Unit:

CHEMICAL REACTIONS

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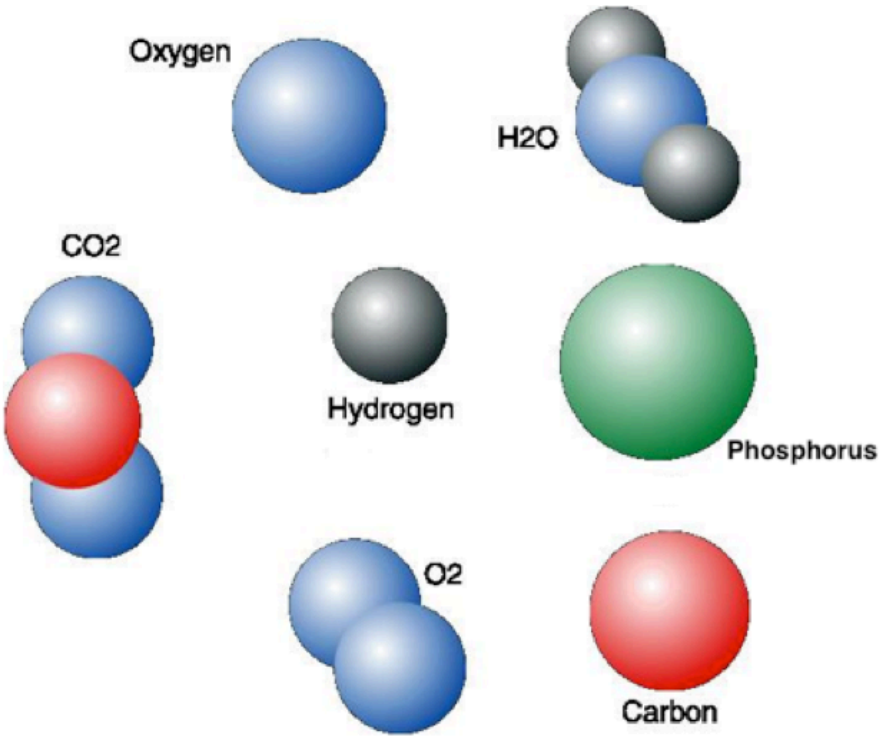
1. INTRODUCTION

As you know, matter is composed of particles (atoms and molecules). In fact, there is a huge amount of different atoms and plenty of combinations of atoms to form molecules or compounds.

Probably, you have always heard that "matter is neither created nor destroyed, only transformed". The law implies that mass can neither be created nor destroyed, although it may be rearranged in space, so the amount of matter in our Universe is always the same. Imagine a cube with many lego bricks pieces Could you build only one structure or more than one?

✓ *Activity **A1**. Remember what you have learned in the unit and give a little definition for **atom** and **molecule**. Furthermore, draw an example of each one.*

✓ *Activity **A2**. The images below are atoms or molecules?*



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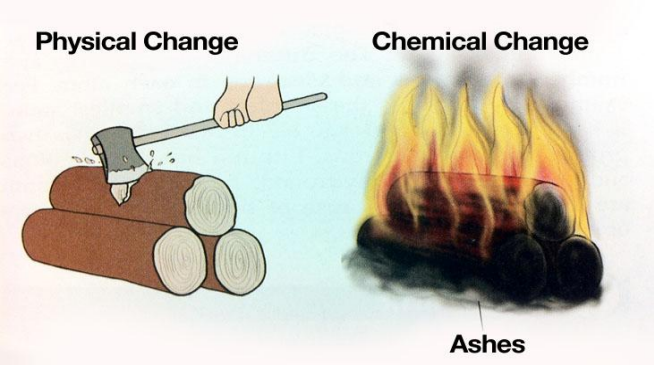
2. PHYSICAL AND CHEMICAL PHENOMENA

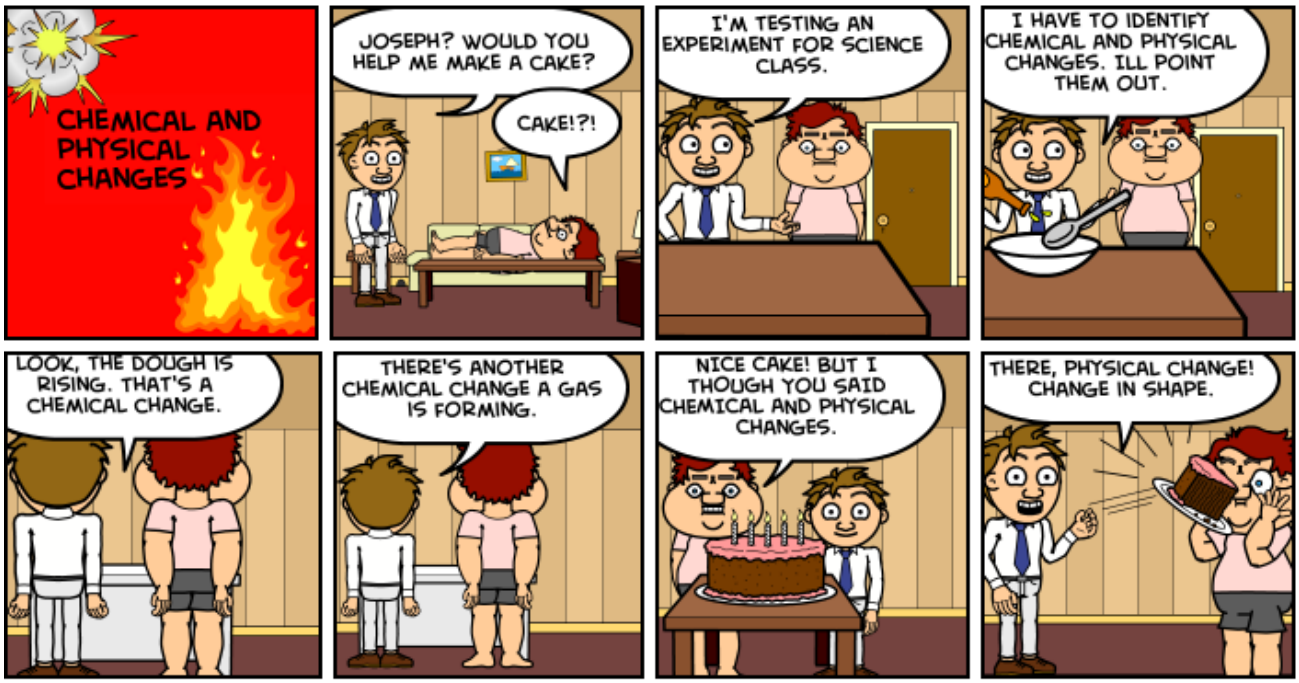
Physical phenomena: they are the processes in which substances do not become different ones. This type of phenomenon is studied in Physics. For example, the movement of a car or dissolution of sugar in water.

