



AMOUNT OF SUBSTANCE

Relative atomic, molecular and formula mass. The Avogadro Constant and the mole.





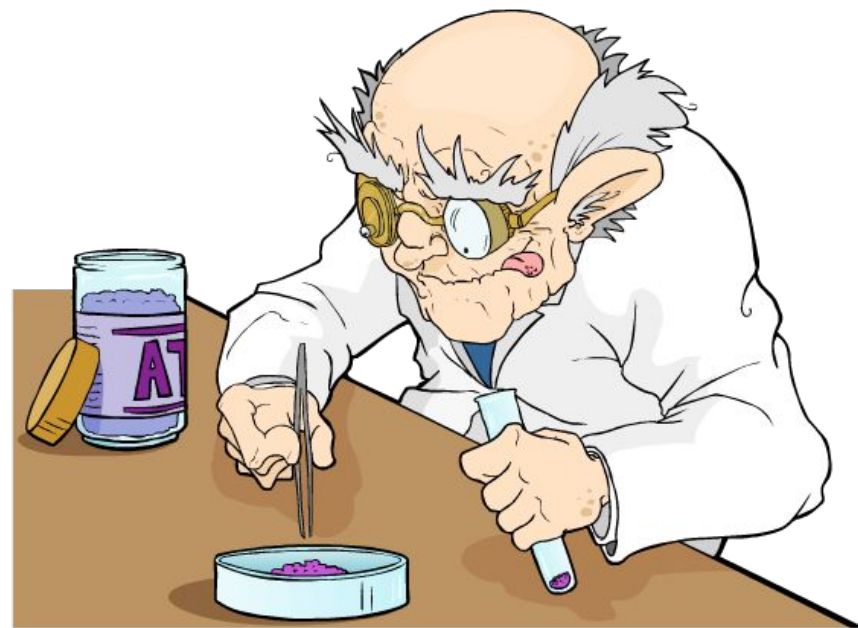
- understand the origin of, and how to calculate relative atomic, molecular and formula mass
- understand the Avogadro number and mole of (particles)
- be able to carry out calculations involving quantities of substances expressed in moles



When conducting a chemical reaction, it is often important to mix reactants in the correct proportions. This prevents contamination of the products by wasted reactants.

However, atoms are very small and impossible to count out. In order to estimate the number of atoms in a sample of an element, it is necessary to find their mass.

The mass of an atom is quantified in terms of **relative atomic mass**.





One grain of sand contains millions of atoms, so atoms must be really small. How is the mass of an atom measured?

Atoms are so small that their masses are not measured directly.

Instead, all atoms are compared with the mass of carbon-12. The mass of an atom on this scale is called its **relative atomic mass**.





What is relative atomic mass?





The **relative atomic mass** (A_r) of an element is the mass of one of its atoms relative to 1/12 the mass of one atom of carbon-12.

$$\text{relative atomic mass } (A_r) = \frac{\text{average mass of an atom} \times 12}{\text{mass of one atom of carbon-12}}$$

