Teaching chemistry and physics to students in the 3rd curs of ESO, by using the bilingual educational program CLIL (*Content and Language Integrated Learning)*

Student's Material

Consuelo Batalla García
Llicències d'Estudis Retribuïdes
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UNIT 1: ATOMIC STRUCTURE

Content:

Unit 1 Atomic structure

1.1. Dalton's atomic theory
1.2. Components of the atom: electrons, neutrons and protons
1.3. Isotopes
1.4. Electron configuration
1.5. Atomic mass. Molecular mass. Mol
1.6. Molecular mass

Learning Aims:

At the end of the unit, the student will know:

- The postulates of Dalton's atomic theory, which are in force nowadays and which not.
- The characteristics of elemental particles of the atom, electrons, protons and neutrons.
- The difference between atomic number and atomic mass number.
- The meaning of isotope.
- The major uses of radioisotopes.
- How to solve questions related to electronic structure.
- The concept of mol.
- How to calculate the molecular mass of a compound.
- To calculate the number of moles, number of molecules and the mass of a chemical substance.
- To use the appropriate language to answer questions and to communicate with teacher and classmates.

Initial Activities

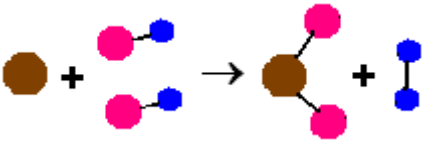
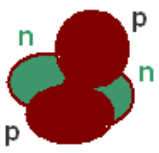
1. What is the name of the tiniest particle of an element?
2. An atom has protons, neutrons and electrons.
   a. Which of these particles are located in the nucleus of the atom?
   b. Which particles have electrical charge?
3. Choose the right answer:
   a. Isotopes are atoms of an element with different number of neutrons.
   b. Isotopes of the same element have different number of electrons.
   c. Isotopes of the same element have different number of protons.
   d. Isotopes of the same element have different atomic mass.
4. Imagine you are John Dalton.
   a. Look for information about his postulates in the following WebPages:

   http://www.iun.edu/~cpanhd/C101webnotes/composition/dalton.html
   http://www.visionlearning.com/library/module_viewer.php?mid=49

   b. Underline the main information.
   c. Create a character in the website: http://www.voki.com/create.php
   d. Write the information about the postulates of John Dalton and listen to its pronunciations.

Key words:

Atom 	An atom is the smallest part of an element. http://www.thefreedictionary.com (dictionary with pronunciation)
Atomic weight 	The average mass of the isotopes of an element.

Chemical Change 	A chemical change is a process where there is a chemical reaction, there is a rearrangement of atoms and new substances are created from the original ones.
Element 	Substance composed of atoms having an identical number of protons in each nucleus.
Isotope 	One of two or more atoms having the same atomic number but different mass numbers.
Law of conservation of mass 	In a chemical reaction, the mass of the products is equal to the mass of the reactants.
Law of defined proportions 	When elements react to form compounds, the compound always contains the same proportion of elements.
Nucleus 	The nucleus of an atom is the central part of the atom, consisting of nucleons (protons and neutrons).

1.1. Dalton's atomic theory

In 1803, **Dalton** proposed the **atomic theory**. He stated the following postulates:

1. Matter is composed of atoms, the smallest particle into which an element can be divided.

2. Atoms belong to the same element are identical and different elements have atoms of different properties.

3. When atoms of different elements combine to form compounds, they do in simple, whole-number ratios.

4. When chemical compounds react, their atoms rearrange to form new substances.

5. Atoms of one element are indestructible and they cannot be changed into atoms of another element.

Questions

1. Choose the correct answer:

1.1. When elements react, their atoms combine in:

a. A simple whole number ratio (unique for each pair of elements)
b. Simple whole number ratios (more than one possible)
c. Arbitrary proportions
d. Pairs
e. Triplets
f. 1:1 ratios

1.2. Dalton viewed chemical change as:

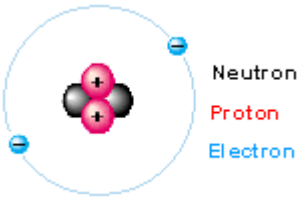
a. A transfer of electrons
b. A transfer of protons
c. A rearrangement of atoms
d. A nuclear exchange
e. Creation and destruction of atoms
f. A change of atoms from one type into another

2. Complete the following sentences:

a. In H_3PO_4 (phosphoric acid) the whole-number ratio for H is …., for P …. and for O …
b. In NaOH (sodium hydroxide) the whole-number ratio for Na is …., for O …. and for H ……

1.2. Components of the atom: electrons, neutrons and protons

An **atom** is the smallest particle of an element.



After 1932, when neutron was discovered, we know atoms are made of **electrons**, **protons** and **neutrons**. Protons and neutrons are located in the nucleus of the atom, and electrons are moving in orbits around the nucleus.

A **proton** has mass and a single positive electrical charge. **Neutrons** also have mass; approximately equal to the proton's mass, but they do not have electrical charge. **Electrons** are extremely light, its mass is 1/1840 of a proton, and have a negative electrical charge equal to the charge of protons.

We define **atomic number** as the number of protons found in the nuclei of an element and **atomic mass number** as the total number of neutrons and protons.

As you can see, most of an atom's mass is in the nucleus. If an atom has the number of electrons equal to the number of protons its total electrical **charge** is equal to **zero**. When the atom has more electrons than protons its charge is **negative**, but when the number of electrons is smaller than the number of protons the charge of the atom is **positive**.

An atom with charge is called **ion**, if it has positive charge is called **cation**, but it his charge is negative, it is called **anion**. For example, when sodium, loses an electron it becomes an ion with a +1 charge (Na^+), but if one electron is added to chlorine, it becomes an ion with a -1 charge (Cl^-). .

Questions:

1. Choose the right answer:

1.1. What determines the element that an atom belongs to?

a. The number of neutrons.
b. The number of protons.
c. The number of orbitals
d. All of the above

1.2. Atoms of a certain isotope have 73 neutrons and a mass number of 123. How many protons, neutrons, and electrons does it have?

a. 73, 73, 50
b. 50, 73, 50
c. 50, 50, 73
d. 73, 50, 73

1.3. How many protons does an atom of calcium have in its nucleus?

a. 40
b. 10
c. 60
d. 20

1.4. Neutrons are particles ...

a. Without charge
b. Without mass
c. Positively charged
d. Negatively charged

1.5. $^{14}_{6}C$ and $^{16}_{8}O$ are examples of atoms with the same number of

a. Protons
b. Electrons
c. Nuclear particles
d. Neutrons

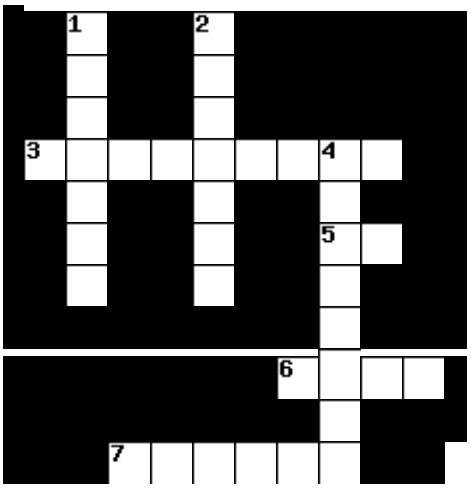
1.6. What do we call positively charged atoms?

a. Anions
b. Cations
c. Oxides
d. Atoms

1.7. What is the symbol for an ion which has 11 protons and 10 electrons?

a. Na^{+}
b. Mg^{+}
c. Na^{-}
d. Mg^{-}

2.- Crossword:



Across

3. Negatively charged particles that circle the nucleus.

5. The name of one of the types of quarks found in protons and neutrons.

6. The name of one of the types of quarks found in protons and neutrons.

7. Protons and neutrons are made up of these particles.

Down

1. The central part of the atom.

2. Positively charged particles found in the nucleus of the atom.

4. Neutral particles found in the nucleus of the atom.

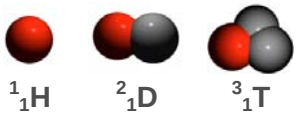
3.- Mach the following words: *proton number, nucleon number, element, nucleus, atom, proton, neutron, electron, isotope,* with its definition:

- A substance made from only one type of atom.
- The smallest piece of an element.
- The central part of an atom containing protons and neutrons.
- A subatomic particle that carries a positive charge.
- A subatomic particle that carries no charge.
- Number of protons in a nucleus.
- Number of particles in a nucleus.
- A subatomic particle that carries a negative charge.
- Atoms with the same number of protons but different number of neutrons.

4.- Complete the following table:

Element	Symbol	Protons	Neutrons	Electrons	Atomic Mass	Atomic Number
Calcium				20	40	
Sodium		11	12			
Hydrogen		1			1	
Nitrogen			7	7		
Sulphur			16	16		
Iodine		53			127	
Chlorine					35	17
Iron			30	26		
Uranium					238	92
Silver		47			108	
Gold			118			79

1.3. Isotopes



Isotopes are atoms of the same element (the same number of protons and electrons) with different numbers of neutrons. For example, hydrogen has three major isotopes (in this case they use different names): **hydrogen** with no neutrons in nucleus; **deuterium**, with one neutron, and **tritium**, with two neutrons.

Radioisotopes, radioactive forms of atoms, can be used in medicine to localize or treat tumours or diseases; they are also useful as smoke detectors, irradiation of food, etc. Look in the following web site: **http://www.ausetute.com.au/nuclesum.html** to complete the following paragraphs:

a. Carbon-14 is used to determinate the age of carbon-containing artefacts up to about …….. years

b. Sodium-24 is used to locate ……. in water pipes, to study body ……..

c. Iodine-131 is used as medical tracer to study and treat the …… gland

d. Uranium-235 is used as a …….. for most nuclear reactors

e. Cobalt-60 is used in cancer treatment as ……. cells tend to be more susceptible to radiation than other cells.

Questions:

1. What is the definition of an isotope? What is the difference between an isotope and an element?

2. Choose the right answer:

2.1. What do we call atoms with the same number of protons but different numbers of neutrons?

a. Isotopes
b. Anions.
c. Cations
d. Inorganic compounds

2.2. What of the following statements are true?

a. Atoms with the same number of protons but different number of neutrons are called ions
b. A subatomic particle that carries a positive charge is called electron
c. In the atoms the number of protons usually is equal to the number of neutrons.
d. The central part of an atom containing protons and neutrons is called nucleus

3.- Complete the following table:

Isotope	Protons	Neutrons	Electrons	Atomic Mass	Atomic Number
		1	1		
	6			14	
	8	7			
			90	228	
				213	84
		15			15
	1	0			

Some isotopes are **unstable**, they are **radioactive**. For this reason, their nucleus decay giving out radiation. This kind of isotopes release **alpha**, **beta**, **positron**, **neutron** particles and **gamma** rays. Such isotopes are called **radioactive isotopes.**

1. Look for additional information about the radioactive series in the website: **http://library.thinkquest.org/C006669/data/Chem/nuclear/natural.html.**

2. Explain the characteristics of **alpha**, **beta**, **positron**, **neutron** particles and **gamma** rays

Write the particle that is missing in the following equations:

$^{14}_{6}C \rightarrow {}^{14}_{7}N + \ldots\ldots\ldots\ldots$

$^{40}_{19}K + {}^{0}_{-1}e \rightarrow \ldots\ldots\ldots\ldots$

$^{239}_{92}U \rightarrow {}^{239}_{93}Np + \ldots\ldots\ldots\ldots$

$^{222}_{86}Rn \rightarrow {}^{4}_{2}He + \ldots\ldots\ldots\ldots$

$^{216}_{84}Po \rightarrow {}^{212}_{82}Pb + \ldots\ldots\ldots\ldots$

$^{225}_{89}Ac \rightarrow {}^{221}_{87}Fr + \ldots\ldots\ldots\ldots$

The **half life** of an isotope is the period of time it takes for half of the parent isotope to decay. For example, if the half live of For example, the half life of ^{11}Be is 13,81 s, if we have 1 g of ^{11}Be, after 13,81 seconds we'll have 0,5 left.

Element	Symbol	Half-life	Radiation
Cobalt	^{60}Co	5,26 years	gamma
Strontium	^{90}Sr	28,1 years	beta
Cesium	^{137}Cs	26,6 years	beta
Americium	^{241}Am	458 years	alpha / gamma

http://www.izotop.hu/radtech/mray3.htm

Questions:

1. A radioactive isotope decays for 75.000 years. At the end of this time 25% of the isotope remains. What is the half life of this isotope?

2. The half life of a radioactive isotope is 4.000 years. How old is a material in which 6,25% of the parent isotope remains?

3. Look in the applet: **http://www.colorado.edu/physics/2000/applets/iso.html** for the radioactive isotopes.

a. What is the half live of ^{13}N?
b. Tell the name of three stable isotopes.