Chemical phenomena: they are the processes in which substances become different ones. This type of phenomenon is studied in Chemistry. For example, petrol combustion or iron oxidation.



- ✓ **Physical changes** are usually connected to physical states of matter. Physical change rearranges molecules but doesn't affect their internal structures neither substance nor composition.

- ✓ **Chemical changes** happen on a molecular level when you have two or more molecules interacting among them. Chemical changes happen when atomic bonds are broken or created during chemical reactions. A chemical change is any change that produces the formation of new chemical substances.



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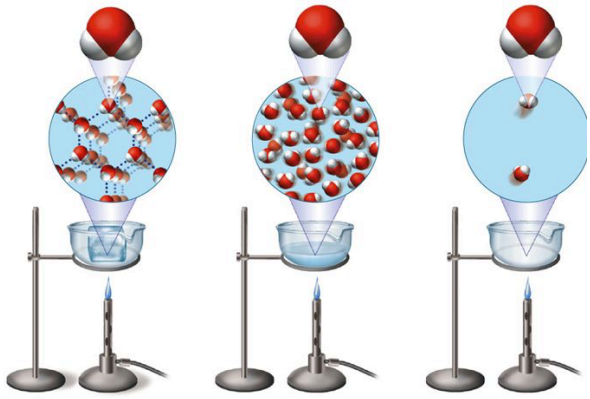
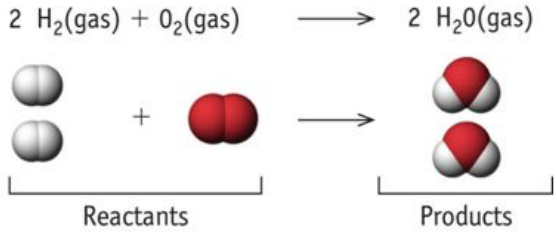
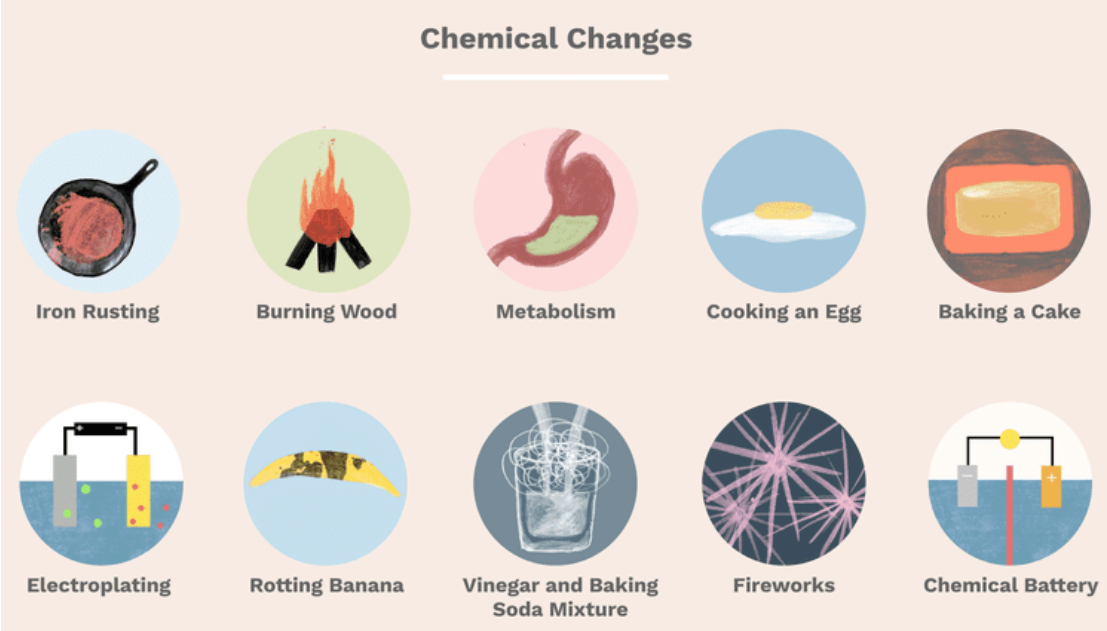
PHYSICAL VS. CHEMICAL CHANGES

PHYSICAL CHANGES	CHEMICAL CHANGES
Physical changes are simply change of state without changes of matter.	Chemical changes occur when new materials are formed by a change in the way atoms are bonded together. ➪ **Colour change, gas created, smell change, new matter created, hot or light created…** are evidences or clues to identify a chemical change. ➪ reactivity changes with the formation of new substances. ➪ heat, light or electrical energy is often emitted or absorbed.
	



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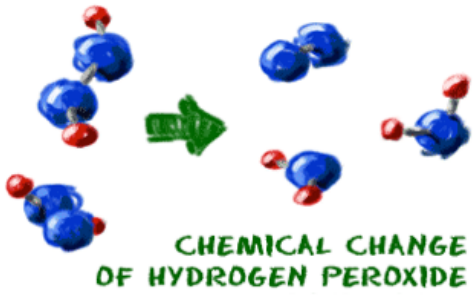

✓ *Activity **A3**. Which of the following phenomena are physical and which are chemical? Why? (the chemical composition is the same after chenge… or not)*

a) Food digestion.

b) The turn of the wheel of a car.

c) The transformation of grape juice into wine.

d) The change of water from liquid into gas.

e) The reflection of light on a mirror.

f) The attraction of iron filings by a magnet.

g) The oxidation of copper statues.

3. WHAT IS A CHEMICAL REACTION?

A **chemical reaction** is a process that leads to the transformation of one set of chemical substances to another.