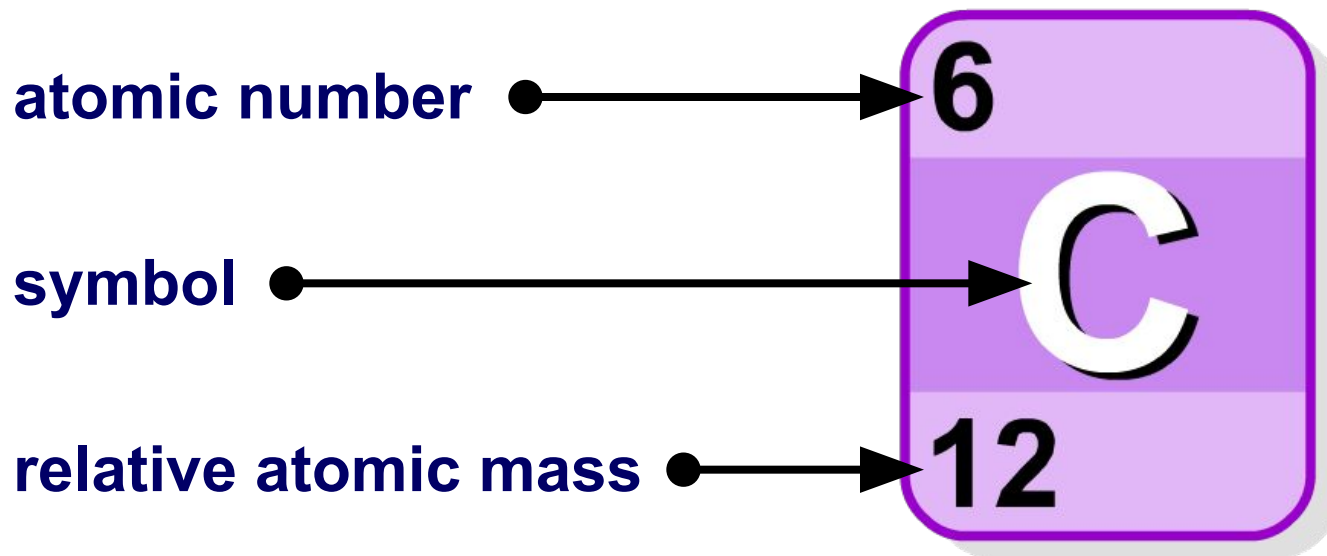
Most elements have more than one **isotope**. The A_r of the element is the average mass of the isotopes, taking into account the abundance of each isotope. This is why the A_r of an element is frequently not a whole number.

16.0 O 8	19.0 F 9	20.2 Ne 10
32.1 P 16	35.5 Cl 17	39.9 Ar 18
79.0 Se 34	79.9 Br 35	83.8 Kr 36



Where are r.a.m. values found?

The values of relative atomic mass (r.a.m.) are usually given in a data book or found in the periodic table. So you don't have to work them out or remember them all!



When looking up relative atomic mass in the periodic table, remember that it always the larger of the two numbers given.

What is the other number?



Identifying relative atomic mass





Why isn't r.a.m. always a whole number?

Relative atomic mass (r.a.m.) is not always a whole number. For example, the r.a.m. of chlorine is **35.5**.

The standard r.a.m. value of each element is actually the **average** relative atomic mass, which takes all the isotopes of each element into account.

Chlorine has two isotopes:
chlorine-35 (75%) and **chlorine-37** (25%).



$$\begin{aligned}\text{average r.a.m. of chlorine} &= (35 \times 75\%) + (37 \times 25\%) \\ &= (35 \times 0.75) + (37 \times 0.25) \\ &= 26.25 + 9.25 \\ &= \mathbf{35.5}\end{aligned}$$





To calculate the average r.a.m. of a mixture of isotopes, multiply the percentage of each isotope by its relative atomic mass and then add these together.

Naturally-occurring bromine is composed of two isotopes: bromine-79 (50.5%) and bromine-81 (49.5%).

What is the average r.a.m. of naturally-occurring bromine?

$$\begin{aligned}\text{average r.a.m.} &= (79 \times 50.5\%) + (81 \times 49.5\%) \\ &= (79 \times 0.505) + (81 \times 0.495) \\ &= 39.895 + 40.095 \\ &= \mathbf{79.99}\end{aligned}$$

This figure can be rounded up.





Most substances are made of molecules, not individual atoms. Molecules are really small too, so can we work out their masses in the same kind of way?

The mass of a molecule is called the **relative molecular or formula mass**.





The **relative molecular mass** (M_r) of a covalent substance is the mass of one molecule relative to 1/12 the mass of one atom of carbon-12.

M_r can be calculated by adding together the masses of each of the atoms in a molecule.

Example: what is the M_r of H_2SO_4 ?

- | | |
|--------------------------------|--|
| 1. Count number of atoms | $(2 \times H) + (1 \times S) + (4 \times O)$ |
| 2. Substitute the A_r values | $(2 \times 1.0) + (1 \times 32.1) + (4 \times 16.0)$ |
| 3. Add the values together | $2.0 + 32.1 + 64.0 = 98.1$ |





The equivalent of relative molecular mass for an ionic substance is the **relative formula mass**.

