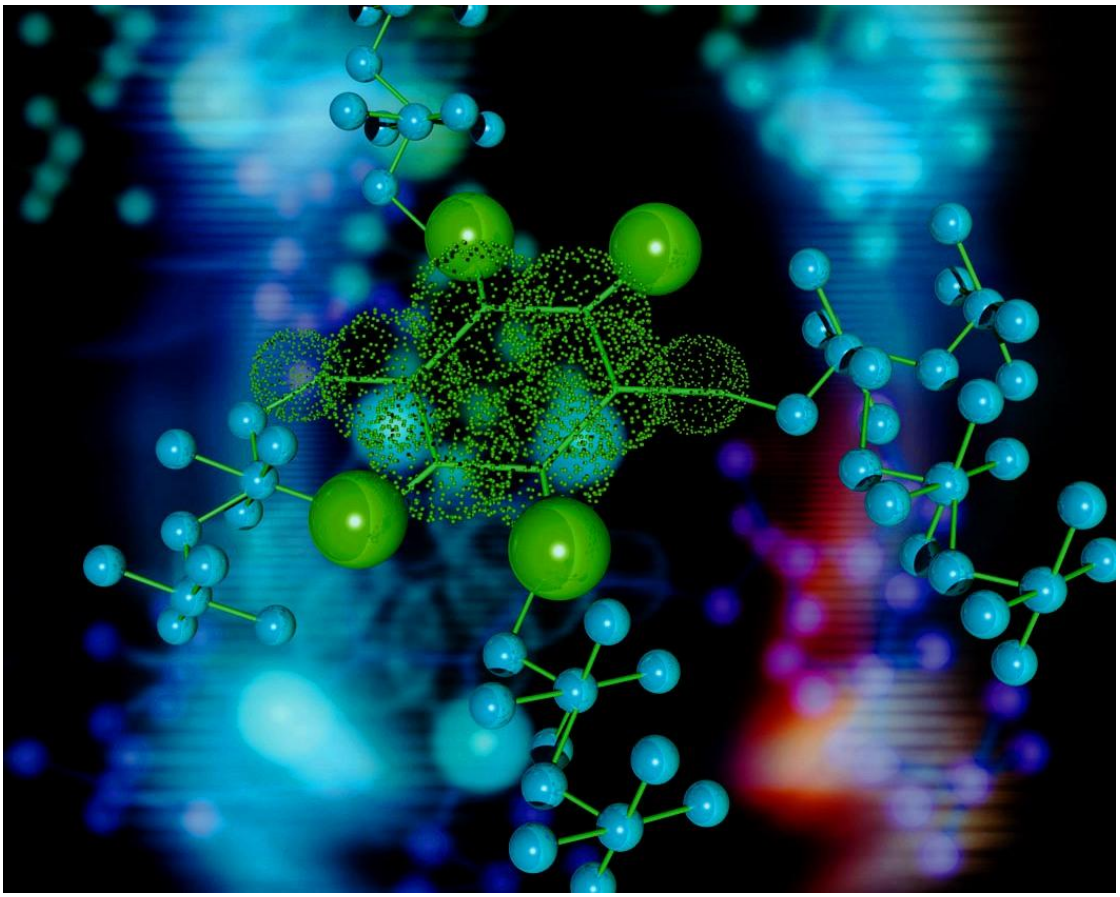
CHEMICAL REACTIONS



In last unit we studied that all matter is composed of corpuscles. This simple idea can help us to understand a lot of phenomena. Have you sometimes observed that substances in nature can change their aspect and properties a lot?

Some examples of spectacular changes:

- Some of your clothes are synthesized from petroleum and also plastic material.
- Petroleum comes from organic remains from a long time ago.
- In the future we will be able to live on the moon and the source of oxygen will be rocks!
- And the most spectacular: our daily digestion. Can you compare the characteristic properties of food and excrement (only from memory, please)?

Now we have to describe these chemical transformations and aftewards we are going to try to understand them.

1. PHYSICAL AND CHEMICAL CHANGES

Physical change is a concept used to contrast with the concept of **chemical change**. A physical change is any change not involving a change in the substance's chemical identity. Matter undergoes chemical change when the composition of the substances changes: one or more substances combine or break up (as in a relationship) to form new substances. Physical changes occur when objects undergo a change that does not change their chemical nature.

Adapted from Wikipedia.

A.1. Give, at least, five examples of every type of change.

A.2. In the next presentation you have to be the judge: physical or chemical changes?

Presentation link

Chemical changes involve chemical reactions. But, what is a chemical reaction?

2. CHEMICAL REACTIONS

A.3. In the laboratory you have to observe the next chemical reactions:

a) Marble with hydrochloric acid ($CaCO_3$ + HCl).