Reactants: The substance (or substances) initially involved in a chemical reaction.
Products: The substance (or substances) obtained in a chemical reaction.

$$H_2 + O_2 \rightarrow H_2O$$

reactants *products*

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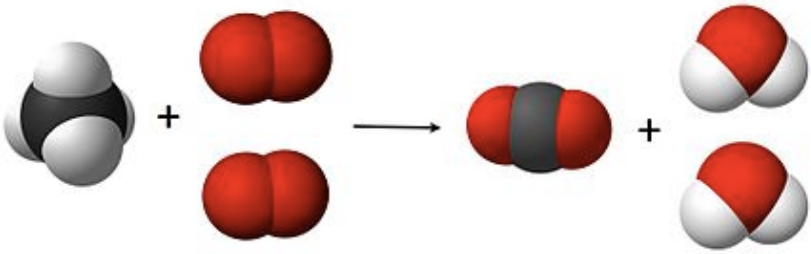
4. CHEMICAL EQUATION

Chemical reactions are described with chemical equations which graphically present the starting materials, end products and reaction conditions.

REACTANTS → PRODUCTS



$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

Reactants and products are represented by formulas. Formulas are expressions made up by chemical symbols and subscripts which inform us of the composition or structure of substances.

Molecular formula: Expresses the number of atoms of each element in the molecule. Examples: HCl, NaCl, H_2O…

How many atoms of each element are there in $Al(OH)_3$?
1 atom of aluminum, 3 atoms of oxygen and 3 atoms of hydrogen.

✓ *Activity **A4**. How many atoms of each element are there in :*

a) $Mg(OH)_2$
b) $Al_2 (SO_4)_3$
c) $C_6H_{12}O_6$
d) H_2CO_3
e) NH_3

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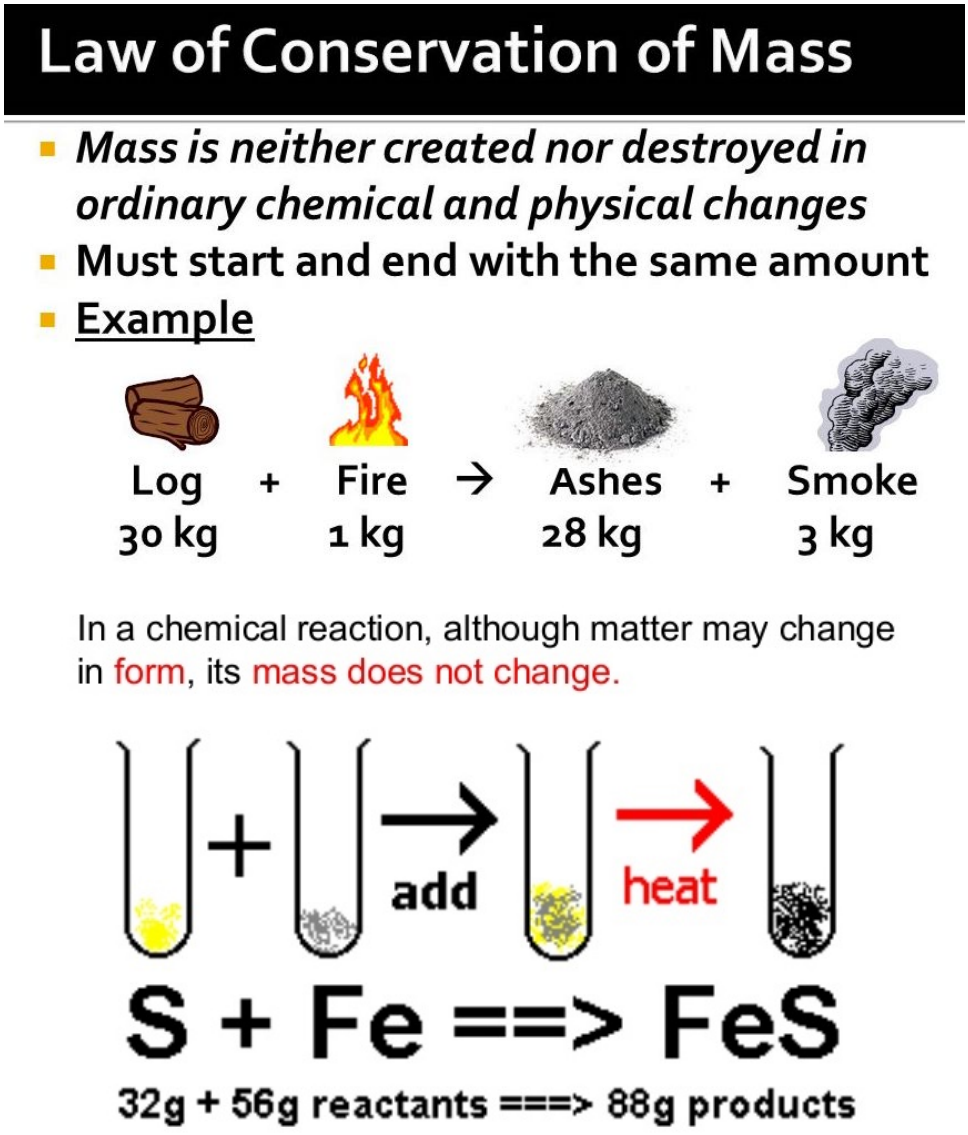
5. BALANCE OF CHEMICAL REACTIONS. LAW OF CONSERVATION OF MASS.

When you write an equation for a chemical reaction, the two sides of the equation should balance (you need the same number of each kind of element on both sides.) If you carry out a chemical reaction and carefully sum up the masses of all the reactants, and then compare the sum to the sum of the masses of all the products, you see that they're the same.

A law in chemistry, the Law of Conservation of Mass, states, "In an ordinary chemical reaction, matter is neither created nor destroyed." This means that you have neither gained nor lost any atoms during the reaction. They may be combined differently, but they're still there.