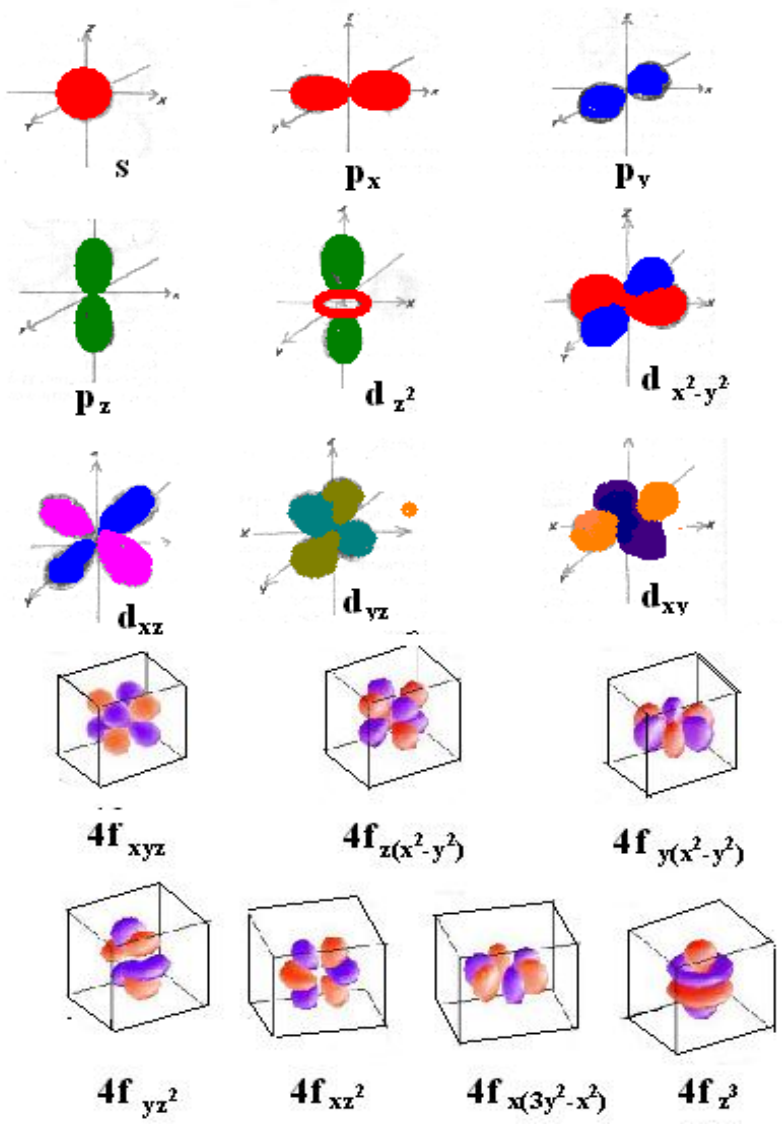
1.4. Electron configuration

The **electron configuration** of an atom informs about the way is electrons are arranged in an atom. Electrons are distributed in different energy levels (1, 2, 3, …), each level has sublevels (s, p, d and f) with different **orbitals** where we can find the electrons.

Sublevel	Orbital	Maximum number of electrons
s	1	2
p	3	6
d	5	10
F	7	14

http://library.thinkquest.org/10429/low/eleconfig/electron.htm

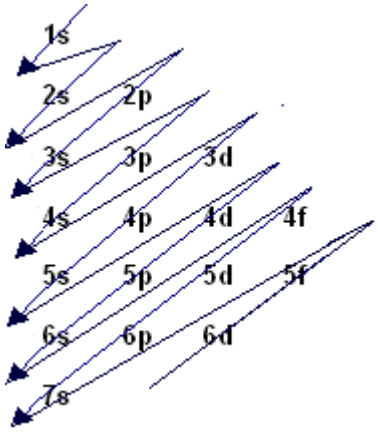
The orbitals have different shape:



http://www.gly.uga.edu/schroeder/geol3010/electronshapes.gif
http://www.chem.tamu.edu/rgroup/hughbanks/courses/673/handouts/4f_orbitals.jpg

Example: The electronic configuration of sodium is: **1**s^2 **2**s^2 **2**p^6 **3**s^1. The first number (**1, 2, 3**) indicates the **energy level**. The letter is the **sublevel** and the number in superscript is the **number of electrons in the sublevel.**

The following diagram will help you to remember to fill the orbitals in order of increasing energy (follow the arrows):



Questions:

1.

a. Explain what information gives the electron configuration about the electrons and the elements of the Periodic Table.

(Consult the webpage **http://education.jlab.org/qa/electron_config.html**)

b. Write the previous answer in webpage **http://vozme.com/index.php?lang=en** and listen the pronunciation.

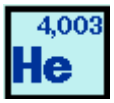
2. Write the electron configuration of the following elements: potassium, chlorine, oxygen, calcium, phosphorus and aluminium.

(Consult the webpage **http://www.chemguide.co.uk/atoms/properties/elstructs.html**)

(Check your answers in the applet **http://www.chemcollective.org/applets/pertable.php**)

3. Tell the name of the atoms with the following electronic configuration:

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2$
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^4$
$1s^2 2s^2 2p^6 3s^1$
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^3$
$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^1$



1.5. Atomic mass. Molecular mass. Mol

Atomic mass (or **atomic weight**) of an element is the average mass of its isotopes. As the atoms have a very small mass, the atomic mass is expressed as the mass in grams of that element which is numerically equal to its atomic mass; in this case we are talking about the mass of one mol of atoms. Atomic mass is represented in the Periodic Table, for example, the atomic mass of helium is 4,003 $g \cdot mol^{-1}$.

Molecular mass (**molecular weight**) is the mass of one molecule of a substance; it is expressed in atomic mass units (amu). Atomic mass unit is equal to one-twelfth the mass of one atom of carbon-12.

Molar mass (**molar weight**) is the mass of one mole of a substance. It is expressed in $g \cdot mol^{-1}$.

Steps to calculate the molecular mass of a compound:

1. In the Periodic Table, look up the atomic masses of all the elements in the compound.
2. Multiply each element's atomic mass by the number of atoms present in the compound.
3. Sum all the atomic masses.

Example: Calculate the molecular mass of $CaCO_3$

Element	Atomic Mass	x number of atoms	Molecular Mass
Ca	40	40	40 + 12 + 48 = **100 g · mol^{-1}**
C	12	12	
0	16	48	

Mol is a number of particles. This number is called Avogadro's number. One mol of particles contain 6.022045 x 10^{23} particles

Questions

1. Calculate the molecular mass of the following compound:

- **a.** H_2SO_4
- **b.** NaOH
- **c.** CO_2
- **d.** $CaCO_3$
- **e.** H_2O
- **f.** KNO_3
- **g.** $C_6H_{12}O_6$
- **h.** Li_2SO_4
- **i.** $Ba(OH)_2$
- **j.** $(NH_4)_3PO_4$
- **k.** $FeCl_2.4H_2O$
- **l.** $Na_2CO_3.10H_2O$

Check your answers in webpage
http://environmentalchemistry.com/yogi/reference/molar.html (Javascript Calculator).

2. How many moles of atoms are contained in:

- **a.** 7 g of nitrogen?
- **b.** 16 g of oxygen?
- **c.** 2,7 g of aluminium?

3. What is the mass, in grams of:

- **a.** 2 moles of helium?
- **b.** 0,5 moles of copper?
- **c.** 10^{20} atoms of sulphur?
- **d.** $3 \cdot 10^{30}$ atoms of potassium?

4. Calculate the number of atoms in:

- **a.** 10^{-5} moles of atoms of lithium
- **b.** $1,5 \cdot 10^{2}$ moles of atoms of hydrogen
- **c.** $4 \cdot 10^{-10}$ moles of atoms of nickel

5. Calculate the number of moles in:

- **a.** 20 g of NaOH
- **b.** 9 g of H_2O
- **c.** 196 g of H_2SO_4
- **d.** 120 g of $CaCO_3$

6. Calculate the mass of the following:

- **a.** 2 moles of hydrogen molecules, H_2
- **b.** 0,1 moles of sulphuric acid, H_2SO_4
- **c.** 6,5 moles of nitric acid, HNO_3

http://www.carlton.srsd119.ca/chemical/molemass/moles6.htm (in this website you will find extra exercises with solutions)

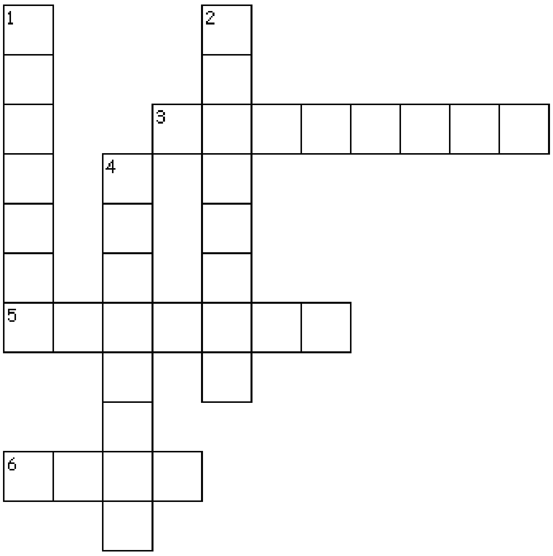
7.

a. Look for eight words related to this unit

V X A V I W D V Q C E Z E E N
V B X Z K M R A X B R P L R O
G E G O E O B C V C O E B P R
R S H H V L S B O T C N O F T
N Q P G H E B G O T T N I X U
S K W P I C T S R F Q E P S E
H U X M G U I O G R N E Q Z N
G I E N Y L N C A Y F T U V F
Y W U L F E P E C X R R C Z P
R W N J C J Z Y K A W E N H M
N Z L N I U I P Z L T Q V W Z
P W P X U H N P R O T O N J L
Q O L D I T N E M E L E M Q Y
M B N L V P J P K B N W S W D
Y Y C R V B Y F R O J B Q D L

b. Write by alphabetical order the previous words and define them.

8. Criss-cross



Across

3. The smallest particle of a compound
5. Central part of the atom
6. A small particle

Down

1. Particle without charge
2. Atoms with different number of neutrons
4. Particle moving in the electronic cloud of an atom

9.-

Cryptogram: Write the missing letters and find a sentence related to isotopes.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
18		20		15				3			9	5			11			6	12						

_ A _ I _ A C T I _ E   I S _ T _ P E S   A _ E
13 18 22 3 19 18 20 12 3 21 15   3 6 19 12 19 11 15 6   18 13 15

_ S E _   T _   _ E T E C T   A _ _   T _ E A T   T _ M _ _ _
10 6 15 22   12 19   22 15 12 15 20 12   18 25 22   12 13 15 18 12   12 10 5 19 10 13

S ,   I _   A _ _ I C _ L T _ _ E ,   I _   _ _ _ _
6 ,   3 25   18 4 13 3 20 10 9 12 10 13 15 ,   3 25   17 19 19 22

P _ E S E _ _ A T I _ _ ,   I _ _ _ S T _ I E S ,
11 13 15 6 15 13 21 18 12 3 19 25 ,   3 25 22 10 6 12 13 3 15 6 ,

T _   _ E _ E _ A T E   E L E C T _ I C   P _ _ E _ ,
12 19   4 15 25 15 13 18 12 15   15 9 15 20 12 13 3 20   11 19 1 15 13 ,

E T C .
15 12 20 .

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

Electron	☐
Proton	☐
Neutron	☐
Element	☐
Atomic mass	☐
Molecular mass	☐
Mole	☐
Nucleus	☐
Electron configuration	☐

2.- Tick the one you think is your answer:

	I know very well	**I need some revision**	**I need some more help**
I know atoms are made of protons, neutrons and electrons.			
I know what is the difference between isotopes of the same element.			
I can remember the Dalton's postulates			
I understand the meaning of the electron configuration			
I know how to calculate molecular masses			
I know the difference between mole, molecule and atom.			
I understand what half life of an isotope means.			
I know what happens when an atom loses or gain electrons.			

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.

UNIT 2: THE PERIODIC TABLE

Content:

Unit 2 The periodic Table

2.1. Structure of the Periodic Table

2.2. Correlation with electron configuration

2.3. Metals, non-metals and semimetals

Learning Aims:

At the end of the unit, the student will know:

- How elements are arranged in the Periodic Table.
- The relationship between the electron configuration of an element and its position in the Periodic Table.
- The symbols of common elements.
- The main properties of metals, non-metals and semimetals.
- The uses of some elements in the everyday life.
- To use the computer to strengthen language and improve his/her knowledge.
- To use the appropriate language to answer questions and to communicate with teacher and classmates.

Initial Activities

1.  Match each word, on the left column with the appropriate words on the right column:

Bad electricity and heat conductors Malleable Fragile Low density Shiny Brittle High density Good electricity and heat conductors Dull Hard	Metal Non-metal

http://www.bbc.co.uk/schools/ks3bitesize/science/chemistry/m_m_physical_props_intro.shtml

2.  How many groups have the Periodic Table? How many periods? 

3. Where are located non-metals in the periodic table:

a. left; **b.** right; **c.** centre.

4. The elements with characteristics of both metals and non-metals are called:

a. noble gases; **b.** metalloids; **c.** halogens; **d.** alkali earth metals.