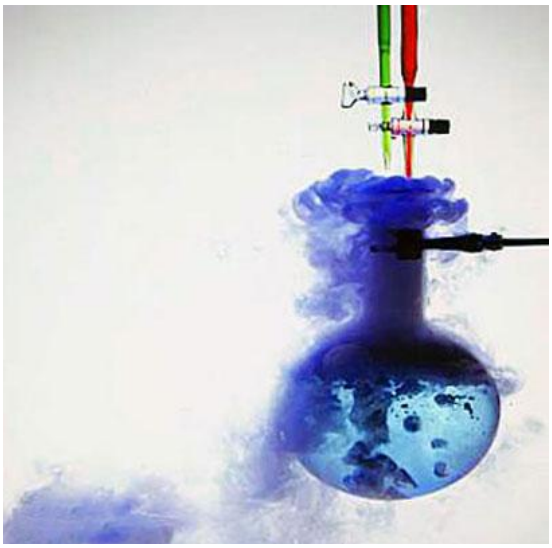
b) Golden rain reaction ($Pb(NO_3)_2$ + KI).

c) Silver chromate precipitation ($AgNO_3$ + K_2CrO_4).

What general conclusions can you infer about chemical reactions?

A chemical change or chemical reaction is a process in which one or more pure substances are converted into one or more different pure substances. How can you know that a chemical change has happened? Logically **characteristic properties** must change a lot. Usually:

- Color changes.
- Physical form changes.
- Bubbles are formed.
- Heat is produced or it is absorbed…



Chemical changes lead to the formation of substances that help to grow our food, make our lives more productive, cure our heartburn, and much, much more. For example, nitric acid, HNO_3, which is used to make fertilizers and explosives, is formed in the chemical reaction of the gases ammonia, NH_3, and oxygen, O_2. Silicon dioxide, SiO_2, reacts with carbon, C, at high temperature to yield silicon, Si, which can be used to make computers, and carbon monoxide, CO. An anti-acid tablet might contain calcium carbonate, $CaCO_3$, which combines with the hydrochloric acid in your stomach to yield calcium chloride, $CaCl_2$, water, and carbon dioxide. The chemical equations for these three chemical reactions are below:

$$NH_3\,(g) + 2O_2\,(g) \rightarrow HNO_3\,(aq) + H_2O\,(l)$$

$$SiO_2\,(s) + 2C\,(s) \rightarrow Si(l) + 2CO(g)$$

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Adapted from this link.

In general you have to make a chemical formula of substances, writing first **reactants** and then **products**:

REACTANTS → PRODUCTS

indicating in every substance its aggregation state in brackets.

A.4. Observe more chemical reactions in the next videos:

Video 1

Video 2

Video 3

Video 4

2.1. Simple and compound substances

A.5. Observe the next chemical reactions:

Thermal decomposition of zinc carbonate

Thermal decomposition of ammonium dichromate (VI)

Electrolysis of water

Electrolysis of sodium chloride

And answer the questions:

a) Look for necessary information and write down all the chemical reactions indicating reactants and products like above.

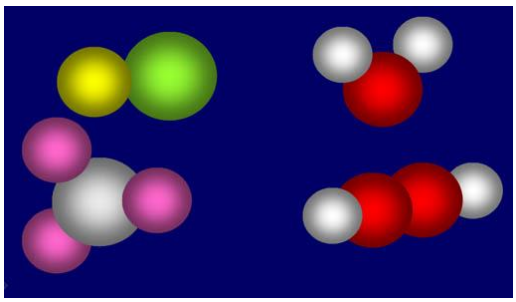
b) In the four cases reactants are always only one substance, do you think this substance is simple or compound? Why?

c) Try to write a definition of compound and simple substances.

3. ATOMIC THEORY

Last unit we studied how kinetic theory can explain physical changes very well, but to understand chemical changes we need another theory, the atomic theory. A simplified model, according to our limited interests, can have the next postulates:

- All the substances are composed of little particles.
- These particles can be atoms or molecules.
- A molecule is a group of atoms united by chemical bonds.
- The properties of substances depend on the type and arrangement of atoms and molecules.
- A simple substance has only one type of atoms although they can be organized in different arrangements.
- A compound substance always has different types of atoms in its molecules, at least two types.



A.6. There are only 90 kinds of atoms in nature (there are more artificials):

a) How many simple substances do you think there would be (estimate them only)? Remember, the same kind of atoms can be arranged in different forms.

b) How many compound substances do you think there would be (estimate them only)?

In the next link you can know the number of chemical compounds studied by chemists until right now.

