

Chapter 4

Chemical Reactions

Chemical Reactions

What are they?

Chemical reactions: When starting substances, called reactants, combine or breakdown chemically to form ending substances, called products.

Examples: light from a firefly, gasoline combusting in an engine, food spoiling, cooking food

Comparison of chemical reaction and physical changes:

Chemical Reaction

Physical Changes

Combining baking soda and vinegar

CO₂ bubbles forming

Muscles using sugars for energy

Muscles contract causing motion and giving off heat

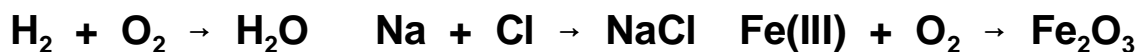
Breakdown of food by stomach acids to small nutrients

Absorption of the nutrients into the body

Writing Chemical Reactions

Balancing Chemical Equations

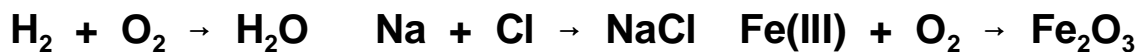
Reactant(s) \longrightarrow Product(s)



Writing Chemical Reactions

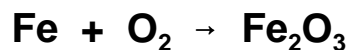
Balancing Chemical Equations

Reactant(s) \longrightarrow Product(s)



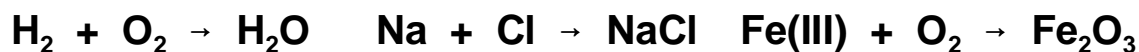
Balancing chemical equations:

1. Write down the formula with the correct form of reactants and products.



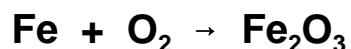
Writing Chemical Reactions

Balancing Chemical Equations



Balancing chemical equations:

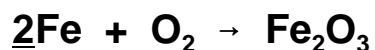
1. Write down the formula with the correct form of reactants and products.



2. Add up the number of atoms on both sides of the equation.

	Reactants	Products
Fe	1	2
O	2	3

3. Identify which elements can be balanced by placing a coefficient in front of one of the formulas.



	Reactants	Products
Fe	<u>2</u>	2
O	2	3

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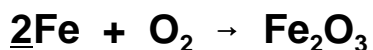
	Reactants	Products
Fe	<u>2</u>	2
O	2	<u>3</u>

4. Adjust the coefficients to balance the next element.



	Reactants	Products
Fe	2	<u>4</u>
O	<u>6</u>	<u>6</u>

3. Identify which elements can be balanced by placing a coefficient in front of one of the formulas.



	Reactants	Products
Fe	<u>2</u>	2
O	2	<u>3</u>

4. Adjust the coefficients to balance the next element.



	Reactants	Products
Fe	2	<u>4</u>
O	<u>6</u>	<u>6</u>

(Note: Placing a coefficient in front of a formula multiplies every element (or atom) by that quantity.)

5. Double check the balance on the other elements and, if necessary, adjust their coefficients.



	Reactants	Products
Fe	<u>4</u>	4
O	6	6

5. Double check the balance on the other elements and, if necessary, adjust their coefficients.



	Reactants	Products
Fe	<u>4</u>	4
O	6	6

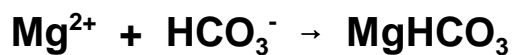
6. Again double check the balance on all elements in the equation.



	Reactants	Products
Fe	4	4
O	6	6

If the formulas contain charges, the charges must also balance!

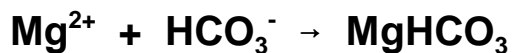
Example: magnesium bicarbonate



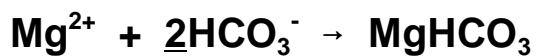
	Reactants	Products
Mg	1	1
H	1	1
C	1	1
O	3	3
Charge Balance	1+	

If the formulas contain charges, the charges must also balance!