This is the mass of a **formula unit** relative to 1/12 the mass of one atom of carbon-12. It is calculated in the same way as relative molecular mass, and is represented by the same symbol, M_r .

Example: what is the M_r of CaCl_2 ?

- | | |
|--------------------------------|---|
| 1. Count number of atoms | $(1 \times \text{Ca}) + (2 \times \text{Cl})$ |
| 2. Substitute the A_r values | $(1 \times 40.1) + (2 \times 35.5)$ |
| 3. Add the values together | $40.1 + 71.0 = 111.1$ |



Calculating relative formula mass





Relative atomic mass – true or false?



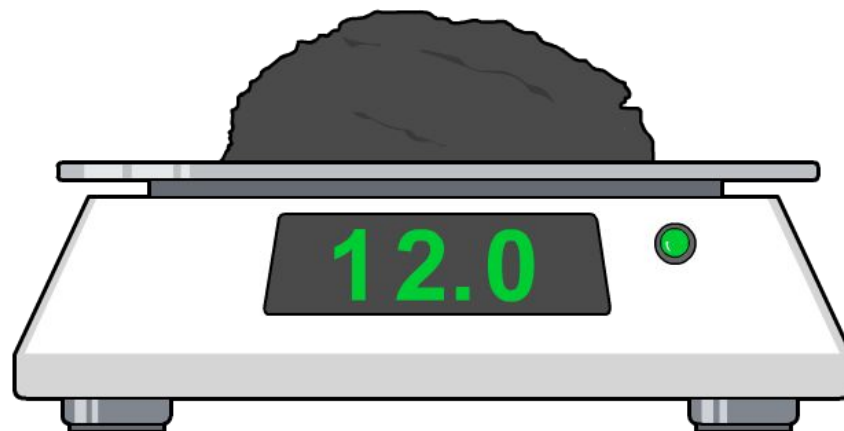


What is a mole?



The term **mole** is also used to talk about mass. **One mole** of a substance is its relative atomic mass, or relative formula mass, in **grams**.

For example, the relative atomic mass of carbon is 12, so **one mole of carbon atoms weighs 12 grams**.



What is the mass of one mole of hydrogen atoms?





What is Avogadro's number?



The number of particles in one mole of a substance is 6.02×10^{23} . This is known as Avogadro's number, L.

The number of particles can be calculated by multiplying the number of moles by Avogadro's number. The number of moles can be calculated by dividing the number of particles by Avogadro's number.

$$\text{(Number of particles)} = \text{(number of moles)} \times L$$





The mass of one mole of a substance is known as its molar mass, and has units of g mol^{-1} .

It must be distinguished from relative atomic/molecular/formula mass, which is a ratio and hence has no units, although both have the same numerical value.





What is the mass of one mole?





Mass (m), molar mass (m_r or a_r) and number of moles (n) are thus related by the following equation:

$$\text{MASS} = \text{MOLAR MASS} \times \text{NUMBER OF MOLES}$$

This relationship can be solved for any one of the three variables in the expression.

$$\text{mass} = (\text{moles})(\text{molar mass})$$

$$\text{moles} = \text{mass}/\text{molar mass}$$

$$\text{molar mass} = \text{mass}/\text{moles}$$

Mass must be measured in grams and molar mass in g mol^{-1} .





- Calculate the number of moles in 58g of CO_2 , then calculate the number of molecules present in the sample, and the number of each type of atom present.





- How can we predict the amount of substance that will be created in a reaction?





- In the reaction



How much MgO will be produced if we start with 12 of Mg?

How much O₂ will be required?





- **relative atomic mass** – The mass of one of its atoms relative to $1/12$ the mass of one atom of carbon-12. Designated by the symbol A_r .
- **relative molecular mass** – the mass of one molecule relative to $1/12$ the mass of one atom of carbon-12. Designated by the symbol M_r .
- **relative formula mass** – The mass of a formula unit relative to $1/12$ the mass of one atom of carbon-12. Designated by the symbol M_r .
- **isotopes** – Atoms of the same element with a different relative atomic mass.





- **mole** – The relative atomic mass or relative formula mass of a substance in grams.
- **Avogadro's number** - The number of particles in one mole of a substance is 6.02×10^{23} . Designated by the symbol L .