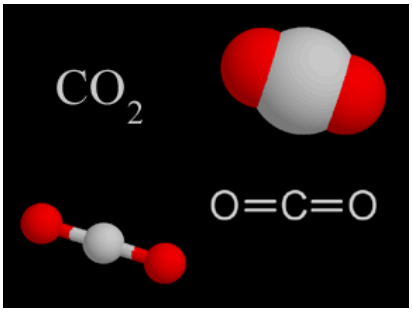
To represent molecules we use formulae. **Formula** shows the number, with subscripts, and types of atoms, with chemical symbols, in a substance.

Substance	**Formula**	**Type of substance**	**Meaning**
Water	H_2O	Compound	Every molecule is integrated by 2 atoms of hydrogen and 1 atom of oxygen.
Ozone	O_3	Simple	Every molecule is integrated by 3 atoms of oxygen.
Sulphur	S_8	Simple	Every molecule is integrated by 8 atoms of sulphur.
Hydrogen chloride	HCl	Compound	Every molecule is integrated by 1 atom of hydrogen and 1 atom of chloride.
Carbon dioxide	CO_2	Compound	Every molecule is integrated by 2 atoms of oxygen and 1 atom of carbon.

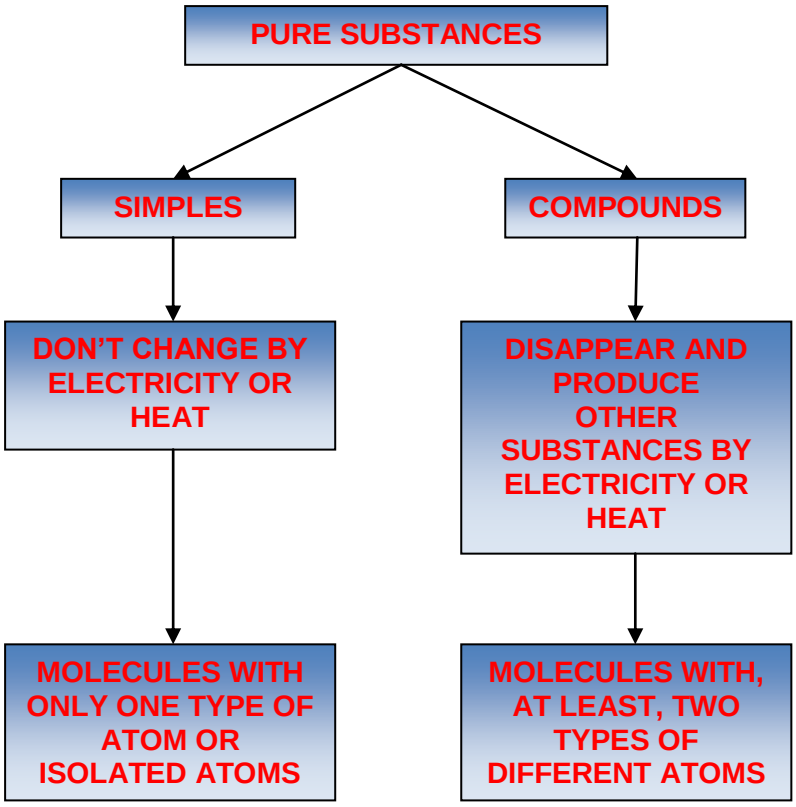
A.7. Make a similar table with the next formulae, looking for information about the name of substances: NH_3, H_2SO_4, $C_6H_{12}O_6$, P_4, C_2H_6O, N_2, NaCl, Au.

A.8. Using formulae and information about aggregation state between brackets, draw how you imagine, at microscopic level, the next substances: Hg (l), CaO (s), Br_2 (l), CH_4 (g), CO_2 (g).

Use little circles of different colours to represent different kinds of atoms.



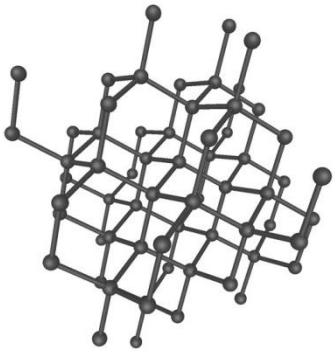
Summarizing:

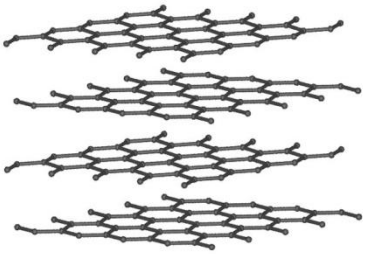


3. 1. Atomic-molecular structure and macroscopic properties

Atomic-molecular structure determines macroscopic properties. A little change in a molecular organization can produce a very big change in physical and chemical properties of a substance. This idea permits us to understand how enormous changes in a chemical reaction can occur: a little change in atoms or their numbers produce different molecules and therefore different substances. Now some examples:

Substance	Formula	Properties
Atomic oxygen	O	Gas; very reactive; dangerous for us.
Molecular oxygen	O_2	Gas; moderately reactive: we can't live without this substance.
Ozone	O_3	Gas; ozone is corrosive, a strong oxidant and very toxic for us.
Chlorine	Cl_2	Greenish yellow gas; highly poisonous.
Sodium	Na	Weak metal; explosive with water.
Sodium chloride	NaCl	White solid salt; we can't live without this substance.
Diamond	C (three-dimensional)	One of the hardest substances; transparent; electric insulator.
Graphite	C (laminated)	Black weak solid; conducts electricity very well.





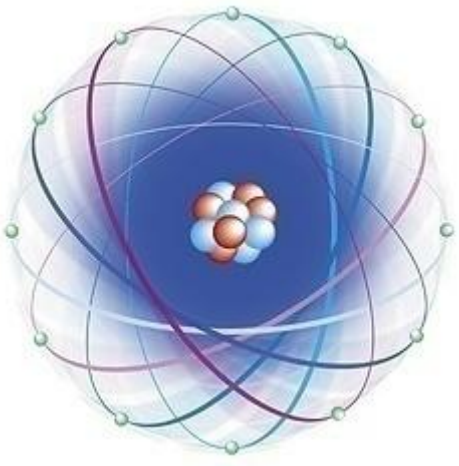
A.9. In graphite, carbon atoms that are between layers are more separated than in diamonds. Do you think it would be possible to transform graphite into a diamond? How could we make a diamond from your pencil point?

Think about this problem and afterwards you can see the next curious link:

http://lifegem.com/

3. 2. Atoms properties

When we think about atoms we usually imagine a little marble. But the real situation is more complicated because atoms have a structure: inside there are other subatomic particles with some important physicall properties like mass or electric charge.



A.10. Look for information and write a report about the next questions:

a) How many subatomic particles are there?

b) How are they disposed in atoms?

c) What is the main difference between every kind of atom?

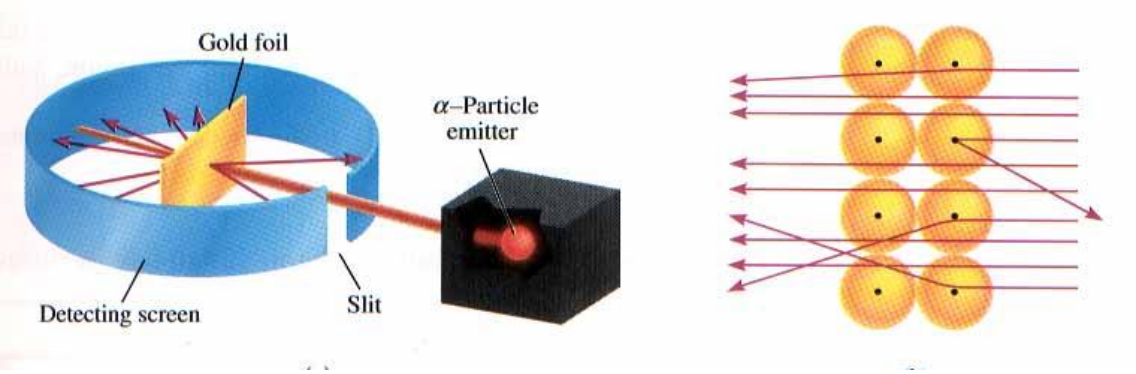
d) What are ions? How many types of ions are there?

At the end of your research see the next links:

Atom helium in flash animation.

About this atomic model (Rutherford's model).

Basic atomic structure video.



Atoms properties

Atomic number

Each element has a unique number of protons in its atoms. This number is called the atomic number (abbreviated Z). Because atoms are normally electrically neutral, the atomic number also specifies how many electrons of an atom there will be. The number of electrons determines many of the chemical and physical properties of the atom.

Mass number

The total number of protons and neutrons in the nucleus of an atom is the mass number of the atom (abbreviated A). The mass number of an atom is an approximation of the mass of the atom. The electrons give little contribution to the mass of the atom, so they are not included in the mass number.

Atomic Mass and Weight

Scientists usually measure the mass of an atom in terms of a unit called the atomic mass unit (abbreviated amu). They define an amu as exactly 1/12 the mass of an atom of carbon with six protons and six neutrons. On this scale, the mass of a proton is 1.00728 amu and the mass of a neutron is 1.00866 amu. The mass of an atom measured in amu is nearly equal to its mass number (A).