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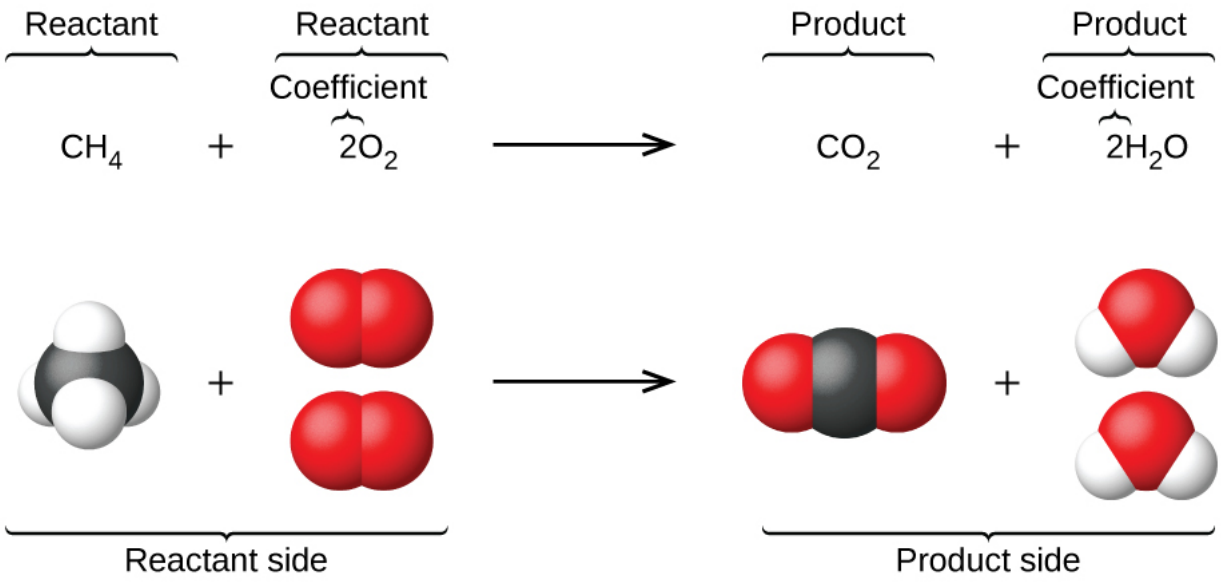
6. STOICHIOMETRY

Stoichiometry is the calculation of reactants and products in chemical reactions.

The branch of chemistry which is called stoichiometry deals with the calculation of various quantities of reactants or products of a chemical reaction. The word “stoichiometry” itself is derived from two Greek words “stoichion” meaning element and “metry” meaning measure.

Stoichiometry is founded on the law of conservation of mass where the total mass of the reactants equals the total mass of the products. This means that if the amounts of the separate reactants are known, then the amount of the product can be calculated. Conversely, if some product of reaction is in known quantity and the chemical equation of the reaction can be determined, then the amount of the other reactants can also be calculated.



THE NUMBER OF ATOMS MUST BE THE SAME BEFORE AND AFTER REACTION

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✓ *Activity **A5**. Balance the following chemical reactions:*

1) $Cl_2 + Ag \rightarrow AgCl$

2) $S + O_2 \rightarrow SO_3$

3) $Br_2 + H_2 \rightarrow HBr$

4) $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$

5) $H_3PO_4 + NaOH \rightarrow Na_3PO_4 + H_2O$

6) $HNO_3 + Fe \rightarrow Fe(NO_3)_2 + H_2$

7) $HCl + Ca(OH)_2 \rightarrow CaCl_2 + H_2O$

8) $P + O_2 \rightarrow P_2O_5$

9) $Ag + HNO_3 \rightarrow AgNO_3 + H_2$

10) $Fe + O_2 \rightarrow Fe_2O_3$

11) $Mg + H_2O \rightarrow Mg(OH)_2 + H_2$

12) $Pb + H_2 \rightarrow PbH_4$

13) $Na + O_2 \rightarrow Na_2O$

14) $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$

15) $PbS + O_2 \rightarrow PbO + SO_2$

16) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

17) $H_2SO_4 + LiOH \rightarrow Li_2SO_4 + H_2O$

18) $Br_2 + O_2 \rightarrow Br_2O_5$

19) $Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + NaOH$

20) $Na_3P + H_2O \rightarrow PH_3 + NaOH$

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7. MOLECULAR MASS

The molecular mass of a substance is the mass of one molecule of that substance expressed in unified atomic mass units (u). The molecular mass can be calculated as the sum of the individual masses (as found in the periodic table) of all the atoms in any molecule.

Example: calculate the molecular mass of CO_2
$M_{CO2} = 1 \cdot C + 2 \cdot O = (1 \cdot 12) + (2 \cdot 16) = 12 + 32 = 44$ u

✓ *Activity **A6**. Calculate the molecular mass these chemica compounds:*

a) H_2CO_3
b) $Mg(OH)_2$
c) $Al_2 (SO_4)_3$
d) Cl_2O_5
e) O_2
f) $CuSO_3$

For knowing the data of atomic mass you can use a periodic table

SOLUTIONS: a) 62u b) 58u c) 342u d) 151u e) 32u f) 143,5u

8. MOLAR MASS

In Chemistry instead of working with masses we have to work in terms of moles. But, what is the relationship between moles and mass? Molar mass.

Molar mass is the mass of one mole and it is the same number as the molecular mass but with different units. Molar mass is expressed in grammes. Therefore, if we can calculate molecular masses, we know the value of the molar mass (expressing it in grammes), which is of great use in a laboratory.

As an example, the molar mass of water:

$M_{H2O} = 2 \cdot H + 1 \cdot O = (2 \cdot 1) + (1 \cdot 16) = 2 + 16 = 18$ g/mol

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We will be able to make chemical calculations by using a simple chemical formula:

$$n = \frac{m}{M}$$

where…

- n are moles
- m is mass (g)
- M is molar mass (g/mol)

As an example, the molar mass of water:

M_{H2O} = 2·H + 1·O= (2·1) + (1·16) = 2 + 16 = 18 g/mol

Examples:

- *In a laboratory glass bottle there are 300 g of $CuSO_4$. Work out how many moles of that substance are contained in the glass.*

✓ *We work out the molar mass M of the CuSO4:*

$$M\ (CuSO_4) = 1\cdot 63{,}5 + 1\cdot 32 + 4\cdot 16 = 159{,}5g$$

$$n = \frac{m}{M} = \frac{300}{159{,}5} = 1{,}88\ moles\ CuSO_4$$

✓ *Activity **A7**. How many moles are in 10 g of Na OH?*

(Na = 23u ; O = 16u ; H = 1u)

Sol: 0.25 moles NaOH

✓ *Activity **A8**. How many grams are in 2 moles of H_3PO_4?*

(H = 1u; P = 31u; O = 16u)

Sol: 196 g of H_3PO_4

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9. AVOGADRO'S NUMBER

Avogadro's number is the total number of particles present in one mole of a substance. It is the number of atoms present in exactly 12g of C-12.

Avogadro number is valued as $6.022 \cdot 10^{23}$ particles/mol

This number can be the number of particles (atoms, molecules, electrons…) in one mol of substance.