5. Imagine you are Dmitri Ivanovich Mendeléiev.

a. Look for information about his biography (birth, family, studies, profession, predictions, etc)

b. Underline the main information.

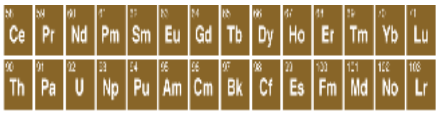
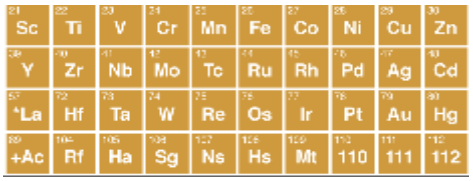
c. Create a character in the website: **http://www.voki.com/create.php**

d. Write and comment the main information with your classmate.

Key words:

Boiling point 	Temperature at which a liquid goes from liquid to gas.
Brittle 	Easy to break; fragile
Conductor 	Substance that conducts heat, light, sound, or an electric charge.

Density 	Mass that the unit volume has
Ductile 	It can be able to be shaped into threads without breaking
Group 	Column of the Periodic Table
Malleable 	It can be able to be shaped into sheets without breaking
	Temperature at which a liquid goes from liquid to gas.
Metal 	Element of the periodic Table, good conductor of electricity and heat
Non-metal 	Element of the periodic Table, bad conductor of electricity and heat

Period 	Horizontal rows in the periodic table
Rare earths 	Any element of the lanthanide and actinide series in the Periodic Table.
Semimetal or metalloid 	Non metallic element with some of the properties of a metal.
Shiny 	Reflect light, bright
Transition metals 	Metals located between groups 3 and 12 of the Periodic Table.

Read the words aloud, the website **http://www.thefreedictionary.com/brittle** (free dictionary with pronunciation) will help you to do it.

2.1. Structure of the Periodic Table

In the **periodic table** elements are arranged in horizontal rows, or **periods**, in order of **increasing atomic number**. The elements with similar chemical properties fall directly beneath one another in the same column, **group or family**.

There are **7 periods** and **18 groups**.

Groups have different names: **alkali metals** (group 1); **alkaline earth metals** (group 2); **transition metals** (groups 3 to 12); **boron group** (group 13); **carbon group** (group 14); **nitrogen group** (group 15); **chalcogens** (group 16); **halogens** (group 17); **noble gases** (group 18) and **lanthanides** (14 elements after lanthanum) and **actinides** (the 14 elements after actinium)

Hydrogen occupies a unique position at the top of the periodic table. It does not fit naturally into any Group

Questions

1. Tell the name of the liquid elements in the Periodic Table

2. Choose the right answer:

2.1. What of the following elements are halogens?

a. Iodine.
b. Sodium.
c. Iron
d. Chlorine

2.2. Group 2 of the periodic table is called.

a. Halogens
b. Alkali metals
c. Alkali earth metals
d. Noble gases

2.3. Which element has the largest mass?

a. Lithium
b. Rubidium
c. Sodium
d. Potassium

2.4. Which element has the lowest boiling point?

a. Neon
b. Helium
c. Radon
d. Xenon

2.5. Which element is a transition metal?

a. Phosphorus
b. Rubidium
c. Copper
d. Carbon

2.6. The elements known as the alkali metals are found in Group

a. 14
b. 2
c. 1
d. 16

2.7. Under ordinary, room temperature conditions, the greatest number of elements are

a. Solids
b. Liquids
c. Gases
d. Plasmas

2.8. How many naturally occurring elements are found on the earth?

a. 117
b. 92
c. 90
d. 104

2.9. The most common elements in Earth's crust are:

a. Calcium and carbon
b. Aluminium and iron
c. Sodium and hydrogen
d. Oxygen and Silicon

2.10. The most common elements in Earth's atmosphere are:

a. Oxygen and hydrogen
b. Nitrogen and oxygen
c. Oxygen and carbon
d. Oxygen and Silicon

2.11. In the Periodic Table, elements are arranged by:

a. Number of protons
b. Atomic number
c. Atomic mass
d. Physical properties

2.12. Elements in the same group of Periodic Table, elements are arranged by:

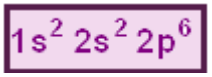
a. Number of protons
b. Atomic number
c. Atomic mass
d. Physical properties

3. Write the symbol of the following elements:

Name	Potassium	Selenium	Manganese	Iodine	Hydrogen	Carbon	Phosphorus
Symbol							
Name	Calcium	Lithium	Tin	Sulphur	Strontium	Helium	Osmium
Symbol							
Name	Boron	Lead	Silicon	Sodium	Cobalt	Rubidium	Thallium
Symbol							

4. Write the name of the following elements

Name								
Symbol	Cs	Ra	Al	Fe	Fr	Ni	Ir	N
Name								
Symbol	V	Be	Cd	Ga	Cr	Mg	Ba	Au
Name								
Symbol	O	W	Sb	Pt	Cl	In	Zn	As

2.2. Correlation with electron configuration 

According to the electron configuration, Periodic Table can be divided in different blocs:

Te **s-block** electrons are been added to outer (s) sublevels.

The **p-block** electrons are been added to outer (p) sublevels

The **d-block** electrons are been added to outer (d) sublevels.

The two sets of 14 elements each, located at the bottom of the Periodic Table (**rare earth**), electrons are been added to outer (f) sublevels.

Elements in the same **Group** have the same **valence electrons*** but different levels. The number of period is the same that the number of the energetic level of the valence shell.

Elements in the s-block have very similar properties.

Note: ***Valance electrons** are the electrons in the outermost principal energetic level.

Questions

1. Choose the right answer:

1.1. An atom of an element belonging to the alkali metal family has

a. One outer shell electron.
b. Two outer shell electrons.
c. Three outer shell electrons.
d. Four outer shell electrons.

1.2. An atom of an element belonging to the alkali earth metal family has

a. One outer shell electron.
b. Two outer shell electrons.
c. Three outer shell electrons.
d. Four outer shell electrons.

1.3. An atom of an element belonging to the halogen family has

a. One outer shell electron.
b. Two outer shell electrons.
c. All outer shell electrons but one.
d. Three outer shell electrons.

1.3. An atom of an element belonging to the noble gas family has

a. One outer shell electron.
b. Two outer shell electrons.
c. All outer shell electrons.
d. Three outer shell electrons.

2. What the elements of the same group have in common?

3. What the elements of the same period have in common?

4. The electron configuration of the elements, A, B, C, D, E, F and G is:

A: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2$

B: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$

C: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^4$

D: $1s^2 2s^2 2p^6 3s^1$

E: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

F: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^3$

G: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^1$

Tell the group and period they belong to:

2.3. Metals, non-metals and semimetals  

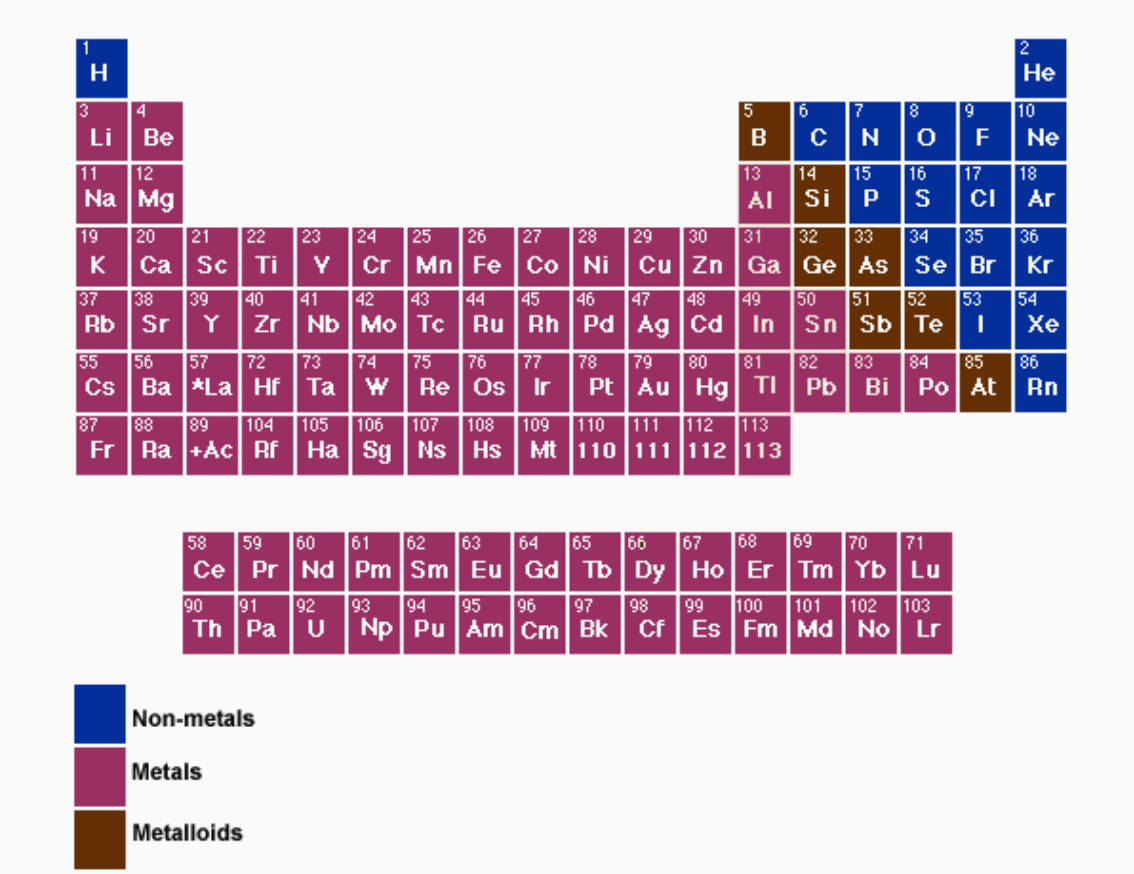
The elements of the Periodic Table also are divided in three groups: on the left are found **metals**; **non-metals** are located on the right; and **metalloids** are situated on the stair-step line.

Most elements are **metals**. They are **shiny**, **good conductors** of heat and electricity, have a high **density**, **high melting** and **boiling point** and they are **ductile** (can be drawn out into thin wires) and **malleable**(can be hammered into thin sheets). Metals lose electrons and corrode easily.

Non-metals are **dull**, **brittle** (breaks easily), **poor conductor** of heat and electricity. They have low **density** and **low melting** and **boiling point**. They tend to gain electrons.

When metals and non-metals react a ionic compound is formed.

Metalloids are solids, **ductile** and **malleable;** they can be **shiny** or **dull**;. They conduct heat and electricity better than non-metals but not as well as metals



http://www.windows.ucar.edu/tour/link=/earth/geology/images/periodic_table_gif_image.html&edu=high

Questions

1. Name and write the symbol of the metalloid elements.

2. Choose the right answer:

2.1. Which is not a characteristic of a metal?

a. Shiny
b. Malleable
c. Insulators of heat and electricity
d. Usually solid at room temperature.

2.2. Which of the following elements is not a non-metal?

a. Al
b. He
c. S
d. Te

2.3. Which is a characteristic of a non-metal?

a. Usually solid at room temperature
b. Malleable
c. Insulators of heat and electricity
d. Ductile.

2.4. Which of the following elements is not a metal?

a. Al
b. K
c. I
d. Be

3.- Copy and complete the paragraph using the following words: *good conductor of heat, react , bridges, airplanes, suitable, aluminum, hard , jewelry, good conductor, copper,.*

The properties of metals make them ……for different uses in daily life: Copper is a …… …… of electricity and is ductile. Therefore …… is used for electrical cables. Gold is used to make …… because is malleable, ductile and difficult to…..... Iron is …….. and strong. Therefore iron is useful to construct…….. Aluminum is used to make saucepans because it is a …… . Because the density of..…….. is low, it is also used to make ……..

4. Use an interactive periodic table and your own knowledge to write a letter explaining how useful metals are. Start by saying how many elements are metals.

Try to fit these words in: **hard, flexible, shiny, strong, conductors, heat, electricity, easy to shape.**

5. Below are lists of the electrical and thermal conductivities of some metal and non-metals:

Metal	Thermal Conductivity ($W \cdot m^{-1} \cdot K^{-1}$)	Electrical Conductivity ($\Omega^{-1} \cdot cm^{-1}$)	Melting Point (ºC)	Boiling Point (ºC)	Density ($g \cdot cm^{-3}$)
Iron	80	$99 \cdot 10^3$	1.538	2.862	7,87
Zinc	116	$166 \cdot 10^3$	419	907	7,14
Copper	400	$596 \cdot 10^3$	1.083	2.562	8,96
Lead	35	$48 \cdot 10^3$	327	1749	11,34
Gold	317	$452 \cdot 10^3$	1.064	2.856	19,3
Silver	429	$630 \cdot 10^3$	962	2.162	10,49
Non-metal	**Thermal Conductivity ($W \cdot m^{-1} \cdot K^{-1}$)**	**Electrical Conductivity ($\Omega^{-1} \cdot cm^{-1}$)**	**Melting Point (ºC)**	**Boiling Point (ºC)**	**Density ($g \cdot cm^{-3}$)**
Sulphur	0	0	113	445	1,92
Oxygen	0	0	-218	-183	0,0014
Graphite	129	$6 \cdot 10^3$	3.652	-	1,9-2,3

Websites used: http://www.standnes.no/chemix/periodictable/melting-points-table.htm, http://www.standnes.no/chemix/periodictable/electrical-conductivity-elements.htm , http://en.wikipedia.org/wiki/Periodic_table

a. Make one list of **all** the elements in order of decreasing electrical conductivity.

b. One of the non-metals is a conductor of electricity, which one?

c. Make a list of all the elements in order of their thermal conductivity, starting with the best.

d. Write a general rule for the electrical and thermal conductivities of metals and non-metals. Are there any exceptions to your rule?

e. Tell the state of each element:

e.1. At room temperature
e.2. At 500ºC

f. Make a list of all the elements in order of increasing density.