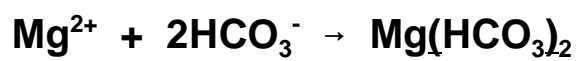
Example: magnesium bicarbonate



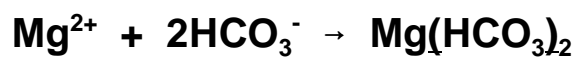
	Reactants	Products
Mg	1	1
H	1	1
C	1	1
O	3	3
Charge Balance	1+	



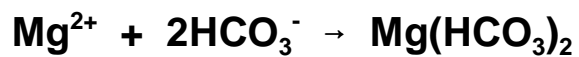
	Reactants	Products
Mg	1	1
H	<u>2</u>	1
C	<u>2</u>	1
O	<u>6</u>	3
Charge Balance	<u>0</u>	



	Reactants	Products
Mg	1	1
H	2	<u>2</u>
C	2	<u>2</u>
O	6	<u>6</u>
Charge Balance	0	



	Reactants	Products
Mg	1	1
H	2	<u>2</u>
C	2	<u>2</u>
O	6	<u>6</u>
Charge Balance	0	



	Reactants	Products
Mg	1	1
H	2	2
C	2	2
O	6	6
Charge Balance	0	

The Mole (not the little fury guy)

Avogadro's Number (a mole in another guise)

Units on Periodic Chart (PC) are in atomic mass units (amu)

$$1 \text{ amu} = \sim 1.66 \times 10^{-24} \text{ grams}$$

Divide atomic mass in amu's by avg. mass # you get approximately 6.02×10^{23} . This is Avogadro's Number.

It is the number that defines what a mole is of the substance. One mole of atoms, molecules, people, whatever has 6.02×10^{23} of the individual whatever in it.

So atomic masses on the PC can be expressed in amu's or as grams / mole (or g/mol).

Example: 6.02×10^{23} atoms of C = 12.01115 amu or g/mol

Formula Weight

A useful conversion factor

What is the mass of one mole of water (H₂O)?

Atom	Qty.	amu	mass
H	2	x 1.01	= 2.02 g
O	1	x 16.0	= 16.0 g

Formula Weight of H₂O = 18.0 amu
Mass of H₂O = 18.0 grams / mole
(Molar mass of H₂O)

Note: In one mole of water there are two moles of hydrogen and one mole of oxygen atoms. In other words it takes 2 moles of hydrogen and 1 mole of oxygen to make one mole of water. (Law of definite proportions)

Converting Units

Moles, grams, atoms, molecules, etc.

Formula weight in g/mol (molar mass in grams) can be used to convert moles-to-grams or grams-to-moles.

Avogadro's number can be used to convert from moles-to-number of particles (etc.) or number of particles (etc.)-to-moles.

$\frac{\text{molar mass (g)}}{\text{mole}}$	or	$\frac{\text{mole}}{\text{molar mass (g)}}$
$\frac{6.02 \times 10^{23} \text{ particles}}{\text{mole}}$	or	$\frac{\text{mole}}{6.02 \times 10^{23} \text{ particles}}$
$\frac{6.02 \times 10^{23} \text{ particles}}{\text{molar mass (g)}}$	or	$\frac{\text{molar mass (g)}}{6.02 \times 10^{23} \text{ particles}}$

Examples:

(Note: molar mass is also called molecular weight (MW))

⚡ How many moles does 14.25 g of BaCl_2 represent?
MW $\text{BaCl}_2 = 208.2 \text{ g mol}^{-1}$

⚡ How many particles (molecules) does this amount of moles equal?

⊛ You have 2.305×10^{30} molecules of $(\text{NH}_4)_2\text{SO}_4$. How many grams of ammonium sulfate do you have?
MW = 118.2 g mol^{-1}

⊛ How many moles are there if you have 4.359×10^{87} molecules of NaCl?

Stoichiometry

Mole ratios and chemical equations

Stoichiometry: The study of the amounts of products and reactants in chemical reactions.



Fe -

O_2 -

Fe_2O_3 -

4 atoms

3 molecules

2 molecules

4×10^6 atoms

3×10^6 molecules

2×10^6 molecules

4 moles

3 moles

2 moles

The coefficients in a balanced chemical equation specify the proportion in moles of each substance in the reaction. Any ratio of these coefficients to each other is called a mole ratio between those two formula components.