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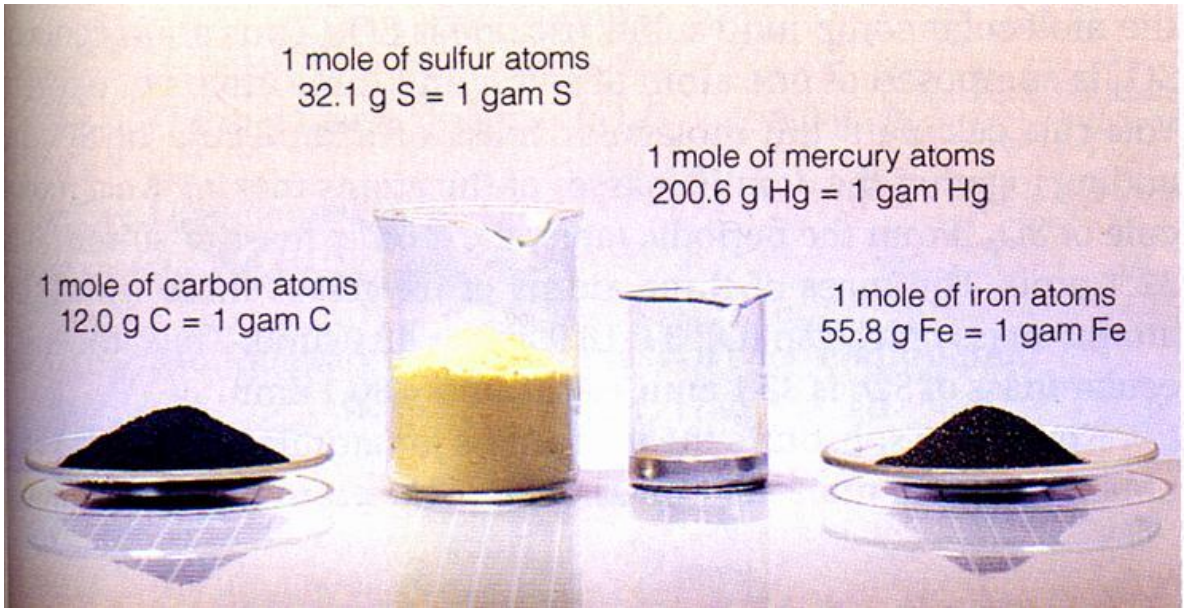
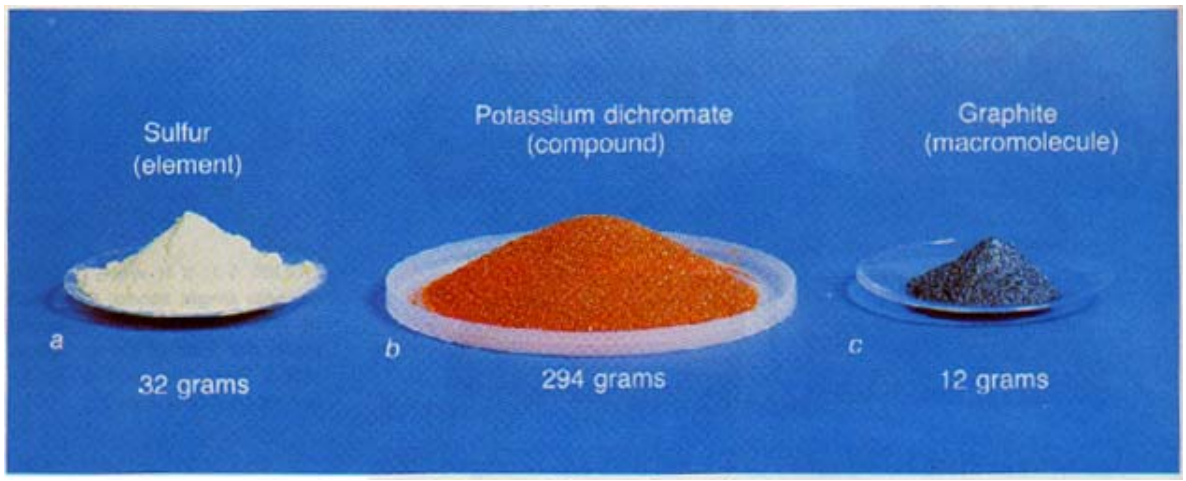


A mol of different substances, doesn't have the same mass, it doesn't occupy the same volume either. However, every mol has the same number of atoms or molecules.



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10. Molar Volume

The molar volume, V_m of a substance is the volume occupied by a mole of atoms or molecules of that substance. If we work with gases (very common), instead of using masses we are going to use volume.

In order to work out the molar volume of gases, 1 mole of any gas at STP (standard conditions of temperatura and pressure, which are 273 K and 1 atm) it is equal to 22.4 L. A mole of any gas in standard conditions (273 K and 1 atm) always occupies 22.4 L, no matter what the gas is.

This means that if we are working at 0°C =273 K and 1 atm of pressure, 1 mole of any gas…

- O_2 (M= 32 g/mol)
- SO_2 (M= 64 g/mol)
- CH_4 (M= 16 g/mol)

…occupy the same volume.

Example:
How many moles of oxygen are there in a container of 45 L at STP?
Solution: 2.04 moles

✓ *Activity **A9**. What is the mass of 150L of nitrogen (N_2) at STP conditions?*
Data: M_N = 14u
Sol.: 187,5 g

✓ *Activity **A10**. What is the volume of 80 g SO_2 gas at STP conditions?*
Data: M_S = 32u M_O = 16u
Sol.: 28 L

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11. Stoichiometric calculations

Stoichiometry is the study of quantitative relationships involved in chemical reactions. To make stoichiometric calculations you have to follow 4 steps:

1.- Balance the equation.
2.- Convert units of a given substance to moles.
3.- Using the mole ratio, calculate the moles of substance yielded by the reaction.
4.- Convert moles of wanted substance to desired units.