6.
a. Divide the following statements in two columns (one for metals and one for non-metals:

Electricity conductors	**Do not conduct electricity**	**High melting point**
Good heat conductors	**Bad heat conductors**	**Solids, liquids or gases**
High melting point	**Low melting point**	**Strong, hard to break**
Low boiling point	**High boiling point**	**Brittle, easy to break**
Shiny when polished or scratched	**Dull, not shiny**	**Heavy, high density**
Light, low density	**Sonorous, ring like a bell**	**Does not ring like a bell**
Some attract magnets	**Do not attract magnets**	

b. Use this table to make four sentences about unusual metals and non-metals.

Mercury	**is an unusual**	**metal**	**Because**	**it conducts electricity**
Carbon graphite				**it is soft and floats on water**
Sodium		**non-metal**		**it is liquid at room temperature**
Aluminium				**it has a low density**

7. Look for the reaction of lithium, sodium or potassium with water in the following websites: **http://www.seilnacht.com/film/english.html** or **http://www.open2.net/sciencetechnologynature/worldaroundus/akalimetals.html** and using the following cards write a paragraph describing the reaction you have seen. Start writing your observations and then add your conclusions. Compare your answers with your mate's answers:

Lots of bubbles	**Smoke forms**	**A few sparks**	**Reacts very quickly**	**Moves quickly about**
Reacts slowly	**A few bubbles**	**Dissolves**	**Burns with a bright flame**	**Reacts explosively**
Very reactive	**In the middle of the reactivity series**	**At the top of reactivity series**	**Very unreactive**	**Quite reactive**

On the blank cards write down any other observation you made.

Activity:

a. Look for a interactive Periodic Table (for example **http://www.periodictable.com/**, interactive periodic table with pictures)

b. Prepare a Power Point with the following slides:

a.1. Title

a.2. Index

a.3. Different slides that include how it works, groups, periods, information about elements,

a.4. Bibliography

http://science.pppst.com/periodictable.html: In this website you will find different power points very useful to do this activity.

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

Alkaline	☐
Halogen	☐
Noble gases	☐
Transition metals	☐
Actinides	☐
Lanthanides	☐
Metal	☐
Non-metal	☐
Metalloid	☐

2.- Tick the one you think is your answer:

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.

UNIT 3: CHEMICAL BONDING. CHEMICAL COMPOUNDS

Content:

Unit 3 Chemical bonding. Chemical compounds

3.1. Chemical bonding
3.2. Chemical compounds
- **3.2.1.** Oxides
- **3.2.2.** Hydroxides
- **3.2.3.** Hydrides
- **3.2.4.** Binary acids
- **3.2.5.** Oxy-acids
- **3.2.6.** Salts

3.3. Nomenclature and Formulas

Learning Aims:

At the end of the unit, the student will know:

- Atoms bond together with other atoms to make a compound.
- To formulate and name different chemical compounds: oxides, hydroxides, hydrides, hydracids, oxy-acids and Salts
- To use the appropriate language to answer questions and to communicate with teacher and classmates.

Initial Activities

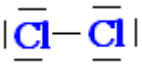
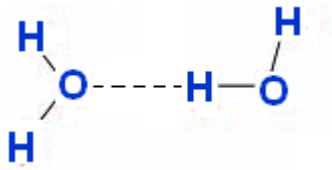
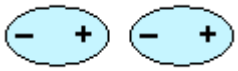
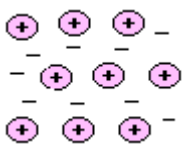
1.  Choose the right statement:

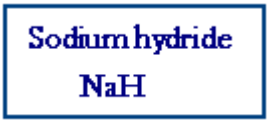
a) Oxides are made of oxygen and another element.
b) A covalent bond occurs between a metal and a non-metal element.
c) Ionic bond involves electron sharing.
d) When an atom loses an electron it becomes negatively charged.

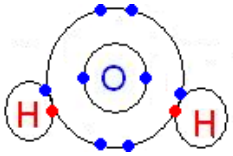
2.  Match a formula in the right column with its appropriate name in the left column.

Ammonia	CO_2
Sodium hydroxide	H_2SO_4
Sulphuric acid	NH_3
Carbon dioxide	KCl
Hydrochloride acid	HNO_3
Potassium Chloride	NaOH
Nitric acid	HCl

Key words:

Ionic bond $Na^+ Cl^-$	Chemical bond between metal and non-metal ions through electrostatic forces http://www.youtube.com/watch?v=xTx_DWboEVs (video, simulation of ionic bond) http://www.visionlearning.com/library/flash_viewer.php?oid=1349&mid=55 (reaction of sodium and chlorine)
Electrical forces 	Forces that bond atoms or molecules together are of electrical character
Covalent bond 	Chemical bond characterized by the *sharing* of pairs of electrons between atoms. http://www.youtube.com/watch?v=1wpDicW_MQQ (video, single covalent bond)
Hydrogen bond 	Attractive force between the hydrogen attached to an electronegative atom (N, O or F) of one molecule and an electronegative atom (N, O or F) of a different molecule.
Van der Waals bond 	Intermolecular attraction between one molecule and a neighbouring molecule.
Metallic bond 	Chemical bond in which mobile valence electrons (electron gas) are shared among positive metallic ions in a crystalline structure
Negative ions Cl^-	Atom or molecule that gains electrons and becomes electrically charged.

Positive ions Na^+	Atom or molecule that loses electrons and becomes electrically charged.
Oxides 	Binary compound of an element with oxygen. http://www.thefreedictionary.com/oxide (dictionary with pronunciation)
Hydroxides 	Chemical compound containing hydroxyl radicals (OH^-).
Hydrides 	Compounds of hydrogen with a metal.
Hydracids 	Acids that does not contain oxygen.
Oxy-acids 	Acids that contain hydrogen, oxygen and a non-metal element.
Salts 	Chemical compound formed by replacing all or part of the hydrogen ions of an acid with metal ions or electropositive radicals. http://www.thefreedictionary.com/salt (Dictionary with pronunciation)



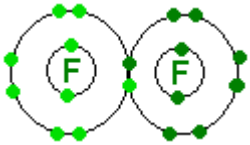
3.1. Chemical bonding

Atoms bond with another atom to make molecules or molecular aggregates. Atoms are held together by **chemical bonds**, attractive forces that keep together the atoms.

A bond is formed when **valence electrons** (atoms that occupies the outermost electron cell) from two atoms interact with each other.

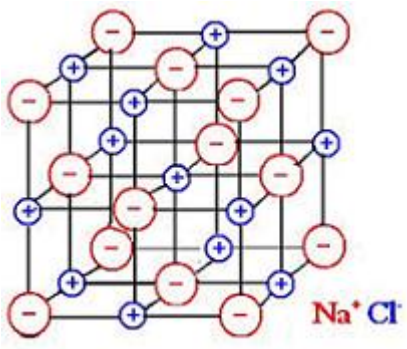
We can differentiate five types of bonds:

1. **Covalent bond:** two atoms share valence electrons between them. Covalent bonds are between non-metals and non-metals or hydrogen and non-metals. They share electrons so that both of them can have a stable octet.



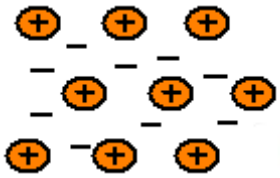
http://www.promotega.org/UGA06004/covalent_bonds.html (simulation of covalent bond)

2. **Ionic bond:** one atom gains a valence electron (forming a negative ion called **anion**) from a different atom, this atom loses the electron and a positive ion or **cation** is obtained. These oppositely charged ions are attracted to each other, forming an ionic bond. The ionic bonds are between metals and non-metals.



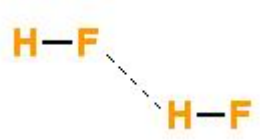
http://www.promotega.org/UGA06004/ionic_bonds.html (simulation of ionic bond)

3. **Metallic bonding:** atoms lose valence electrons; these mobile valence electrons (electron gas) are shared among positive metallic ions in a crystalline structure. This is the characteristic bonding of metals.



4. **Van der Waals bond:** intermolecular attraction between one molecule and a neighbouring molecule.

5. **Hydrogen bond:** attractive force between the hydrogen attached to an electronegative atom (N, O or F) of one molecule and an electronegative atom (N, O or F) of a different molecule.



More information:

http://www.chm.bris.ac.uk/pt/harvey/gcse/struc_bond_welcome.html
http://www.beyondbooks.com/psc92/3.asp
http://www.chemguide.co.uk/atoms/bonding/metallic.html

Questions

1. Choose the correct answer:

1.1. Non-metals and non-metals tend to form ……. bond.
- **a)** Covalent.
- **b)** Ionic
- **c)** Metallic

1.2. Metals and non-metals tend to form ……. bond.
- **a)** Covalent.
- **b)** Ionic
- **c)** Metallic

1.3. Non-metals and hydrogen tend to form ……. bond.
- **a)** Covalent.
- **b)** Ionic
- **c)** Metallic

1.4. Non-metals tend to _____ electrons to become _____ ions.
- **a)** gain, negative.
- **b)** lose, positive.
- **c)** gain, positive
- **d)** lose, negative

1.5. Metals tend to _____ electrons to become _____ ions.

a) gain, negative.

b) lose, positive.

c) gain, positive

d) lose, negative

1.6. When an atom of magnesium loses two electrons, it gets a charge

a) +2.

b) -2

1.7. When an atom of sulphur gains two electrons, it gets a charge _____

a) +2.

b) -2

1.8. Negative ions are called _____

a) electrons.

b) protons.

c) anions.

d) cations.

1.9. Positive ions are called _____

a) electrons.

b) protons.

c) anions.

d) cations.

2. Match one formula of left column with their corresponding bond in right column.

O_2	
NaCl	
HCl	Covalent
H_2O	Ionic
Al_n	Metallic
SO_2	
CaS	

3. Write down the ions formed by the following elements:

a) Sodium

b) Beryllium

c) Fluorine

d) Sulphur

e) Aluminium

3.2. Chemical compounds

A chemical compound is a substance formed by chemical union of two or more different elements bounded together in definite proportion by mass. The elements of a compound can not be obtained from the compound by physical methods.

Later we will speak about different inorganic compounds:

3.2.1. Oxides

Oxides are binary compound of an element with oxygen.

Example: Fe_2O_3: Iron (II) oxide

3.2.2. Hydroxides

Hydroxides are chemical compounds containing hydroxyl radicals (OH^-).

Example: NaOH: Sodium hydroxide

3.2.3. Hydrides

These chemicals compounds are a combination of hydrogen with another element.

Example: NaH: Sodium hydride

3.2.4. Binary acids

These acids do not contain oxygen; they contain hydrogen and a no-metal element of group 16 or 17 of the Periodic Table.

Example: HCl: Hydrochloric acid

3.2.5. Oxy-acids

Oxy-acids contain hydrogen, oxygen and usually a non-metal element.

Example: $HClO_4$: Perchloric acid

3.2.6. Salts

Salts are formed by replacing all or part of the hydrogen ions of an acid with metal ions or electropositive radicals.

Example: Na_2SO_4: Sodium sulphate

3.3. Nomenclature and Formulas

Now is the time to learn a few rules of the **IUPAC nomenclature of inorganic chemistry** (International Union of Pure and Applied Chemistry) to name and formulate inorganic compounds):

1. In binary compounds
   - **a)** The more electropositive element is placed first in the formula.
   - **b)** The more electronegative element is written last and with an ***-ide*** suffix
2. Before each element prefixes are used to indicated the number of atoms: 1 (**mono-**); 2 (**di-**); 3 (**tri-**); 4 (**tetra-**); 5 (**penta-**); 6 (**hexa-**); 7 (**hepta-**); 8 (**octa-**); 9 (**nona-**); 10 (**deca-**). Exception: The prefix **mono-** is not used with the first element.

   Example: NO: nitrogen monoxide;
3. Ion **OH^-** is called **hydroxide**.

   Example: KOH: potassium hydroxide
4. Ion **H^-** is called **hydride**

   Example: NaH: sodium hydride
5. There are some binary compounds with common names: BH_3: Borane; NH_3: Ammonia; PH_3: Phosphane; CH_4: Methane
6. **Binary acids** follow the pattern of ***hydro***element***ic*** acid

   Example: HBr: hydrobromic acid
7. **Ternary acids** follow the pattern of *"**hipo**element**ous**, element**ous**, element**ic**, **per**element**ic**,"* acid, depending on the valence of central atom.