Adapted from Encarta

3.3. Periodic table of elements

A.11. Read the article about History of the periodic table in Wikipedia and answer these questions:

a) What is the periodic law?

b) What was the criterion for the first classification of elements made by Lavoisier?

c) How many elements and groups were established by John Newlands in 1865?

d) What was the criterion to Mendeleev's table?

e) What was the main benefit of Mendeleev's table?

f) In the picture below (Mendeleev's table) try to recognize differences and similarities with the current periodic table.

g) Who was Lothar Meyer? Why was Mendeleev more famous than him if their tables were “virtually identical”?

h) What was the definitive criterion to the current periodic table? Who was its discoverer? What kind of research was he doing?

Row	*Group I*	*Group II*	*Group III*	*Group IV*	*Group V*	*Group VI*	*Group VII*	*Group VIII*
1	H = 1							
2	Li = 7	Be = 9	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27	Si = 28	P = 31	S = 32	Cl = 35.5	
4	K = 39	Ca = 40	Sc = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe = 56 Co = 58.5 Ni = 59
5	Cu = 63	Zn = 65	Ga = 70	Ge = 72	As = 75	Se = 79	Br = 80	
6	Rb = 85	Sr = 87	Y = 89	Zr = 90	Nb = 94	Mo = 96		Ru = 103 Rh = 104 Pd = 106
7	Ag = 108	Cd = 112	In = 113	Sn = 118	Sb = 120	Te = 125	I = 127	
8	Cs = 133	Ba = 137	La = 138	Ce = 140				
9								
10			Yb = 173		Ta = 182	W = 184		Os = 191 Ir = 193 Pt = 196
11	Au = 198	Hg = 200	Tl = 204	Pb = 206	Bi = 208			
12				Th = 232		U = 240		

A.12. Seeing the current periodic table answer these questions:

a) Research the meaning of these words: metals; non-metals; metalloids; alkali; alkali earth; halogens; noble gases; transition elements; inner transition elements; lanthanides; actinides; decay elements; synthetic elements; group; period.

b) How many elements are solid in standard conditions.

c) How many elements are liquid in standard conditions.

d) How many elements are gaseous in standard conditions.

4. INTERPRETING THEORETICALLY CHEMICAL REACTIONS

A.13. Put an effervescent aspirin in water. What happens? Do you think this change is physical or chemical? Why? Now you have to weigh the system before and after the process. After the process in two conditions: in a closed glass or in an open glass. What conclusions can you infer about the experimental results?

A.14. Compare your previous conclusions with the conservation mass law in chemical reactions. Look for information about this law. Why do you think mass is conserved in chemical reactions?

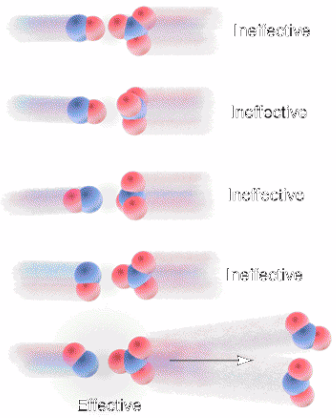
A.15. But what actually happens in a chemical reaction? For example, when hydrogen, H_2 (g), reacts with oxygen, O_2 (g), we can obtain water, H_2O (l). Thinking about this chemical reaction answer these questions:

a) Look for information about properties of hydrogen, oxygen and water.

b) When a chemical reaction is in progress, why do chemical properties change so much?

c) What do you think must happen with chemical bonds?

d) What process do we need to change in a chemical bonds arrangement?



Interpreting theoretically chemical reactions

To transform reactants in products we need for molecules to change: if molecules change physical and chemical properties change too. This change involves chemical bonds that must be broken and reorganized. To break initial chemical bonds and to form new ones it is necessary that molecules collide but not all the collisions are effective. A collision is effective if:

- Molecules have enough kinetic energy (collision is strong enough).
- Suitable spatial orientation.

Mass doesn't change in chemical reactions because we have the same amount of atoms reorganized in different forms.

A.16. Seeing the next presentation about chemical reaction between hydrogen and oxygen to form water, answer these questions:

a) Draw a collision with suitable spatial orientation between hydrogen and oxygen molecules.

b) Draw a collision with unsuitable spatial orientation between hydrogen and oxygen molecules.

