine the total number of each type of atom.

Step 2: Add the molar masses of the individual atoms.

Name: ____ Period:______ Date:____________

The Mole and Molar Mass Guided Notes – Teacher Edition

Example 1: Calculate M (CO_2), given M (C) = 12 g mol^{-1}, M (O) = 16 g mol^{-1}

There is 1 carbon atom and 2 oxygen atoms therefore:

M CO_2 = (12 x 1) + (16 x 2) = 44 g mol^{-1}

Example 2: Calculate M (SO_4^{2-}), given M (S) = 32 g mol^{-1}, M (O) = 16 g mol^{-1}

There is 1 sulfur atom and 4 oxygen atoms therefore:

M SO_4^{2-} = (32 x 1) + (16 x 4) = 96 g mol^{-1}

Practice Problems

1. Calculate M ($Ca(NO_3)_2$), given M (Ca) = 40 g mol^{-1}, M (N) = 14 g mol^{-1} , M (O) = 16 g mol^{-1}

   Answer: 164 g mol^{-1}

   Explanation:

   Numbers of atoms = 1 x Ca, 2x N, 6x O

   Molar mass = 40 + (2 x14) + (6 x 16) =164 g mol^{-1}

2. Calculate M ($CuSO_4.5H_2O$), given M (Cu) = 63.5 g mol^{-1}, M (S) = 32 g mol^{-1} , M (O) = 16 g mol^{-1}, M (H) = 1.0 g mol^{-1}

   Answer: 249.5 g mol^{-1}

   Explanation:

   Number of atoms: Cu x1, S x1, O x 9, H x 10

   Molar mass = 63.5 + 32 + (9 x 16.0) + (10 x 1.0) = 249.5 g mol^{-1}

Relative Formula Mass (M_r)

Relative formula mass is another way of referring to molar mass. However, relative formula mass is usually reserved for ionic compounds (such as NaCl), which do not actually exist as individual molecules. It can be obtained by adding the relative atomic masses (A_r) in an ionic compound. M_r has no units.

Isotopes affect Molar Mass

Many elements exist in nature as a number of different isotopes. Isotopes are atoms of the same element which have identical numbers of protons and electrons but differ in their number of neutrons. This gives the isotopes of a particular element their different masses. The molar mass

The Mole and Molar Mass Guided Notes – Teacher Edition

value for an element will rarely be a whole number because they take into account the relative abundance of all the isotopes of the element.

Example: Molar Mass of Chlorine:

Chlorine has two naturally occurring isotopes:

- Chlorine- 35, comprising about 75% of all chlorine atoms.
- Chlorine-37, comprising about 25% of all chlorine atoms.

This means that for every three Cl-35 atoms there will be one Cl-37 atom. Therefore the average molar mass of chlorine will be:

$$\frac{(35\ x\ 75) + (37\ x\ 25)}{100} = 35.5$$

Elemental chlorine, therefore, has a molar mass of 35.5 g mol^{-1}, written M (Cl) = 35.5 g mol^{-1}.

Chlorine, by comparison, is on average, 35.5/12 = 3.0 times heavier than an atom of carbon-12.

Practice Problem:

Calculate the relative atomic mass of uranium using the data in the table below:

Isotope	Relative Abundance (%)
^{238}U	99.27
^{235}U	0.72
^{234}U	0.01

Answer: Relative atomic mass = 237.99

Explanation:

Relative atomic mass = (99.27 x 238) + (0.72 x 235) + (0.01 x 234)

= 23797.8 / 100

= 237.99