   Example: $HBrO_3$: bromic acid
8. Some elements form two or more different ions with different charges. To distinguish the compounds, its charge is included with its name as a Roman numeral in parentheses.

   Example: Fe_2O_3: iron (III) oxide; FeO: iron (II) oxide
9. In **oxy-salts** suffix ***–ous*** of acid is changed by ***–ite*** and the suffix ***–ic*** by ***– ate***

   Example: $NaNO_3$: sodium nitrate

   Oxy-anions names

   CO_3^{2-} Carbonate ion
   NO_2^-: Nitrite ion
   NO_3^-: Nitrate ion
   PO_3^{3-}: Phosphite ion
   PO_4^{3-}: Phosphate ion
   SO_2^{2-}: Hyposulphite ion
   SO_3^{2-}: Sulphite ion
   SO_4^{2-}: Sulphate ion
   ClO^-: Hypochlorite ion
   ClO_2^-: Chlorite ion
   ClO_3^-: Chlorate ion
   ClO_4^-: Perchlorate ion

Questions

1. Choose the correct answer:

1.1. The chemical formula of the product formed from the reaction between hydrogen and chlorine is:

a) HCl
b) H_3Cl
c) H_5Cl

1.2. The chemical formula of calcium oxide is:

a) Ca_2O
b) CaO
c) CaO_2

1.3. The chemical formula of potassium chloride is:

a) K_2Cl
b) KCl_2
d) KCl

1.4. The chemical formula of potassium sulphate is:

a) K_2SO_3
b) KS_2
e) KSO_4
f) K_2SO_4

2. Write the chemical formula for a compound that has

a) one calcium atom and 1 sulphur atom.
b) two iron atoms and three oxygen atoms.
c) one aluminium atoms and three hydroxyl groups
d) one nitrogen atom and three hydrogen atoms.

3. Write the formula for:

dinitrogen monoxide
nitrogen monoxide
dinitrogen trioxide
dinitrogen pentoxide
carbon monoxide
carbon dioxide
sodium chloride
zinc iodide

4. Match the formulas on the left to their names on the right.

NaOH	hydrochloric acid
HNO_3	sulphuric acid
$Al(OH)_3$	carbonic acid
HF	potassium hydroxide
$Ca(OH)_2$	aluminium hydroxide
H_3PO_4	sulphurous acid
$HClO_2$	sodium nitrate
$HClO_3$	nitric acid
HCl	hydrobromic acid
$NaNO_3$	ammonium hydroxide
H_2CO_3	calcium sulphate
KClO	phosphoric acid
H_2SO_3	chromic acid
KOH	potassium hypochlorite
NH_4OH	magnesium hydroxide
$CaSO_4$	hydrosulfuric acid
$Fe(OH)_3$	hydrofluoric acid
HBr	calcium hydroxide
H_2CrO_4	chlorous acid
H_2S	sodium hydroxide
$Mg(OH)_2$	chloric acid
H_2SO_4	iron(III) hydroxide

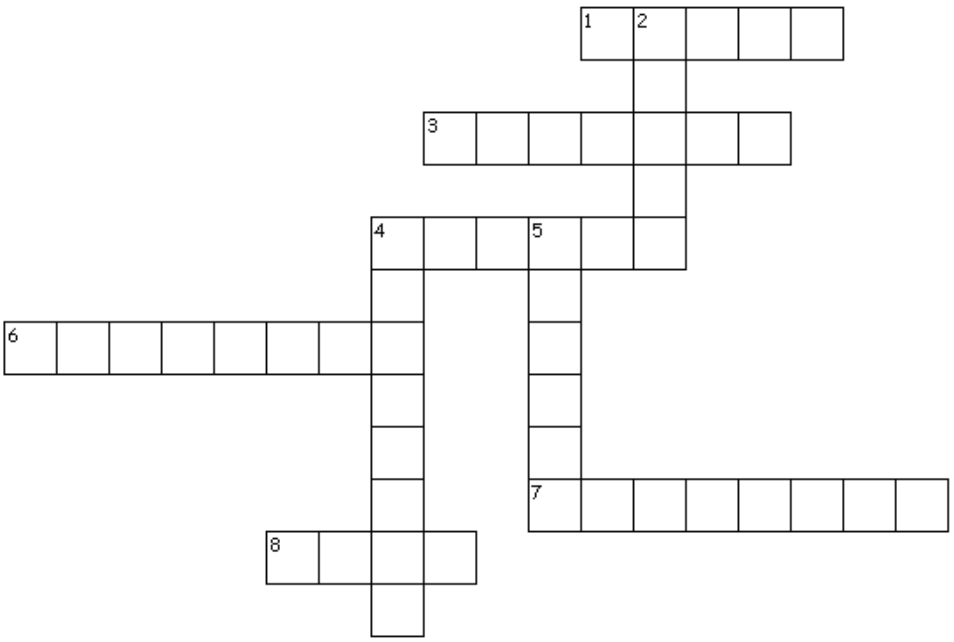
5.  Give the name for the following formulas:

$NaNO_3$
Ag_2CO_3
$(NH_4)_2SO_4$
CuO
Cu_2O
Cr_2O_3
HCl
HBr
H_2S
$HClO_3$
H_2SO_4
HNO_3
H_3PO_3
$HClO_2$
HClO

6. Word search: look for ten words related to nomenclature

R	R	I	S	J	P	E	J	X	C	R	A
U	H	U	A	U	Y	N	D	E	K	W	H
E	D	I	R	F	L	T	S	E	G	P	I
S	D	D	U	A	P	P	D	Q	G	R	K
G	R	I	Z	M	B	I	H	X	H	V	H
T	I	X	X	M	X	N	F	I	M	Y	R
C	A	R	B	O	N	A	T	E	D	T	E
S	L	V	R	N	U	Q	K	R	L	E	T
R	H	D	L	I	G	X	I	A	P	N	A
J	Y	U	N	A	K	D	S	Z	H	I	W
H	A	C	I	D	E	N	A	R	O	B	J
F	L	E	B	U	X	P	V	Q	J	O	V

7. Criss-cross



Across

1. Chemical bond between two ions with opposite charges
3. Compound of hydrogen with another element.
4. Common name of calcium carbonate
6. Chemical bond formed by the sharing of one or more electrons between atoms
7. Name of an element and of a type of bond
8. Substance having a sour taste

Down

2. Binary compound of an element or radical with oxygen
4. Chemical bond characteristic of metals
5. Common name of sodium hypochlorite

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

Covalent bond	☐
Ionic bond	☐
Metallic bond	☐
Hydrogen bond	☐
Van der Waals bond	☐
Oxide	☐
Hydroxide	☐
Hydride	☐
Acid	☐
Salt	☐

2.- Tick the one you think is your answer:

	I know very well	**I need some revision**	**I need some more help**
I know that in covalent bond electrons are sharing.			
I know that an ionic bond occurs by the attraction of positively charged metal and a negatively charged non metall.			
I know that in metallic bond a cloud of electrons is moving around a crystalline structure of positive ions of metallic elements.			
I understand the meaning of a chemical formula.			
I know how to formulate oxides, hydroxides, hydrides and the most common inorganic acids and salts.			

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.

6.- If you have some problem to name or formulate chemical compound, specify it.

UNIT 4: MATTER: ELEMENTS, COMPOUNDS AND MIXTURES

Content:

Unit 4 Matter: Elements, Compounds and Mixtures

4.1. Difference between a pure substance and a mixture.
4.2. Classification of mixtures: homogeneous and heterogeneous.
4.3. Preparation of aqueous solutions.
4.3.1. Mass percentage.
4.3.2. Mass per unit volume.
4.3.3. Moles per cubic decimetre of solution (concentration).

Learning Aims:

At the end of the unit, the student will know:

- To distinguish a pure substance from a mixture.
- To distinguish an element from a compound.
- To distinguish an homogeneous mixture from an heterogeneous mixture.
- To prepare aqueous solutions.
- To work out questions related to mass percentage.
- To work out questions related to concentration.

Initial Activities

1. Using the words: *suspension, atoms, solution, compound, molecule, particles, element, heterogeneous, homogeneous, mixture*, fill in the blanks with the correct word.

a) An _____ is made up of just one kind of atom.
b) Two or more elements chemically combined form a _____.
c) Granite is an example of a _____.
d) A mixture that is not the same throughout is called a _____ mixture.
e) Seawater is an example of a _____ mixture because it is the same throughout.
f) In a _____ one substance is dissolved in another.
g) In a mixture called a _____ the particles are larger and can settle out.

2. What is the difference between distillate water and sea water?

3. Tell if the following statements are true or false:

a) Matter made up of just one kind of element is a compound.

b) Running water is a compound.

c) The components in a mixture can be separated by physical methods.

d) Oil and vinegar is an example of a heterogeneous mixture.

e) In an homogeneous mixture components are well differentiated with the naked eye.

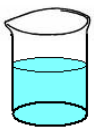
f) An increase in temperature often increases the solubility.

4. Identify each of the following as an element, a compound, a homogeneous mixture or a heterogeneous mixture.

$C_6H_{12}O_6$	O_2	Running water
Bronze	CO_2	Aluminium
Soft drink (Fanta …)	Sugar aqueous solution	H_2SO_4

5. How many grams of sodium chloride are in 200 grams of a 5% solution of sodium chloride?

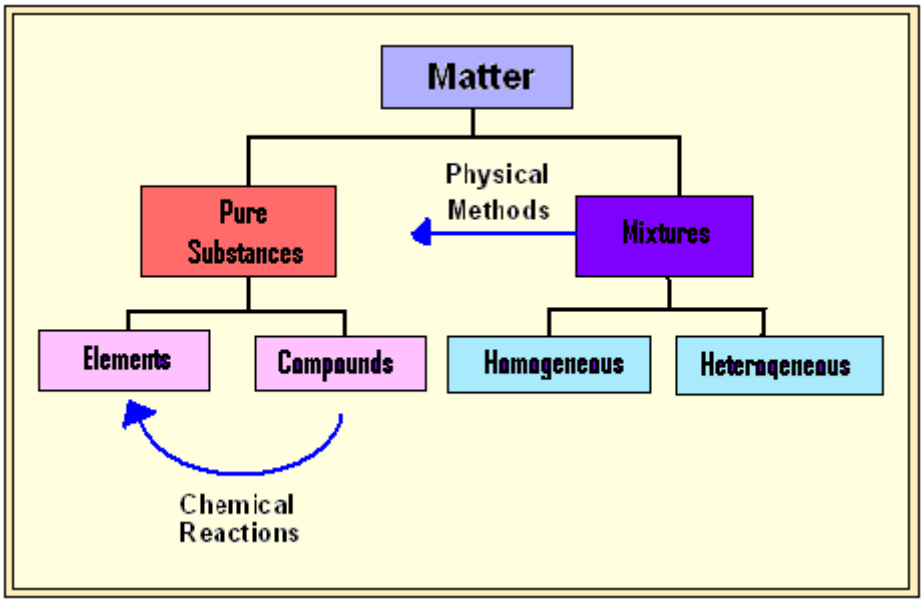
Key words:

Element  Cu	Substance composed of atoms having an identical number of protons in each nucleus.
Compound  $CaCO_3$	Combination of two or more elements in definite proportions that cannot be separated by physical means.
Solution 	Homogeneous mixture of two or more substances that can be separated by physical means.
Homogeneous Mixture 	Mixtures with uniform composition.

Heterogeneous Mixture 	Mixtures with non-uniform composition.
Suspension 	Heterogeneous mixture where particles of one substance are suspended in the other substance.
Miscible 	Can be mixed in all proportions.
Immiscible 	Liquids that cannot mix together.
Foam 	Particles of a gas dispersed throughout a liquid or solid.
Emulsion 	Mixture of two liquids in which particles of one are suspended evenly throughout the other.
Aerosol 	Particles of a solid or liquid dispersed throughout a gas.
Percentage in mass %	Mass of solute contained in 100 grams of solution.
Concentration $mol \cdot dm^{-3}$	Number of moles of a given substance per liter of solution.

http://www.thefreedictionary.com/ (dictionary with pronunciation)

4.1. Difference between a pure substance and a mixture.



Pure substances cannot be separated in smaller particles by physical methods (filtration, distillation, etc). **Elements** and **compounds** are both pure substances. The difference between them is that **elements** consist of only one type of atom whereas **compounds** consist of more than one type of atom combined together in defined proportions.

The difference between **elements** and **compounds** is that elements do not break down in a normal chemical reaction, but we can separate the elements in a compound from a chemical reaction.

Example: Oxygen (O_2) is an element; sucrose ($C_{12}H_{22}O_{11}$) is a compound.

A **mixture** contains more than one pure substance combined together, but these compounds can be separated by physical methods.

Another difference between a **compound** and a **mixture** is that the components of a mixture retain their properties (density, boiling point, etc), but the characteristics of a compound are completely different from the isolated elements.