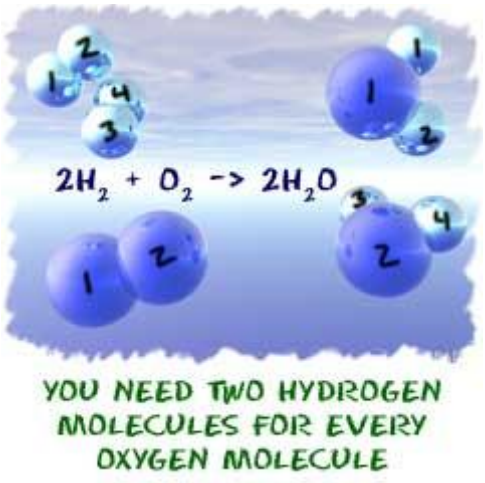
c) What happens if molecules don't have enough kinetic energy?

d) What happens if molecules have enough kinetic energy?

e) Which chemical bonds are broken and which new chemical bonds are formed?

f) Draw how you can imagine substances (not isolated molecules) before and after a chemical reaction. Keep in mind aggregation states.

4. 1. Chemical equations



When hydrogen and oxygen react to form water you always need two hydrogen molecules for every oxygen molecule to form two molecules of water.

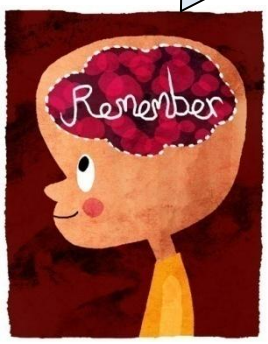
We can represent this process with a chemical equation like this:

$$2\ H_2\ (g) + 1\ O_2\ (g) \rightarrow 2\ H_2O\ (l)$$

In this chemical equation we can distinguish two type of numbers: **subscripts** that inform of molecules composition and **estequiometric coefficients** that inform us what number of molecules or atoms react in a chemical reaction. When we have the same number of atoms in every part of the equation we can say that the chemical equation is **balanced**.

YOU CAN'T CHANGE SUBSCRIPTS IN A MOLECULE BECAUSE IF YOU CHANGE SUBSCRIPTS THE SUBSTANCE IS DIFFERENT.

TO BALANCE A CHEMICAL EQUATION YOU ONLY CAN ADJUST ESTEQUIOMETRIC COEFFICIENTS TO ACHIEVE THE EQUALITY OF NUMBER OF ATOMS IN EVERY PART OF THE EQUATION.



Our chemical equation balancing method will be by **inspection**. You can find an explanation of this method in the next link.

A.17. Balance by inspection the next chemical equations:

1. _____ H_2 + _____ O_2 → _____ H_2O
2. _____ N_2 +_____ H_2 →_____ NH_3
3. _____ S_8 + _____ O_2 → _____ SO_3
4. _____ N_2 + _____ O_2 → _____ N_2O
5. _____ HgO → _____ Hg + _____ O_2
6. _____ CO_2 + _____ H_2O → _____ $C_6H_{12}O_6$ + _____ O_2
7. _____ Zn + _____ HCl → _____ $ZnCl_2$ + _____ H_2
8. _____ $SiCl_4$ + _____ H_2O → _____ H_4SiO_4 + _____ HCl

Adapted from this link

A.18. Balance by inspection the next chemical equations and then check yourself:

Balancing Chemical Equations Worksheet

Balancing Chemical Equations Worksheet-Answers

A.19. Another balance exercise in:

Tutorial on Balancing Equations

4. 2. A compound substance is not the same as a mixture of substances

A.20. The aim of this activity is to correctly distinguish a compound substance from a mixture of substances. Considering water and a mixture of hydrogen and oxygen answer these questions:

a) Draw how you imagine water molecules when you boil this substance.

b) Draw how you imagine water, at microscopic level, when you decompose this substance by electricity.

c) Distinguish the types of changes, physical or chemical, in the previous processes.

d) Look for information about properties of $H_2(g)$, $O_2(g)$ and $H_2O(l)$.

e) Which of these substances do you think permits fish to breathe?

f) Why can fish breathe in water?

