

THE MOLE

A sensitive balance can weight to the nearest 0.0001 g, but a typical atom has a mass of only 0.000 000 000 000 000 000 000 01 g

Is it possible to keep track of atoms by counting them?
Yes, but not directly. We count them in groups. That is we count atoms in the same way we count eggs by the dozen (12), bottle rockets by the gross (144), beer by the case (24), and sheets of paper by the ream (500).

The relative mass of an atom is compared to a reference atom using an instrument called a mass spectrometer. Carbon-12 has been chosen as a reference and it is assigned a mass of exactly 12 amu. The masses of other atoms are compared relative to carbon-12.

Atomic Mass Scale

A hydrogen(¹H) atom has a mass of 1.6735×10^{-24} g

It is convenient to use a unit called the atomic mass unit (amu).

1 amu = 1.66054×10^{-24} g and 1g = 6.02214×10^{23} amu

The amu is defined by assigning a mass of exactly 12 amu to the ¹²C isotope of carbon.

Experiments have shown that 12.01 g of carbon contains 6.02×10^{23} atoms of carbon.

In fact, the gram atomic mass of each element contains 6.02×10^{23} atoms of that element.

MOLE:

Amount of a substance containing 6.02×10^{23} particles

AVOGADRO'S #:

Number of atoms in 12.01 grams of carbon
 6.02×10^{23} atoms

55.845 g of Fe contains 6.022×10^{23} Fe Atoms.

How many Fe atoms are in a 1.00 kg iron bar?

$$1000 \text{ g Fe} \times \left[\frac{6.022 \times 10^{23} \text{ Fe atoms}}{55.845 \text{ g Fe}} \right] = 1.078 \times 10^{25} \text{ Fe atoms}$$

Stoichiometry 1: a branch of science that deals with the application of the laws of definite proportions and of the conservation of matter. 2: quantitative chemical properties and composition esp. as a factor in processes of chemical or physical change

Interpreting A Chemical Formula

A chemical formula describes the proportionate quantities of atoms found in the compound.

Consider glucose $\text{C}_6\text{H}_{12}\text{O}_6$

Q: How many atoms of oxygen are there in one $\text{C}_6\text{H}_{12}\text{O}_6$ molecule?

A: Six

Q: How many moles of oxygen are there in 1 mole of $\text{C}_6\text{H}_{12}\text{O}_6$?

A: Six moles

Q: How many moles of oxygen are there in 2.8 mol of $\text{C}_6\text{H}_{12}\text{O}_6$?

$$2.8 \text{ mol of } \text{C}_6\text{H}_{12}\text{O}_6 \left[\frac{6 \text{ mol O}}{1 \text{ mol } \text{C}_6\text{H}_{12}\text{O}_6} \right] = 16.8 \text{ mol O}$$

Formula and Molecular Weights

The formula weight of a substance is the sum of the atomic masses, for each element, found in the compound.

Exp: Calculate the formula mass of $\text{C}_6\text{H}_{12}\text{O}_6$

$$\text{FW} = 6(\text{AW of C}) + 12(\text{AW of H}) + 6(\text{AW of O})$$

$$6(12.011) + 12(1.01) + 6(15.9994) = 180.182 \text{ amu}$$

MOLAR MASS:

Mass in grams of one mole of any substance, element, or compound.

Has the same numerical value as formula weight.

Q: What is the mass of 6.02×10^{23} $\text{C}_6\text{H}_{12}\text{O}_6$ molecules?

A: 180.182 g

How many moles of glucose are there in 200.0g of $C_6H_{12}O_6$?

$$\frac{200.0 \text{ g of } C_6H_{12}O_6}{180.182 \text{ g } C_6H_{12}O_6} \times \frac{1 \text{ mol } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} = 1.110 \text{ mol } C_6H_{12}O_6$$

How many moles of oxygen are there in 200.0g of $C_6H_{12}O_6$?

$$\frac{200.0 \text{ g of } C_6H_{12}O_6}{180.182 \text{ g } C_6H_{12}O_6} \times \frac{1 \text{ mol } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} \times \frac{6 \text{ mol O}}{1 \text{ mol } C_6H_{12}O_6} = 6.66 \text{ mol O}$$

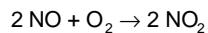
How many grams of oxygen are there in 200.0g of $C_6H_{12}O_6$?

$$\frac{200.0 \text{ g of } C_6H_{12}O_6}{180.182 \text{ g } C_6H_{12}O_6} \times \frac{1 \text{ mol } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} \times \frac{6 \text{ mol O}}{1 \text{ mol } C_6H_{12}O_6} \times \frac{15.9994 \text{ g O}}{1 \text{ mol O}} = 106.6 \text{ g O}$$

Interpreting A Chemical Equation

A balanced chemical equation describes the proportionate quantities of reactants and products.