Example: Quartz (SiO_2) is a compound and granite is a mixture of quartz, feldspar and mica.

Questions

1. Identify each of the following as an element, a compound or a mixture: sodium carbonate; vinegar; platinum; wine; nitric acid; aluminium oxide; drinking water; phosphorus; iodine; calcium fluoride.

2. Tell if the following statements are true or false:

a) Sulphur is a chemical compound.

b) Combination of two or more elements chemically forms a compound.

c) At least two millions of compounds are known.

d) Many compounds have been obtained from plants.

e) Most of the foods we eat are pure substances.

f) An atom is the smallest particle of a compound.

g) In mixtures the properties of their components remains the same.

h) Drinking water is a pure substance.

i) In a mixture two or more substances are chemically combined.

j) In a compound, each of the different substances maintains its own properties.

k) An element can be easily changed into a simpler substance.

3. Choose the correct answer:

3.1. Kind of matter which cannot be broken down into a simpler substance.

a) Compound
b) Mixture
c) Element

3.2. Matter composed of two different substances in no definite ratio.

a) Compound
b) Mixture
c) Element

3.3. Can be separated into individual substances by a physical change.

a) Compound
b) Mixture
c) Element

3.4. Matter that only can be separated into other substances by a chemical change.

a) Compound
b) Mixture
c) Element

3.5. Matter composed of only one kind of atom.

a) Compound
b) Mixture
c) Element

3.6. A chemical symbol represents a

a) Compound
b) Mixture
c) Element

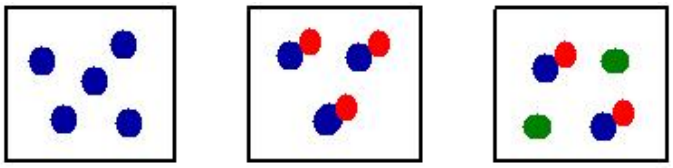
3.7. Which of the following is not a pure substance?

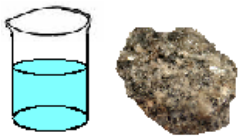
a) Aluminum
b) Carbon dioxide
c) Glucose
d) Bleach

3.8. The word pure substance refers to?

a) Mixtures
b) Solids
c) Solutions
d) Elements and compounds

4. In the following diagrams, atoms are represented by circles; circles with the same size and colour correspond to the same kind of atom. Identify each of the diagrams as a compound element or mixture. Explain the atomic composition of each diagram.





4.2. Classification of mixtures: homogeneous and heterogeneous.

Mixtures can be classified in **homogeneous** or **heterogeneous**.

In **homogeneous mixtures** composition is uniform throughout the material and the component cannot be visually differentiated. Homogeneous mixtures are also known as **solutions**. In solutions, a **solute** is dissolved in another substance, known as a **solvent**. A solution that can hold no more of the solute at a particular temperature is said to be a **saturated**.

Mixture of two liquids in which particles of one are suspended evenly throughout the other are called **emulsions**.

Example: In a solution of salt and water, water is the solvent and salt is the solute. Mayonnaise is an emulsion

In **heterogeneous mixtures** composition is not uniform throughout the material and the component can be visually differentiated.

Example: A mixture of water and flour.

Suspensions, **composites**, **foams** and **colloids** are heterogeneous mixtures.

Suspensions contain solid or liquid particles dispersed in a liquid or gas; these particles are sufficiently large for sedimentation. When particles are less than 1 μm in diameter they do not settle and the mixture is called **colloid**. A suspension liquid droplets or fine solid particles in a gas are called an **aerosol**.

Examples: Sand in water is a suspension and milk is a colloid. Examples of aerosols are the atmospheric air and sprays.

In **composites** two or more different structurally substances, especially metals, ceramics, glasses and polymers, combine to produce structural or functional properties not present in any individual component.

Examples: Adobe brick (straw mixed with mud or clay); plywood (thin slabs of wood held together by an adhesive). These composites make the structure stronger.

Questions

1. Mach one of the following words with their corresponding definition: *element; volume; mass; solution; homogeneous mixture; aerosol; molecule; pure substance; matter; suspension; mixture; atom; foam; heterogeneous mixture; compound; colloid; composite.*

a) Anything that has mass and volume.

b) Composed of only one kind of particle.

c) Two or more pure substances combined retaining their own properties and combined in any ratio

d) Muddy water is an example of that kind of mixture.

e) The smallest part of an element.

f) Cannot be broken down by ordinary chemical means

g) Two or more elements chemically combined in a definite ratio.

h) Bread is an example of that kind of mixture.

i) A cloud is an example of that kind of mixture.

j) Mixture that has the substances evenly distributed throughout.

2. Tell if the following statements are true or false:

a) Iced tea is a solution.

b) Granite is a homogeneous mixture.

c) After-sun is an emulsion.

d) Running water is a suspension.

e) In a solution only one substance can be the solute.

f) A mixture that is not the same throughout is called a heterogeneous mixture.

g) Oil and vinegar are miscible.

h) Gelatine is an example of foam.

i) In smoke, particles are suspended in the air.

j) In colloids particles are very small, but are large enough to reflect light.

k) In suspensions, particles can settle out.

l) Substance dissolved in a liquid is called solute.

m) Solutions can be solids, liquids or gases.

n) Solubility increases with temperature.

o) In a saturated solution usually is not possible to solve more quantity of solute.

3. Many medicines are suspensions. Why is necessary to shake them before taken them?

4. Complete the following table, referred to mixtures, written in each box one example of heterogeneous mixtures and another one of homogeneous mixtures:

	Solid	**Liquid**	**Gas**
Solid			
Liquid			
Gas			

5. Tell the composition of the following composites:

a) Adobe brick.

b) Plywood

c) Glass fibres.

d) Tires.

6.

a) Look for the definition of **alloy**.

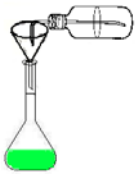
b) Prepare a Power Point about alloys with the following slides:

b.1. Title

b.2. Index

b.3. Different slides that include **definition** of alloy, **composition**, **properties** and **uses** of the following alloys: *steel, duralumin, bronze, stainless steel, pewter, manganin, nichrome, cupronickel, solder, brass and dental amalgam.*

b.4. Bibliography



4.3. Preparation of aqueous solutions

4.3.1. Mass percentage

The **mass percentage** of a compound in a solution is the mass of the compound found in 100 g of solution:

$$\text{mass \%} = \frac{\text{mass}_{\text{substance}}}{\text{mass}_{\text{solution}}} \cdot 100$$

Example: The mass percentage of a solution containing 10 grams of glucose solved in 190 grams of water will be:

$$\text{mass \%} = \frac{10\ \text{g}}{200\ \text{g}} \cdot 100 = 5\%$$

Commercial concentrated aqueous reagents such as acids and bases are often labeled in concentrations of mass percentage (abbreviated as **mass %**, **%w/w**, or **wt%**).

In mixtures of gases and sometimes in liquid-liquid solutions, **volume-volume percentage** (**% v /v**) is used. This percentage describes the volume of the solute in mL per 100 mL of solution. Volume is only additive in the case of mixtures of ideal gases.

Example: The volume percentage of a solution containing 12 mL of alcohol in 150 mL of solution will be:

$$\%\ \text{v/v} = \frac{12\ \text{mL}}{150\ \text{mL}} \cdot 100 = 8\ \%$$

4.3.2. Mass per unit volume

Mass-volume percentage (**m/v** or **w/v**) describes the mass of solute divided by the volume of solution. This measure of concentration is often used for solutions made from a solid dissolved in a liquid.

$$\text{m/v} = \frac{\text{mass}_{\text{solute}}}{\text{volume}_{\text{solution}}}$$

Example: a 40 g · dm^{-3} sugar solution contains 40 g of sugar per 1 dm^3 of solution.

4.3.3. Moles per cubic decimetre of solution (concentration)

A mole per cubic decimetre is also known as **molarity** or **concentration**. It indicates the number of moles of solute contained in a litre of solution. This is the most widely used unit for concentration when preparing solutions in chemistry or biology.

$$[\text{solute}] = \frac{\text{moles of solute}}{\text{dm}^3 \text{ of solution}}$$

Example: What is the concentration of a litre of solution containing 0,2 moles of $CaCl_2$ in 800 cm^3 of solution?

$$[CaCl_2] = \frac{0{,}2 \text{ moles}}{0{,}9 \text{ dm}^3} = 0{,}25 \text{ mol} \cdot \text{dm}^{-3}$$

Questions

1. A solution contains 20 g of KCl dissolved in 500 g of water. Calculate the mass percentage of potassium chloride in solution.

2. A 950 cm^3 of solution contains 45 g of $NaHCO_3$ dissolved. Calculate the concentration of $NaHCO_3$ in kg of solute per dm^3 of solution.

3. 10 g of NaCl are dissolved in 1,5 dm^3 of water solution. Calculate the concentration of NaCl**.**

4. 12 g of KCl are dissolved in 1,0 litre of water solution. Calculate the concentration of KCl.

5. After doing calculations, choose the right answer.

5.1. 10,0 g of sugar are dissolved in 90 g of water. The mass percent of sugar is:

a) 1 %
b) 0,9 %
c) 10 %
d) None of these are correct

5.2 A 200 g solution of alcohol contains 150 g of water. The mass percent of alcohol is:

a) 5 %.
b) 10 %
c) 50%
d) None of these are correct

5.3. How many grams of NaBr are needed to make 150 g of a 5.0% solution

a) 7,5 g

b) 0,125 g

c) 0,75 g

d) None of these are correct

5.4. How many grams of KOH are needed to make 500 cm^3 of a 5 g . dm^{-3}?

a) 5 g

b) 0,25 g

c) 2,5 g

d) None of these are correct

5.5. Which volume of 2 g · dm^{-3} Na_2SO_4 solution contain 1 g of Na_2SO_4?

a) 50 cm^3

b) 5 dm^3

c) 500 cm^3

d) None of these are correct

5.6. How many moles of $CaCl_2$ are there in 50 mL of 0,25 mol · dm^{-3} solution?.

a) 0,0025 moles.

b) 0,0125 moles.

c) 0,125 moles.

d) None of these are correct

5.7. 0,05 moles of NaCl occupy a volume of 100 mL. What is the concentration of the solution?

a) 0.05 mol · dm^{-3}.

b) 0.5 mol · dm^{-3}.

c) 0.005 mol · dm^{-3}.

d) None of these are correct

5.8. 4 g of NaOH were used to create a 0,1 mol · dm^{-3} solution. What is the volume of the solution?

a) 1 dm^3.

b) 0,1 dm^3.

c) 10 cm^3.

d) None of these are correct

5.9. What is the concentration of a solution containing 0,3 moles of NaCl in 300 cm^3 solution?

a) 10 mol · dm^{-3}.

b) 0,1 mol · dm^{-3}.

c) 1 mol · dm^{-3}.

d) None of these are correct

5.10. How many moles are there in 400 ml of 0,20 mol · dm^{-3} solution of sodium chloride?

a) 8 moles.

b) 80 moles.

c) 0,8 moles.

d) None of these are correct

6.  Solve the following questions:

6. 1. How many grams of KNO_3 and water are needed to prepare 50 g of a 4,0 % solution?

6.2. What mass of NaI must be mixed with 25 mL = 25 g (water's density: 1 g · cm^{-3}) of water to obtain a 5% solution.

6.3. A 500 g solution of sugar contains 100 g of water. What is the mass percent of solute in this solution?

6.4. What is the mass percent of a solution created by adding 20 g of alcohol to 180 g of water?

6.5. What is the concentration, expressed in g · dm^{-3} for 8 g of NaBr dissolved in 800 cm^3 of solution

6.6. How many grams of KNO_3 are needed to make 250 cm^3 of a 4 g · cm^{-3} solution?

6.7. Calculate the molarity of 15 g $CuSO_4$ contained in 500 cm^3 of solution.

6.8. How many mL of alcohol solute are in a 2 L sample of a 12% (% v/v) solution of alcohol dissolved in water?

6.9. What is the concentration of a solution in g · dm^{-3} when 10 grams of potassium chloride, KCl, are dissolved in 1.500 cm^3 of solution?

6.10. How many grams of calcium chloride are in 100 cm^3 of a 0,1 mol · dm^{-3} solution of calcium chloride?

Hint: In some questions about molarity concentration, remember first to calculate the number of moles.

Held: Web site **http://www.unitconversion.org/** will help you to prove if you have done correctly mass, volume, etc. arithmetic conversions.

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

Chemical element	☐
Chemical compound	☐
Chemical Solution	☐
Heterogeneous mixture	☐
Homogeneous mixture	☐
Suspension	☐
Miscible	☐
Immiscible	☐
Foam	☐
Emulsion	☐
Aerosol	☐
Percentage in mass	☐
Mass per unit volume	☐
Concentration, Molarity	☐

2.- Tick the one you think is your answer:

	I know very well	**I need some revision**	**I need some more help**
I know the difference between an element, a compound and a mixture.			
I know the difference between a heterogeneous mixture and a homogeneous mixture.			
I know the difference between immiscible and miscible liquids.			
I can differentiate the terms: suspension, foam, emulsion and aerosol.			
I know how to solve questions and do calculations related to percentage in mass solution concentration.			
I know how to solve questions and do calculations related to mass per unit volume solution concentration.			
I know how to solve questions and do calculations related to molarity.			