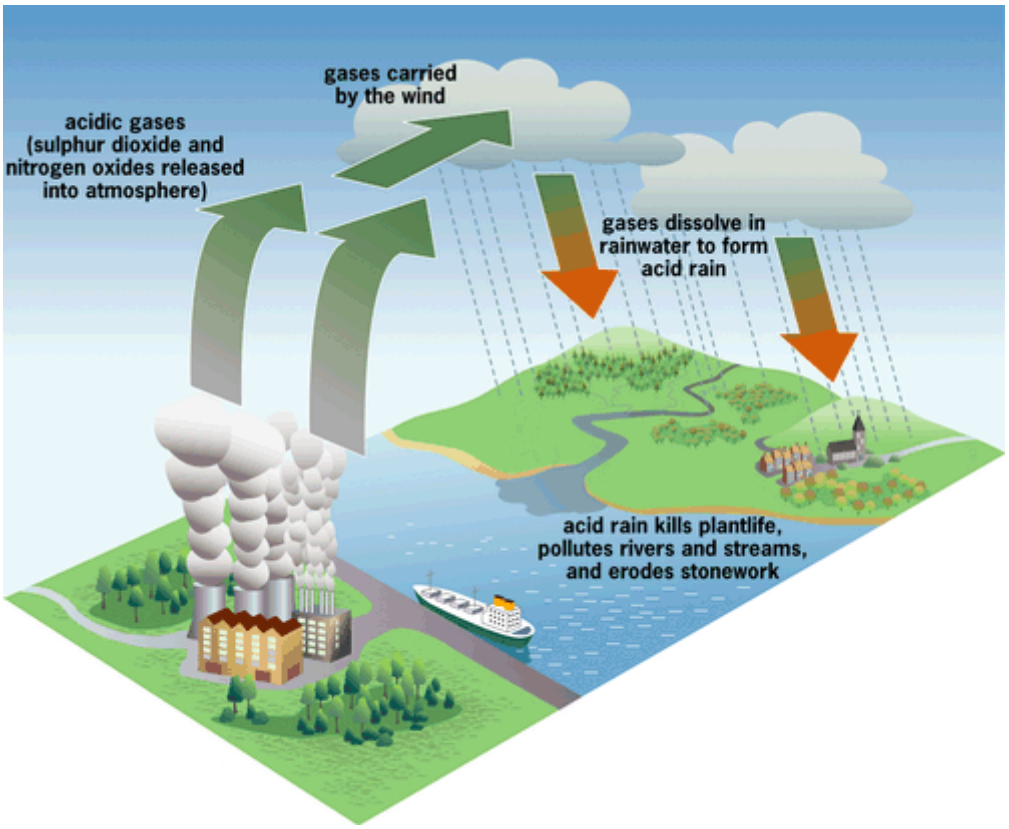
g) Sometimes, normally in summer, a lot of dead fish appear in a lake. Look for information about the cause of this phenomenon.

A.21. Complete the next table and consider a general conclusion about a compound substance and a mixture of substances with the same elements.

	Properties	**Draw molecules or atoms**
H_2 (g)		
Cl_2 (g)		
HCl (g)		
N_2 (g)		
H_2 (g)		
NH_3 (g)		
C (s)		
O_2 (g)		
CO_2 (g)		
Fe (s)		
O_2 (g)		
Fe_2O_3		

5. WE ARE MODIFYING THE ATMOSPHERE COMPOSITION

5.1. Acid rain



A.22. Read the next article in Wikipedia about acid rain and answer the next questions:

a) Which chemical processes produce acid rain?

b) Summarize the main adverse effects.

c) Are the adverse effects of acid rain local or global? Why?

5.2. Greenhouse effect and climatic change

Nowadays the globally averaged temperature near the Earth's surface is increasing. Scientists are sure that the cause of this change are human activities and the greenhouse effect.

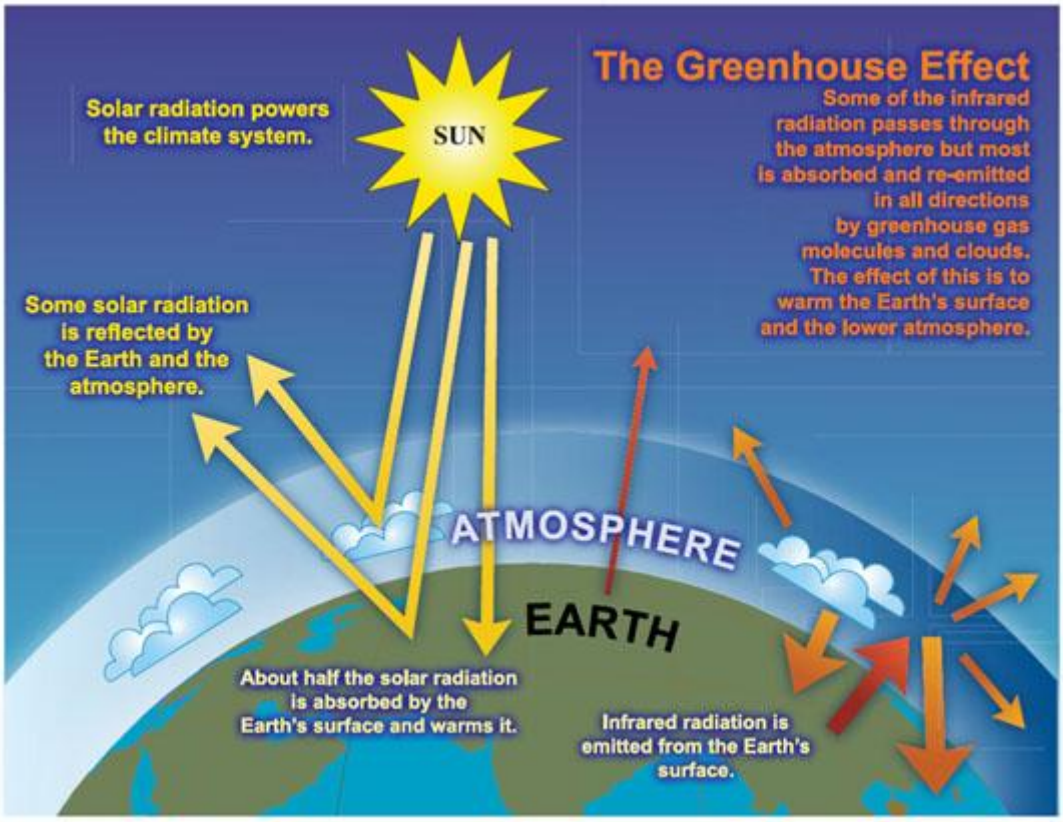
A.23. To understand the greenhouse effect see the next flash animation. Look for information and answer these questions:

a) What is the main cause of the greenhouse effect?

b) Why are we speaking about the greenhouse effect in a chemical reactions unit?

c) Which kind of chemical reactions produce carbon dioxide?

d) Why is it so difficult for countries to reduce their greenhouse effect gases?



A.24. Seeing the next links discuss in small groups the meaning of the graphics. What general conclusion can you extract?

Globally averaged temperature near the Earth's surface versus time.

Carbon dioxide concentration versus time.

Arctic ice surface versus time.

6. CHEMICAL REACTIONS WEBQUESTS

WebQuest 1: Chemical reactions

WebQuest 2: The chemistry of fireworks

WebQuest 3: To react or not to react? That is the question

BIBLIOGRAPHY

Hierrezuelo Moreno J. et al.: *Física y Química, 3º E.S.O.* Editorial Elzevir (Granada, 2007).

WEBGRAPHY

http://chemistry.about.com/library/formulabalance3.pdf

http://chemistry.about.com/library/formulabalance3answers.pdf

http://depts.washington.edu/chemcrs/bulkdisk/chem110A_aut01/notes_Week_5.pdf

http://en.wikipedia.org/wiki/Acid_rain

http://en.wikipedia.org/wiki/File:Instrumental_Temperature_Record.png

http://en.wikipedia.org/wiki/History_of_the_periodic_table

http://en.wikipedia.org/wiki/Periodic_table

http://en.wikipedia.org/wiki/Physical_change

http://encarta.msn.com/encyclopedia_761567432_2/Atom.html

http://lifegem.com/

http://nsidc.org/news/press/2007_seaiceminimum/images/20071001_septembertrend.jpg

http://preparatorychemistry.com/Bishop_Book_4_eBook.pdf

http://staff.fcps.net/jswango/unit4/reactions/balancing%20chem%20equations%20WS1.pdf

http://www.can-do.com/uci/ssi2002/chemicalreactions.html

http://www.cas.org/cgi-bin/cas/regreport.pl

http://www.chemistry.ohio-state.edu/betha/nealChemBal/fr2.1.html

http://www-das.uwyo.edu/~geerts/cwx/notes/chap01/Image18.gif

http://www.epa.gov/climatechange/kids/global_warming_version2.html

http://www.glencoe.com/sec/science/webquest/content/fireworks.shtml

http://www.mc.maricopa.edu/~johnson/animations/atom_helium.swf

http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/ruther14.swf

http://www.pershing.k12.nv.us/emints/montes/webquest/chemicalphysicalchanges/template.htm

http://www.slideshare.net/benwildeboer/chemical-reaction-basics

http://www.slideshare.net/guest801d0b/physical-or-chemical-reaction-presentation

http://www.wfu.edu/~ylwong/balanceeq/balanceq.html

http://www.youtube.com/watch?v=7viGKZW6reE

http://www.youtube.com/watch?v=9BOBJ_fpLDw

http://www.youtube.com/watch?v=Fy4LLdhjsb8

http://www.youtube.com/watch?v=Mx5JJWI2aaw

http://www.youtube.com/watch?v=lP57gEWcisY

http://www.youtube.com/watch?v=ul4xRy8hcsQ

http://www.youtube.com/watch?v=XcBAJ0NMaII

http://youtu.be/A5H6DVe5FAI

http://youtu.be/R6bBs2D0cpA

APPENDIX 1: GENERAL VOCABULARY OF THE UNIT

APPENDIX 2: SPECIFIC VOCABULARY OF THE UNIT