Example:

- *What will be the mass of iodine needed to react completely with 7 grams of aluminum?*

$$Al + I_2 \rightarrow AlI_3$$

Data: $m_{Al} = 27\ g/mol$ $m_I = 127\ g/mol$

1.- Balance the equation	$2\ Al + 3\ I_2 \rightarrow 2\ AlI_3$
2.- Convert units of a given substance to moles.	*Moles = mass/ molecular mass* *moles = 7 / 27 = 0.26 moles of Al*
3. Using the mole ratio, calculate the moles of substance yielded by the reaction.	2 moles Al → 3 moles I_2 *0.26 moles Al → x* *x = 0.39 moles of* I_2
4.-Convert moles of wanted substance to desired units.	*Moles = mass/ molar mass* *mass = moles x molar mass* *mass = 0.39 · (127 ·2) = 99.06 g*

✓ *Activity **A11**. What will be the mass of KCl obtained when we have 5 g of* $KClO_3$*?*

$$KClO_3 \rightarrow KCl + O_2$$

Data: $m_K = 39u$ $m_{Cl} = 35.5u$ $m_O = 16u$

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✓ *Activity **A12**. The following reaction is one of the methods for obtaining nitric acid:* $NO_2 + H_2O \rightarrow HNO_3 + NO$

Calculate how many grammes of nitrogen dioxide must react in order to produce 8.8 g of nitric acid.

Data: m_N=14u m_O=16u m_H=1u

✓ *Activity **A13**. Hydrochloric acid HCl reacts with calcium carbonate, $CaCO_3$, and produces calcium chloride, $CaCl_2$, carbon dioxide CO_2 and water. What mass of water is obtained when 18 g of calcium carbonate react fully?*

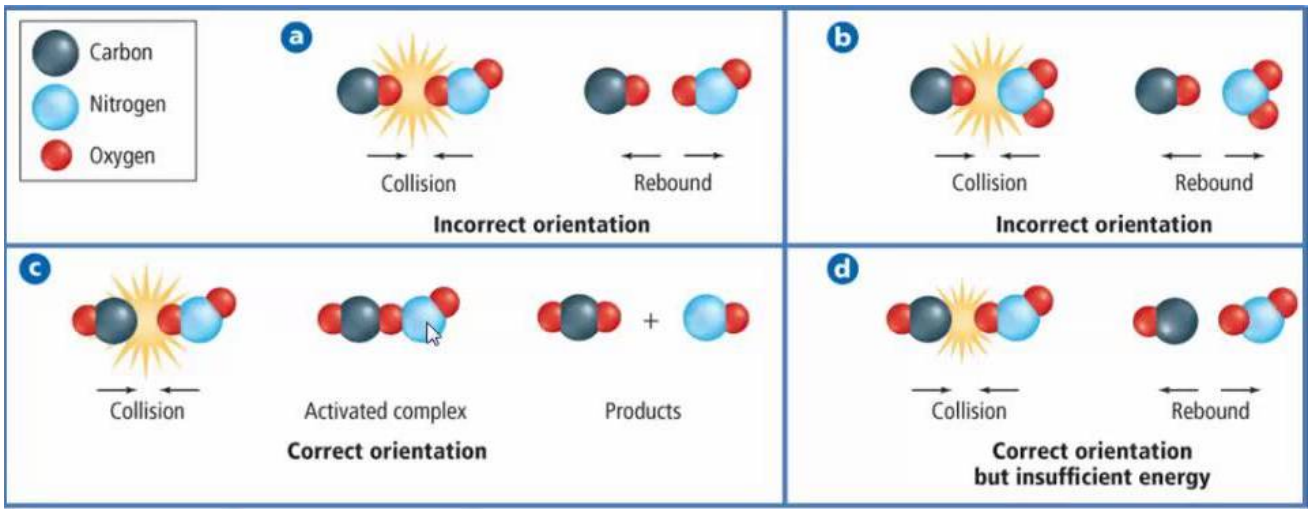
Data: m_{Ca}=40u m_C=12u m_{Cl}=35.5u m_O=16u

12. COLLISION THEORY

The rate of a reaction is the speed at which a reaction happens. If a reaction has a low rate, that means the molecules combine at a slower speed than a reaction with a high rate. Some reactions take hundreds, maybe even thousands, of years while others can happen in less than one second. The rate of reaction depends on the type of molecules that are combining. If you want to think of a very slow reaction, think about how long it took dinosaur bones to become fossils through breakdown. You can thank chemical processes in bacteria for most of those dinosaur bones in the museum.

There is another big idea for rates of reaction called collision theory. The collision theory says that as more collisions in a system occur, there will be more combinations of molecules bouncing into each other. If there are a higher number of collisions in a system, more combinations of molecules can occur. The reaction will go faster and the rate of that reaction will be higher. Even though they are both liquids, think about how slowly molecules move in honey when compared to your soda. There are a lower number of collisions in honey.

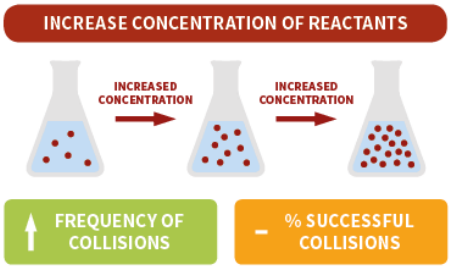
PARTICLES MUST COLLIDE WITH ENOUGH ENERGY AND CORRECT ORIENTATION



Reactions happen - no matter what. Chemicals are always combining or breaking down. The reactions happen over and over, but not always at the same speed. A few things affect the overall speed of the reaction and the number of collisions that can occur.

13. FACTORS THAT AFFECT REACTION RATES

- **Concentration:** If there is more of a substance in a system, there is a greater chance that molecules will collide and speed up the rate of the reaction. If there is less of something, there will be fewer collisions and the reaction will probably happen at a slower speed. Sometimes when you are in a chemistry lab, you will add one solution to another. When you want the rate of reaction to be slower, you will add only a few drops at a time instead of the entire beaker.