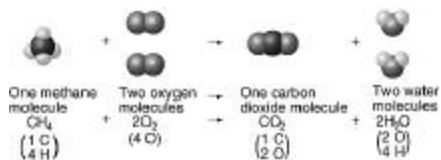
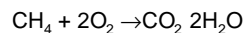
Consider the following chemical equation:



The coefficients in the balanced equation indicate that 2 molecules of NO react with 1 molecule of O_2 .

Similarly, this equation also states that 2 moles of NO react with 1 mole of O_2 to yield 2 mole of NO_2 product.

Chemical reactions are represented in a concise way by chemical equations.



Interpretation of Chemical Equation Coefficients

For the General Equation $2A + 3B \rightarrow C + 2D$

The ratio of molecules is 2 : 3 : 1 : 2

The ratio of moles is 2 : 3 : 1 : 2

The ratio of volumes of gas is 2 : 3 : 1 : 2

Writing Chemical Equations

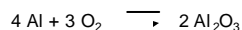
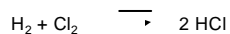
reactants \longrightarrow products

A + B \longrightarrow C + D



Balancing Chemical Equations

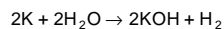
An equation is balanced when the number of atoms of each element is the same on each side of the arrow. The amounts of reactants and products are equal.



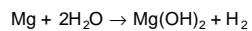
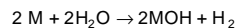
Guidelines for Balancing A Chemical Equation

1. Use Correct formulas
2. Balance each element in the equation by placing a coefficient in front of each formula.
 - a) Begin balancing with the most complex formula (first balance those elements that occur in the fewest chemical formulas on each side of the equation. Balance H and O atoms last).
 - b) Balance polyatomic ions as a single unit. (sometimes they decompose)
 - c) The coefficients in an equation must be whole numbers.
3. Check the # of each element on both sides of the equation.

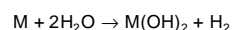
USING THE PERIODIC TABLE TO MAKE CHEMICAL PREDICTIONS (PATTERNS OF CHEMICAL REACTIVITY).



Alkali metal + water \rightarrow Metal hydroxide + hydrogen

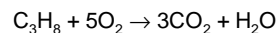


Alkaline earth metal + water \rightarrow Metal hydroxide + hydrogen



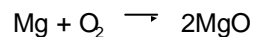
Combustion Reactions

When hydrocarbons are combusted they react with O_2 to form CO_2 and H_2O



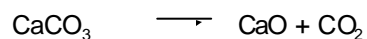
Combination reaction

Two or more substance combine into a single compound.

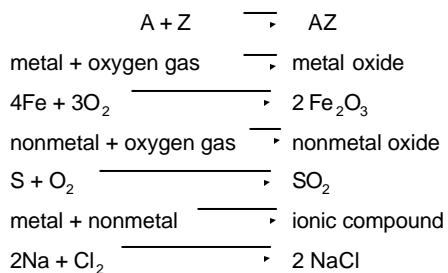


Decomposition reaction

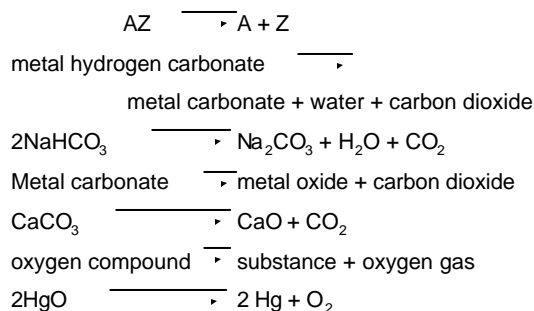
A single compound is broken down into two or more substances.



Combination reaction

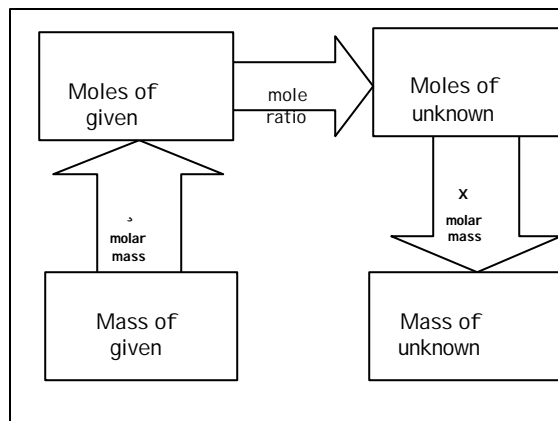


Decomposition reaction

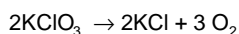


Some stoichiometric calculations relate a given amount of reactant with an unknown amount of product or vice versa. Or, a given amount of reactant can be related to another reactant. Same goes for two products.

The same method of problem solving is used regardless of the quantity sought.