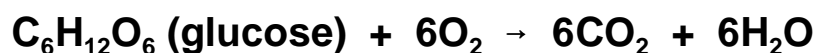
Examples:

The ratio of iron (Fe) to iron(III) oxide is $\left(\frac{4 \text{ mol Fe}}{2 \text{ mol Fe}_2\text{O}_3} \right)$ or

vice versa (flip ratio) for iron (III) oxide to iron.

✪ Likewise, oxygen to iron; iron (III) oxide to oxygen; iron (III) oxide to Fe.

Mole - Mole Calculations

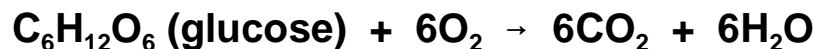


Given 1.35 moles of glucose, how many moles of water will be produced?

How much CO_2 will be produced?

✪ Given the reaction $4\text{Cr} + 3\text{O}_2 \rightarrow 2\text{Cr}_2\text{O}_3$, how many moles of Cr_2O_3 will be produced from 0.278 moles of chromium?

Mole - Mass Calculations

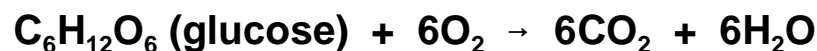


Given 1.35 moles of glucose, how many grams of water will be produced?

How many moles of glucose are needed to produce 38.60 g of CO_2 ?

⊛ How many grams of oxygen is required to make 7.0 moles of chromium (III) oxide?

Mass - Mass Calculations



How many grams of glucose are needed to produce 38.60 g of CO_2 ?

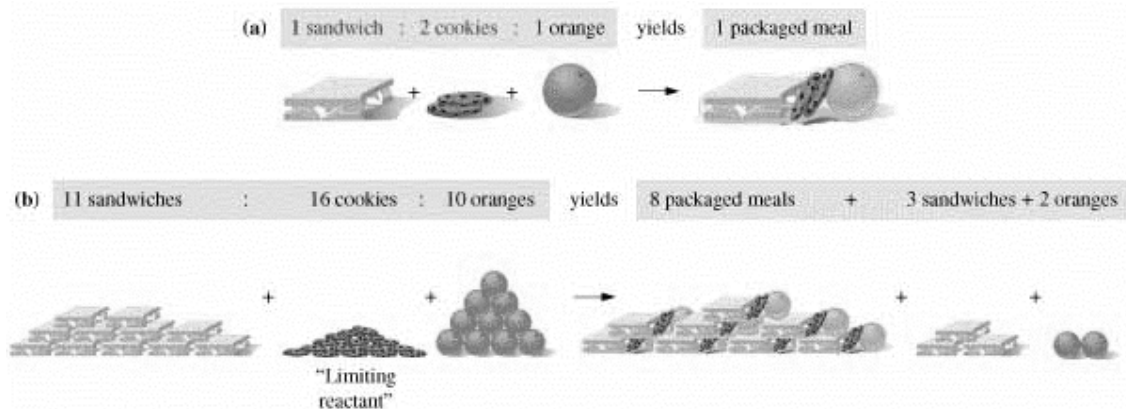


Given 13.270 grams of Cr, how much Cr_2O_3 in grams will be produced?

Limiting Reagent

How much can you really make?

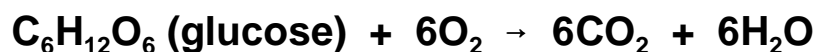
Limiting reagent: the reagent that limits the amount of products produced.



Limiting Reagent

How much can you really make?

Limiting reagent: the reagent that limits the amount of products produced.



Given 35.0 grams of glucose and 87.0 grams of oxygen, which is the limiting reagent?

Percent Yield

percent yield = (actual yield \div theoretical yield) x 100%

Theoretically 35.0 grams of glucose will yield 1.16 moles of CO₂. This is equivalent to 51.1 grams of CO₂. If only 48.7 grams of CO₂ were actually produced, what would the percent yield be for this reaction?