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.

Experiments:

Experiment 1: Elements, Compounds and Mixtures

OBJECTIVE

Investigate some of the characteristics of both elements and compounds.

EQUIPMENT

Safety goggles
Magnet
Watch glass
Bunsen burner
Test tube
Test tube tongs
Beaker

MATERIALS

Iron filings,
Powdered sulphur
Water

PROCEDURE

1. Place a small amount of powdered sulphur on a watch glass. Write your observations in the table.
2. In another watch glass place a small amount of iron filings. Write your observations in the table.
3. Draw the magnet toward the iron filings and the powdered sulphur. Write your observations in the table.

	Colour	State	Element, compound or Mixture?	Magnetic or non-magnetic?
Iron				
Sulphur				

4. Stir the mixture well. Draw the magnet toward the iron filings, and then put the mixture into a beaker with 100 cm^3 of water. Write your observations in the table.

	Homogeneous or heterogeneous mixture	Magnetic or no-magnetic	Float or sink?
Mixture		**Iron:** **Sulphur:**	**Iron:** **Sulphur:**

5*.

a) **Teacher** will combine the mixture of sulphur and iron filings from several students in a test tube mixing them well.

b) Pick up the test tube with test tube tongs and heat the tube with the flame of a Bunsen burner for five minutes.

c) After five minutes, immerse the test tube cold water to break the test tube. If the test tube does not break, wrap it with paper towels and carefully broke it with an object.

d) Carefully remove the substance from the pieces of glass.

e) Observe the compound obtained, repeat the tests previously made with the reactants and annotate the observations in the table.

CAUTION:

Do not point the open end of the test tube away from people!

Wear eye protection (safety goggles)

	Colour	State	Element, compound or Mixture?	Magnetic or non-magnetic?	Float or sink
Substance (Iron (II) sulphide)					

* This part of the activity will be conducted by the **teacher**.

QUESTIONS

1. Compare the properties of iron and sulphur with those of compound obtained. How they differ from those of the separate elements?

2. Is it possible to separate sulphur and iron mixture into its individual parts? Is it possible to separate the compound obtained after heating into the initial sulphur and iron?

3. Complete this word equation for the previous reaction:

Iron + …….. → ……. sulphide

Experiment 2: Preparation of aqueous solution

OBJECTIVE

Prepare 100 cm^3 of a 2 $g \cdot dm^{-3}$ aqueous solution of sugar.

EQUIPMENT

Beaker
Balance
Spatula
Funnel
Watch glass
Balance
100 mL volumetric flask
Pipette
100 ml graduated cylinder
Densimeter

MATERIALS

Sugar
Distilled water

PROCEDURE

1. Before doing the solution is necessary to calculate how many sugar do we need to prepare 100 cm^3 of a 2 $g \cdot dm^{-3}$ aqueous solution. Annotate the mass of sugar needed:

Mass of sugar = …… g

2. Weight the sugar on an electronic balance (or a gram balance).

3. Dissolve the salt in a beaker with a little amount of water.

4. Transfer the solution to the volumetric flask (use a funnel so that you do not spill the solution).

5. Rinse the beaker two or three times and, again, transfer this solution to the volumetric flask in order to have all the sugar in the solution.

6. Add distillate water to the volumetric flask, close up the 100 cm^3 signal.

7. Add the last drops of water with a pipette, to avoid going beyond the signal

8. Put a stopper to the flask and sake the solution.

9. Transfer the solution to a 100 ml graduated cylinder and calculate the density with a densimeter.

10. Transfer the solution to a 1 litre bottle

QUESTIONS

1. Why do you use a clean spatula to get a solid?

2. Sugar has to be weighted on a watch glass. Why?

3. All the sugar has to be added to the flask. Why?

4. How do you have to look at the flask signal? Up to where liquid has to come to know that we have exactly the volume that we want to prepare?

5. This mixture of sugar in water is a homogeneous or a heterogeneous mixture? Why?

6. With a densimeter, calculate the density of the prepared solution and compare it with that of the distilled water. Explain why they do not have the same value.

Activity

In web page **http://sciencehack.com/videos/category/2** watch this video about solutions.

a) If you have some problem in word pronunciation, consult the wed site **http://www.thefreedictionary.com/** (dictionary with pronunciation).

b) If you want to listen with a good pronunciation a text, paragraph, etc, of these chemistry units, web sites: **http://vozme.com/index.php?lang=ca** and **http://www.voki.com/create.php** have a program to generate sound.

UNIT 5: SEPARATION OF MIXTURES

Content:

Unit 5 Separation of mixtures

5.1. Filtration

5.2. Liquid-liquid extraction (decantation)

5.3. Crystallization

5.4. Chromatography

5.5. Distillation

Learning Aims:

At the end of the unit, the student will be able to:

- Define key words related to this unit: solution, solvent, solute, filtrate, residue, immiscible and miscible liquids, distillate, ebullition, condensation, boiling point, crystallization, evaporation, aadsorption, desorption and chromatography.
- Select the best method for separating a given mixtures.
- Describe the different methods of separating mixtures.
- Use properly laboratory equipment to conduct the experiment.
- Perform simple experiments involving separation of mixtures.
- Use the appropriate language to answer questions and to communicate with teacher and classmates.

Initial Activities

1.  Choose the right answer:

1.1. A mixture of iron filings and sulphur could be separated by

a) a magnet.
b) distillation.
c) filtration
d) crystallization

1.2. The best technique to separate the colours of ink is:

a) Decantation.
b) Distillation.
c) Chromatography.
d) Crystallization.

1.3. The best technique to obtain the sediment from a suspension is:

a) Decantation.
b) Distillation.
c) Chromatography.
d) Filtration.

1.4. The best technique to separate a mixture of liquids with different boiling points is::

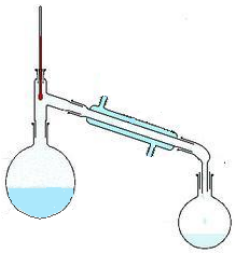
a) Decantation.

b) Distillation.

c) Chromatography.

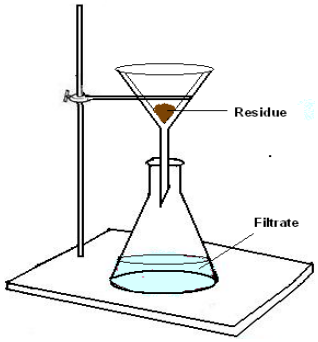
d) Filtration.

2. Match each mixture to the best apparatus you may use to separate the following substances:

a) Alcohol from wine.	**1)** 
b) Iron filings from sand.	**2)** 
c) Chalk powder from water	**3)** 
d) Ether from water	**4)** 

Key words:

Filtration Filtrate Residue

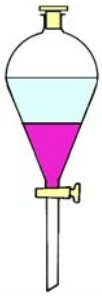


Filtration is commonly used to separate an insoluble solid from a liquid. The **residue** is the substance that remains on the filter paper and the **filtrate** is the substance that flows through the filter paper.

http://www.wonderhowto.com/how-to/video/how-to-perform-hot-filtration-in-the-chemistry-lab-259803/view/ (video about filtration)

http://www.saskschools.ca/curr_content/science10/unita/redon17.html (animation about filtration)

Decantation Immiscible Density



In **liquid-liquid extraction** two or more substances are separated due to their different solubility in **immiscible** liquids.

http://www.wonderhowto.com/how-to/video/how-to-do-a-liquid-liquid-extraction-in-the-chemistry-lab-259811/view/ (video of liquid-liquid extraction -decantation-)

Crystallization Solute Solvent Evaporation

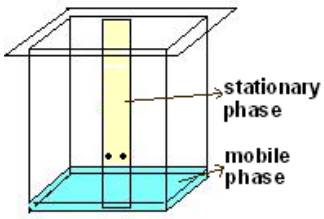
In **crystallization** soluble substances precipitate from a solution and a regularly-shaped, -sized, and -patterned solid forms known as crystals.

Videos related to crystallization:

http://www.youtube.com/watch?v=CajiRZhfxGw
http://www.youtube.com/watch?v=sH5HTDhATxQ&feature=related
http://www.youtube.com/watch?v=Cl-QYPkdeyM&feature=related
http://www.youtube.com/watch?v=Xf53FOPHFR4&feature=related
http://www.youtube.com/watch?v=NMHkAIlP7WI&feature=related

Chromatography

Thin layer chromatography
Mobile phase
Stationary phase
Adsorption
Desorption



Chromatography is a technique used to separate or analyze the components of a chemical mixture by moving the mixture along a stationary material.

Videos related to chromatography:

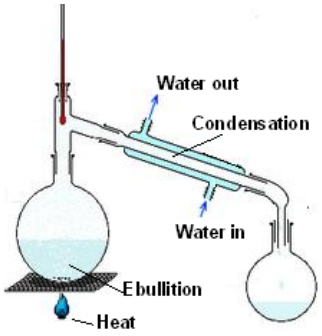
http://www.youtube.com/watch?v=NTDEYX4TtZg&feature=related
http://www.youtube.com/watch?v=fLc36wxLrVI&feature=related
http://www.youtube.com/watch?v=6fzBJ8nuuzk&feature=related

Applet:

http://www.chem.uoa.gr/applets/appletchrom/appl_chrom2.html

Distillation

Condensation
Ebullition
Distillate



Distillation is a method of separating substances from a mixture due to their different boiling points by heating the mixture. Substance first evaporate and then their vapour condensate. The condensed vapour is called **distillate**.

http://www.saskschools.ca/curr_content/science10/unita/redon18.html (Animation: distillation)

http://video.aol.com/video-detail/organic-chemistry-lab-demo-isolation-of-limonene-part-2/2882303878321833 10/?icid=VIDURVHOV04 (Video: isolation of limonene)

http://www.wonderhowto.com/how-to/video/how-to-perform-simple-distillation-in-the-chemistry-lab-259797/view/ (Video: simple distillation)

Consult the web site **http://www.thefreedictionary.com/** (dictionary with pronunciation) to know the pronunciation of key words.

In web site **http://ochem.jsd.claremont.edu/index.htm** you will find videos, songs, theory, many things related to chemistry.

http://www.intute.ac.uk/ is a free online service providing you with a database of hand selected Web resources for education and research.

Introduction

As we already know, **mixtures** are made by the combination of two or more different substances without a chemical reaction occurring.

In this unit we are going to know different techniques to separate the components of mixtures: filtration, distillation, etc.

5.1. Filtration

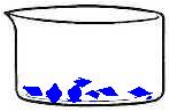
Filtration is a technique used to separate insoluble solids from liquids. To carry out a filtration a filter paper placed inside a glass funnel is necessary. The solid remaining in the filter paper is called **residue**. The liquid which has passed through the filter paper is called **filtrate**.

Example: mixture of chalk powder and water.

5.2. Liquid-Liquid extraction (decantation):

Liquid-liquid extraction is used to separate **immiscible** liquids or two immiscible liquid solutions. In this technique a separation funnel is used. The top layer is **less dense** than the bottom layer.

Example: Paraffin and water, olive oil and water.

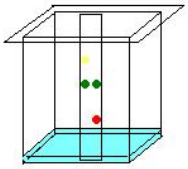


5.3. Crystallization

Crystallization is used to separate a soluble solid from a liquid (solution) by allowing the solid to form **crystals**. The dissolved substance is called the **solute**. The liquid used for dissolving is called the **solvent**.

In this process, the solution is warmed in an open container, allowing the solvent to **evaporate** until a saturated solution has been formed, then this solution is leaving to room temperature until the solvent evaporates completely and crystals are formed.

Example: Growing of copper (II) sulphate crystals.



5.4. Chromatography

Chromatography is used to know if we have a pure substance or a mixture. In this technique, small quantities of substances are used. This technique use the difference in rates of movement of solutes over a porous medium like filter paper by a moving solvent

Chromatography involves a sample dissolved in a **mobile phase**. The mobile phase is then forced through an immobile, immiscible **stationary phase**. The differences in nobilities of sample components by the mobile phase through the immobile phase will become separated from each other as they travel through the stationary phase.

The solvent travels up the filter paper leaving a line called the **solvent front**.

Example: Analysis of colours of ink, chlorophyll, dyes, sodas, a mixture of phenolphthalein and methyl orange indicators.

5.5. Distillation

Distillation is used to separate liquids or volatile solids by heating the mixture. The substance with the lowest boiling point **boils** first and becomes a vapour, and then the vapour is cooled in the **condenser** and **condenses** back into a liquid which is collected in a container. The collected liquid is called the **distillate**. The condenser has cold water running through a jacket around the outside to keep the temperature below the boiling point of the substance.

Once the liquid with the lowest boiling point has leave the mixture, the temperature of the remaining mixture will rise and with the next lowest boiling point substance will boil and will leave the mixture, and so on.

Example: Isolation of essentials oil from plants.