How many grams of O₂ is produced when 0.500 g of KClO₃ is decomposed into potassium chloride and oxygen gas?



$$\frac{0.500 \text{ g KClO}_3}{122.55 \text{ g KClO}_3} \left| \frac{1 \text{ mol KClO}_3}{2 \text{ mol KClO}_3} \right| \left| \frac{3 \text{ mol O}_2}{1 \text{ mol O}_2} \right| \left| \frac{32.0 \text{ g O}_2}{1 \text{ mol O}_2} \right| = 0.196 \text{ g O}_2$$

$$\frac{0.500 \text{ g KClO}_3}{122.55 \text{ g KClO}_3} \left| \frac{1 \text{ mol KClO}_3}{2 \text{ mol KClO}_3} \right| \left| \frac{2 \text{ mol KCl}}{1 \text{ mol KCl}} \right| \left| \frac{74.55 \text{ g KCl}}{1 \text{ mol KCl}} \right| = 0.304 \text{ g KCl}$$

Empirical formula Simplest formula for a compound; it is the smallest whole-number ratio of the atoms present.

Molecular formula Expression of the formula for a compound; it shows the actual number of atoms of each element present in one molecule of the compound.

Percent Composition

The percent composition is a list of the mass percent of each element in a compound.

Calculate the percent composition of propyl chloride (C₃H₇Cl)

$$3(12.01) + 7(1.01) + 1(35.45) = 78.55 \text{ g/mol}$$

$$(36.03/78.55) \times 100 = 45.87\% \text{ carbon}$$

$$(7.07/78.55) \times 100 = 9.00\% \text{ hydrogen}$$

$$(35.45/78.55) \times 100 = 45.13\% \text{ chlorine}$$

Calculate the empirical formula for a compound composed of 26.6% potassium, 35.4% chromium, and 38.1% oxygen.

Percent means a fraction of 100. Thus, if we assume a 100 grams of sample we can then use the percent values as grams of each element.

From grams we find moles of each element in the formula.

$$26.6 \text{ g K} \left(\frac{1 \text{ mol K}}{39.10 \text{ g}} \right) = 0.6803 \text{ moles K}$$

$$35.4 \text{ g Cr} \left(\frac{1 \text{ mol Cr}}{52.00 \text{ g}} \right) = 0.6808 \text{ moles Cr}$$

$$38.1 \text{ g O} \left(\frac{1 \text{ mol O}}{16.00 \text{ g}} \right) = 2.381 \text{ moles O}$$

Next, set up a mole ratio that relates the moles of each element to the moles of the element that is least present.

$$\text{K} \left(\frac{0.6803}{0.6803} \right) = 1 \quad \text{Cr} \left(\frac{0.6808}{0.6803} \right) = 1 \quad \text{O} \left(\frac{2.381}{0.603} \right) = 3.5$$

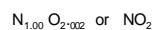
Because a chemical formula must have only whole number we multiply by 2 to yield: K₂Cr₂O₇ as the empirical formula.

An oxide of nitrogen gave the following analysis: 3.04g of nitrogen combined with 6.95g of oxygen. Experiments show that the molecular mass of this compound is 91.7 amu. Determine its molecular formula

$$\text{Find moles nitrogen } 3.04 \text{ g N} \left(\frac{1 \text{ mole N}}{14.01 \text{ g N}} \right) = 0.217 \text{ moles N}$$

$$\text{Find moles oxygen } 6.95 \text{ g O} \left(\frac{1 \text{ mole O}}{16.00 \text{ g O}} \right) = 0.4344 \text{ moles O}$$

$$\text{Set up mole ratio } \text{N} \left(\frac{0.217}{0.217} \right) \quad \text{O} \left(\frac{0.4344}{0.217} \right)$$



NO_2 has a molecular mass of, $14+2(16)=46$ amu

We are told that the compound has molecular mass of this compound is 91.7 amu. Given that the empirical formula is some multiple of the molecular, lets ratio the two molecular masses $(91.7/46)=1.99$

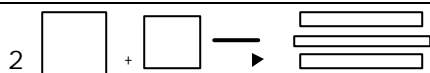
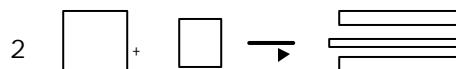
Thus, the molecular formula is a multiple of two and must be N_2O_4

Limiting Reagent

The reactant that is completely used up in a chemical reaction.

The amount of this reactant limits the amount of new compound that can be formed.

If you have six pieces of bread and four pieces of ham, how many sandwiches can you make?



For each reactant, calculate the amount of product that can be produced.

$$(6 \text{ pieces of bread}) \left(\frac{1 \text{ sandwich}}{2 \text{ pieces of bread}} \right) = 3 \text{ sandwiches}$$

$$(4 \text{ pieces of ham}) \left(\frac{1 \text{ sandwich}}{1 \text{ pieces of ham}} \right) = 4 \text{ sandwiches}$$

If 0.654 g of hydrogen react with 0.500 g of oxygen how many grams of water are produced? Which is the limiting reactant hydrogen or oxygen?