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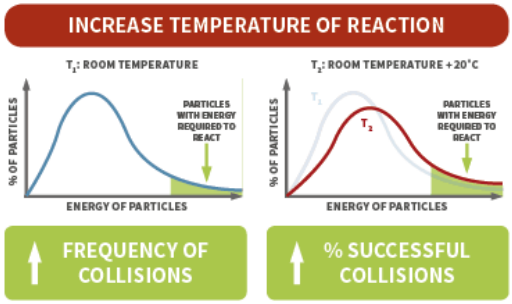
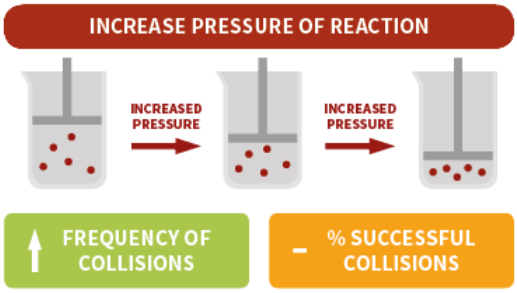
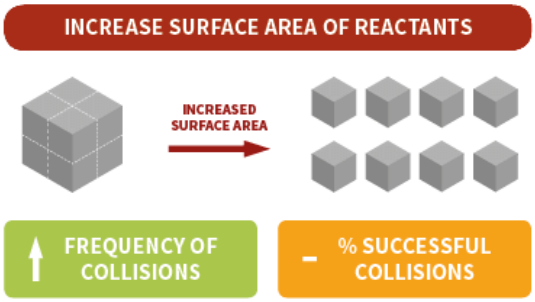
- **Temperature:** When you raise the temperature of a system, the molecules bounce around a lot more because they have more energy. When they bounce around more, they are more likely to collide. That fact means they are also more likely to combine. When you lower the temperature, the molecules are slower and collide less. That temperature drop lowers the rate of the reaction. Back to the chemistry lab! Sometimes you will mix solutions in ice so that the temperature of the system stays cold and the rate of reaction is slower.



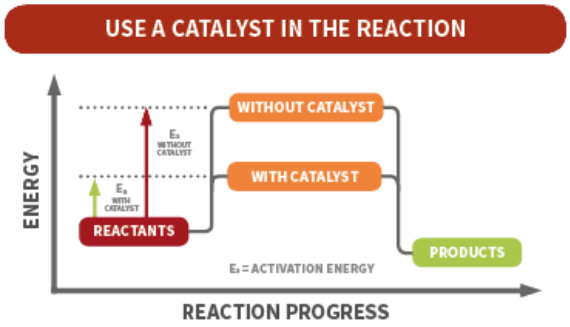
- **Pressure:** Pressure affects the rate of reaction, especially when you look at gases. When you increase the pressure, the molecules have less space in which they can move. That greater density of molecules increases the number of collisions. When you decrease the pressure, molecules don't hit each other as often. The lower pressure decreases the rate of reaction.



- **Surface area of reactants:** Increasing the surface area of solid reactants icreases the number of particles thar are exposed and available to react, and as conseqyuence this increases the frequency of particle collisions, increasing rate.



- **Catalyst:** Catalysis is the increase in the rate of a chemical reaction due to the participation of a substance called a catalyst. Unlike other reagents in the chemical reaction, a catalyst is not consumed. A catalyst may participate in multiple chemical transformations. The opposite of a catalyst, a substance that reduces the rate of a reaction, is an inhibitor. Surface area .This means that the more finely divided a solid or liquid reactant the greater its surface area per unit volume and the more contact it makes with the other reactant, thus the faster the reaction.

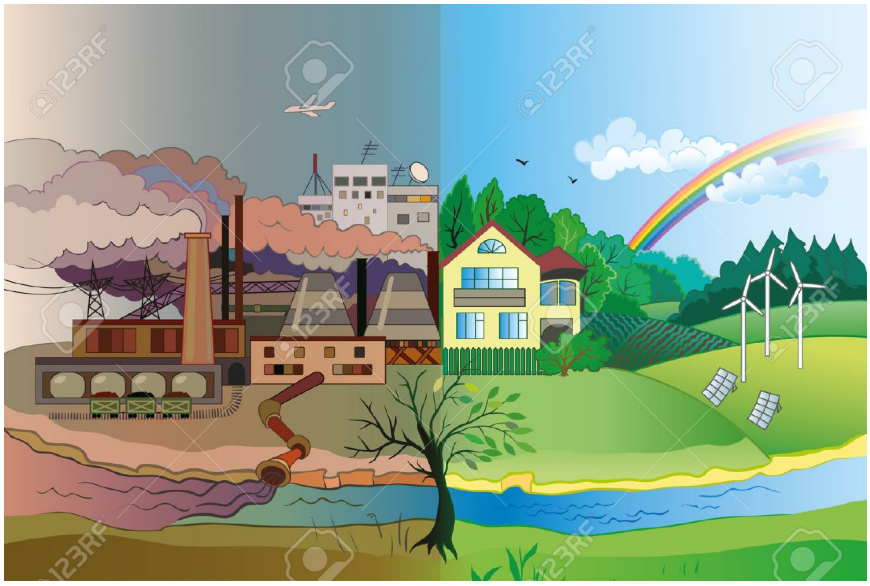


✓ ***PROJECT**, working in groups:*

- *you do a little presentation in English for your classmates and try to answer this question expressing your own opinion:*

Is the chemistry a problem or a solution for the society and environment?

You have 10 minutes approximately. You can use images as help source.



ACTIVITIES

With mass...

P1. Carbon disulphide reacts with oxygen to produce carbon dioxide and sulphur dioxide, both in a gaseous state. Write the equation and calculate the mass of oxygen that is to be consumed so that 100g of carbon dioxide are produced.
m_C = 12 u m_O = 16 u m_S = 32 u

Sol: 218 g of O_2

P2. Given the reaction Mg + O_2 → MgO , work out the mass of oxygen which is consumed and the mass of magnesium oxide produced if we get 8.1 g of magnesium to react.
m_{Mg} = 24 u m_O = 16 u

Sol: 5.3g O_2 13.4g MgO

P3. Ethyl alcohol C_2H_5OH burns in the presence of oxygen O_2 in the air thus producing water and carbon dioxide. Calculate the mass of oxygen needed to burn 10.5 g of ethanol. Calculate the masses of water and carbon dioxide obtained.
m_C = 12 u m_O = 16 u m_H = 1 u

Sol: 21.9g; 12.3g and 20.1g

P4. The process of roasting of zinc sulphide is represented by the reaction

$$ZnS\ (s) + O_2\ (g) \rightarrow ZnO\ (s) + SO_2\ (g)$$

a. What amount of oxygen is needed to react with 974 g of zinc sulphide?
b. What amount of sulphur dioxide is emitted in the process?
m_{Zn} = 65.4 u m_O = 16 u m_S = 32 u

Sol:480g ; 640g

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With volume...

P5. When zinc is attacked by hydrochloric acid HCl, a dissolution of zinc chloride, $ZnCl_2$ takes place, and hydrogen gas, H_2 is released. Calculate the volume of this gas as measured at STP, which is obtained by allowing 20 g of Zn to react.

$m_{Zn} = 65.4$ u $m_H = 1$ u $m_{Cl} = 35.5$ u

Sol: 6.72 L

P6. Calculate the volume of ammonia NH_3 which is obtained from 15 L of hydrogen H_2, both at 1 atm and 0ºC, according to the reaction:

$$N_2\,(g) + H_2(g) \rightarrow NH_3\,(g)$$

sol: 10 L

P7. Iron in contact with the oxygen ,O_2 ,in the air is oxidised and iron oxide(III) is obtained. Calculate the amount of iron oxide(III) which is obtained when 8 g of iron come in contact with oxygen, measured at STP.

$m_{Fe} = 56$ u $m_O = 16$ u

Sol:11,4g

P8. Calculate the volume of C_3H_8 that we need to burn to produce 5 L of carbon dioxide. The chemical reaction is:

$$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$$

Sol: 1.66 L

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PRACTICE EXAM

1.- a) Define: reactant, product, chemical reaction.
b) Name the Law of Conservation of Mass and explain with an example.
c) Explain the factors that affect chemical reactions.

2. Balance and classify the following reactions:

a) $N_2 + O_2 \rightarrow N_2O_3$

b) $FeS + HCl \rightarrow FeCl_2 + H_2S$

c) $H_2O \rightarrow H_2 + O_2$

d) $HCl + Al \rightarrow AlCl_3 + H_2$

3.- Calculate the molar masses of:

a) $Ca(OH)_2$ c) CO_2

b) H_2SO_4 d) H_2

Sol: a) 74 g b) 98 g c) 44 g d) 2 g

4- A test tube contains 5 moles of water. What mass of water is contained in the test tube?

Sol: 90g

5.- Work out how many moles are contained in 140g of calcium chloride $CaCl_2$

Sol: 1.26 moles

6.- Sodium carbonate (Na_2CO_3) reacts with hydrochloric acid (HCl) as seen in the following:

$$Na_2CO_3 + HCl \rightarrow NaCl + CO_2 + H_2O$$

Calculate the mass of CO_2 and water that result from a complete reaction of 15 g of sodium carbonate in enough hydrochloric acid.

Sol: a) 6.23 g b) 2.55 g

7.- Calculate the volume of C_4H_{10} that we need to burn to produce 5 L of carbon dioxide. The chemical reaction is:

$$C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$$

Sol: 1.25 L

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DEFINITIONS

A) Match the words and the explanations:

1	Atom	A	Substances that are consumed in the course of a chemical reaction
2	Molecule	B	Substance that produces hydrogen ions when it is dissolved in water
3	Chemical equation	C	Substances that are formed during chemical reactions
4	Mole	D	Atom or molecule in which the total number of electrons is not equal to the total number of protons
5	Acid	E	One or more chemical changes that occur at the same time
6	Products	F	Substance that produces hydroxide ions when it is dissolved in water
7	Base	G	The basic unit of the matter
8	Chemical reaction	H	The amount of substance containing $6{,}023.10^{23}$ particles
9	Ion	I	The symbolic representation of a chemical reaction
10	Reactants	J	An electrically neutral group of two or more atoms

B) What is the diference:

Atom	Ion
Atom	Molecule
Reactants	Products
Chemical reaction	Chemical equation
Acid	Base

Useful phrases/ structures to communicate

- The most important difference between..... and..... is.....
- Let me think
- I think this is a...
- I think so
- I don't agree
- I understand what you say but...
- What I meant was
- As you probably know
- What do you think?

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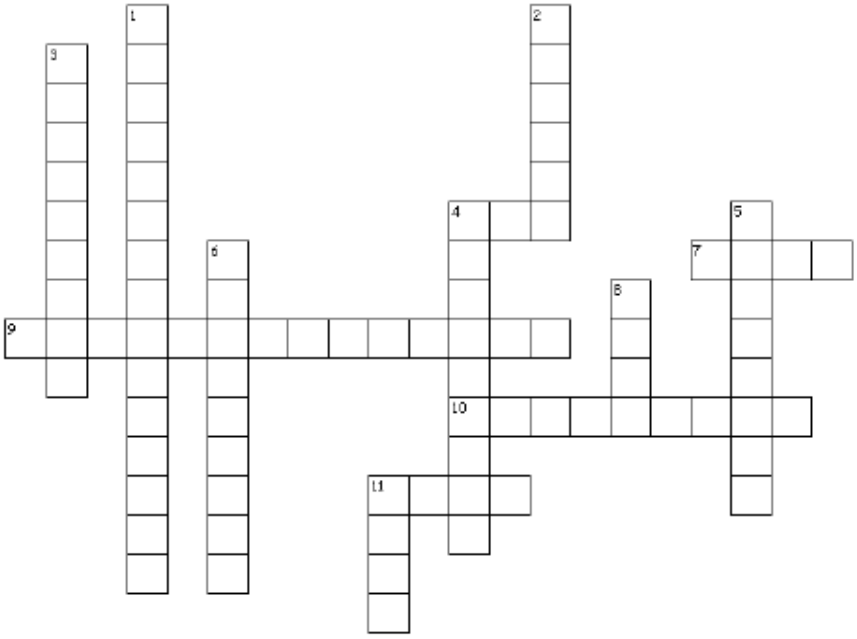
CROSSWORD

What I have learnt.

Complete the crossword puzzle by using the clues below.



A_ _ _ _

4. Atom or molecule in which the total number of electrons is not equal to the total number of protons.
7. The amount of substance containing $6{,}022.10^{23}$ particles.
9. The name for the type of chemical reaction between an acid and a base.
10. Author of one of the theories of acids and bases.
11. The basic unit of the matter.

Down

1. One kind of indicator.
2. He is best known for his pioneering work in the development of modern atomic theory.
3. The father of modern chemistry.
4. Chemicals that change colour depending on the pH of the solution they are placed in.
5. An electrically neutral group of two or more atoms.
6. Substances that are consumed in the course of a chemical reaction.
8. Compound that produces solutions with a pH of more of 7 when it is dissolved in water.
11. Substance that produces hydrogen ions when it is dissolved in water.

- Can you help me with the word in across/down number ....?
- I think the word in across/down number.... is.....
- What do you think..... is?
- How do you spell....?

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VOCABULARY

In the table below write down the keywords learned from the unit with their meaning.

key word	meaning	key word	meaning

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