Questions

1. What separation method could be used for separating the following mixtures?

- **a)** Sodium chloride and water
- **b)** Chalk powder and iron filings
- **c)** Chlorophyll in spinaches.
- **d)** Sunflower oil and water
- **e)** Copper(II) sulphate and sulphur

2. Explain the difference between:

- **a)** Evaporation and ebullition
- **b)** Solute and solvent
- **c)** Miscible and immiscible liquids
- **d)** Filtrate and residue.
- **e)** Condensation and ebullition.
- **f)** Distillate and filtrate.
- **g)** Melting and boiling point

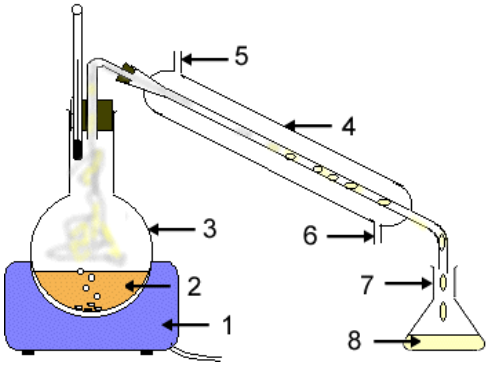
3. Sulphur is insoluble in water and sugar is soluble.

- **a)** What will happen if a mixture of these two substances is stirred into water?
- **b)** What happen if you then pour this mixture through a filter paper?
- **c)** How could you recover sugar from the mixture?

4. How can you separate a mixture of different liquids if they have different boiling points?

5. The following picture shows a simple distillation set up.

a) Write the names: *Erlenmeyer flask, thermometer, heater, solution, flask, cold water in, cold water out, Liebig condenser, distillate* on the appropriate place of the parts of the distillation apparatus:



http://phys.free.fr/images/dist.gif (there is a simulation)

b) What is the role of the condenser?

c) What is the thermometer used for?

6. Hidden word

a) Read the clues below and write your answer in the boxes. Reading the letters on green boxes from top to bottom you will find a hidden word.

Physical method used to analyze a mixture.		H						O				P		
Goes from liquid to gas.	E							T						
Technique in which an evaporation followed by a condensation takes place.	D					L								
Substance that remains on the filter paper in a filtration			S											
Liquid used to dissolve a substance				V			T							
Dissolved substance in a solution.				U										
Liquid that flows through the filter paper in a filtration			L					E						
Technique in which a solid with a crystalline structure is separated.			Y						Z					

The hidden word is														

b) Define the hidden word

7. Drink water is a homogeneous mixture of different substances. How can you obtain pure water from drink water?

8. You use **red**, **blue** and **yellow** dyes to make three new colours: blue and yellow were mixed to produce **green**; blue and red were mixed to produce **purple**; and red and yellow were mixed to produce **orange**. Then you want to separate the colours using thin layer chromatography. With the solvent you are using, yellow dye travels furthest up the paper and the blue dye travels the least. Draw a diagram to show how the filter paper looks like when the experiment is finished.

9. Explain the different steps you have to do to separate a mixture containing sodium chloride, chalk powder, iron filings and iodine.

Hint: Sodium chloride is soluble in water but it is not soluble in hexane. Iodine is soluble in hexane but it is not soluble in water.

10. Prepare sand filter beds. Make a report of the activity. In the web site http://www.wessexwater.co.uk/education/threecol.aspx?id=1444 (a video is included) you will find information.

Experiments:

Experiment 1: Filtration

OBJECTIVE

Prepare the mixture and separate the components.

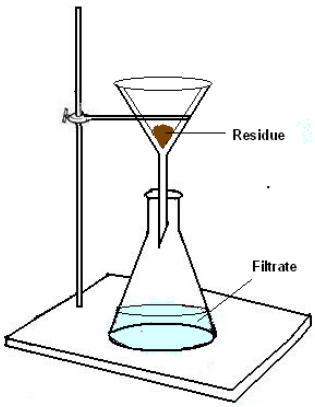
EQUIPMENT

Funnel	2 beakers
Filter paper	Watch glass
Spatula or coffee spoon	Balance

MATERIALS

Water	Salt
Sand	

PROCEDURE



1. Weight 5 g of salt and 5 g of sand and put these substances onto a piece of paper.

2. Stir the mixture well. Put the mixture into the beaker with 200 cm^3 of water.

3. Filter the mixture.

QUESTIONS

1. Mixture of sand and salt is homogeneous or heterogeneous? Why?

2. Mixture of sand, salt and water is homogeneous or heterogeneous? Why?

3. Substances in the mixture have changed their original properties?

4. Draw and name the following apparatus you have needed to do the filtration:

5. Number the following instructions in the order you did the experiment:

Pour the mixture into the funnel
Put the funnel into the flask
Fold the filter paper
The liquid is in the flask and the residue in the paper
Put the paper into the funnel

6. Sort these cards to make true sentences:

The sand	is in the flask	because it can go through the paper
Solution	is in the paper	because it can not go through the paper

Experiment 2: Liquid-Liquid Extraction

OBJECTIVE

Prepare the mixture and separate the components.

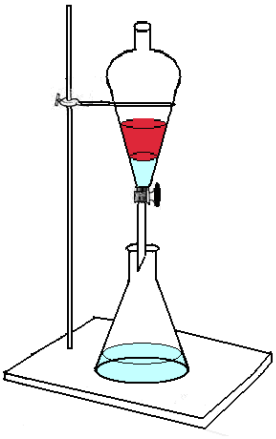
EQUIPMENT

Decantation funnel
Separating funnel,
Beaker
Stand
Ring holder

MATERIALS

Iodine
Water
Hexane

PROCEDURE



1. Weight 1 g of salt and add it to a mixture of 100 mL of water and 100 mL of hexane.

2. Stir the mixture well and then put the mixture in the separating funnel.

3. Close the tap, and then gently shake the funnel and its contents.

4. Release any pent up gas. Repeat this process several times or until no gas is observed being released.

5. Place the funnel into the ring and remove the stopper.

6. Left settle the mixture for several minutes while the layers separate out and settle down.

7. Open the key until the entire lower layer have been separated.

QUESTIONS

1. Mixture of iodine, water and hexane is homogeneous or heterogeneous? Why?

2. Where iodine has been dissolved? Why?

3. Which liquid is in the top layer? Why?

Experiment 3: Crystallization

OBJECTIVE

Prepare the solution and separate the components.

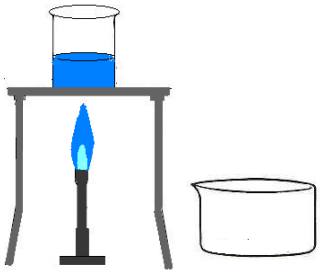
EQUIPMENT

Crystallizer	Beaker
Stirring rod	Bunsen burner

MATERIALS

Copper (II) sulphate	Water

PROCEDURE



1. In a beaker, solve copper (II) sulphate in 100 mL of boiling water until saturation.

2. Put he saturated solution in a crystallizer until all the solvent evaporate.

3. Observe how crystals grow.

4. Collect the crystals and allow them to dry.

QUESTIONS

1. Mixture of ´copper (II) sulphate and water is homogeneous or heterogeneous? Why?

2. Describe and draw the crystals obtained.

3. Why is not correct to say crystal when we are taking about the window glasses?

Experiment 4: Chromatography

OBJECTIVE

Prepare the filter paper with the mixture and separate the components.

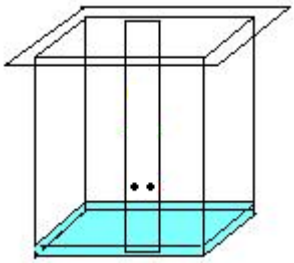
EQUIPMENT

Filter paper Bottle with wide mouth
Lid

MATERIALS

Felt-tipped pen (different colours)

PROCEDURE



1. Cut the filter paper in a rectangular shape (6 · 12 cm).

2. Draw four spots with felt-tipped pens of different colours or brands; 1 cm one of another and 2 cm from the bottom end of filter paper.

3. Pour 1 cm of water in a wide mouth bottle and place the paper into the bottle so as the ink does not touch the solvent.

4. Close the bottle

5. After some minutes, you will observe that the ink has separated in different colours.

QUESTIONS

1. Ink of felt-tipped pen is made of only one substance? Why?

2. If the ink you have use is a mixture of substances, what kind of mixture is it, homogeneous or heterogeneous? Why

3. Describe all you have observed?

Experiment 5: Distillation

OBJECTIVE

Set the devise and separate the essential oil from mint.

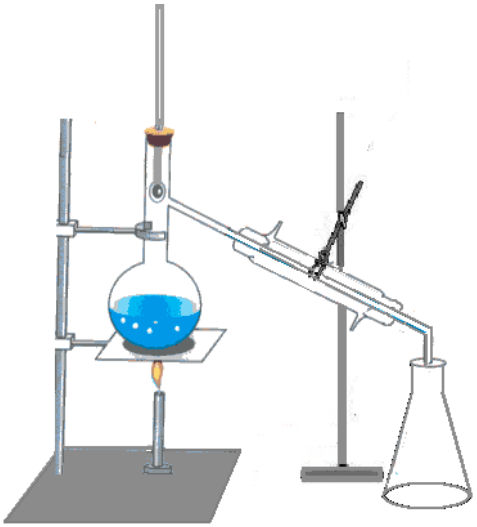
EQUIPMENT

Clamp stand	Clamp
Thermometer	Distillation flask
Broken porcelain	Bunsen burner
Condenser	Erlenmeyer flask

MATERIALS

Mint	Water

PROCEDURE



1. Set the distillation apparatus.

2. Put little pieces of broken porcelain in the distillations flask.

3. Fill until roughly the half of the distillation flask with a mixture of mint and water.

4. Heat the mixture until enough essential oil has been separated.

QUESTIONS

1. Explain what broken porcelain is used for.

2. Name the two state changes that are taking place in the flask and the condenser.

3. Why the thermometer is placed close to the opening where gases leave the flask?

4. The first substance that leaves the flask is the essential oil of mint, why?

5. Observe the thermometer from the beginning to the end of the process of distillation. What do you observe in relation to the temperature when the essential oil is leaving the distillation flask?

6. Write these sentences in the correct order to describe distillation:

The whole process is called distillation	Mint and water is heated in a flask
Mint essential oil evaporates to steam above the mixture	The steam cools down and condenses to form oil
The essential oil is collected in an Erlenmeyer flask	

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

Filtration	☐	Filtrate	☐
Residue	☐	Extraction	☐
Immiscible	☐	Density	☐
Miscible	☐	Crystallization	☐
Crystal	☐	Chromatography	☐
Mobile phase	☐	Stationary phase	☐
Adsorption	☐	Desorption	☐
Distillation	☐	Evaporation	☐
Condensation	☐	Distillate	

2.- Tick the one you think is your answer:

	I know very well	**I need some revision**	**I need some more help**
I know how the filtration technique works.			
I know how the extraction technique works.			
I know how the crystallization technique works.			
I know how the chromatography technique works.			
I know how the distillation technique works.			
I can differentiate the terms: filtrate and residue, immiscible and miscible, evaporation and condensation, solute and solvent.			
I know how to set the different apparatus we have use in the laboratory to separate compounds in mixtures.			

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.

UNIT 6: CHEMICAL REACTIONS

Content:

Unit 6: Chemical reactions

6.1. Physical and chemical changes

6.2. Chemical equations

6.3. Mol and chemical reaction. Calculations

6.4. Types of chemical reactions

- **6.4.1.** Combustion
- **6.4.2.** Synthesis
- **6.4.3.** Decomposition
- **6.4.4.** Single displacement
- **6.4.5.** Double displacement
- **6.4.6.** Acid-base

6.5. Energy in a chemical change

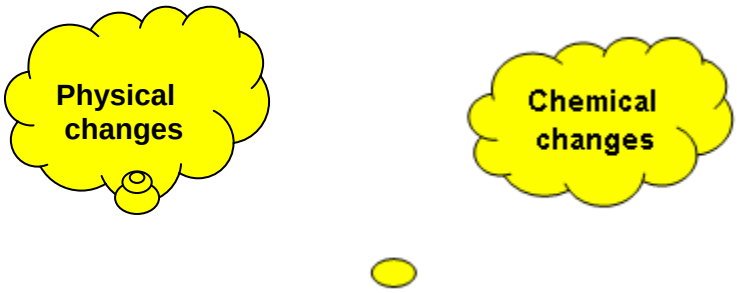
Learning Aims:

At the end of the unit, the student will know:

- The difference between physical and chemical changes.
- The concept of mol and its application in a chemical reaction
- The meaning of a chemical equation.
- The meaning of the different kinds of chemical reactions.
- How to solve problems and questions related to stoichiometric calculations.
- How to use the chemical and mathematical language appropriated to the problem solutions.
- How to follow a guided experiment in the laboratory.
- How to manipulate in a correct way the material and reactants in the laboratory.
- The difference between an exothermic and an endothermic reaction.
- The meaning of kinetics.

Initial Activities

1. **a) Thought shower.** Say aloud different words related with the following two terms. What do these words suggest to you?



b) Decide which words belong to physical change and which words to chemical changes and fill the table below:

Physical change	Chemical change

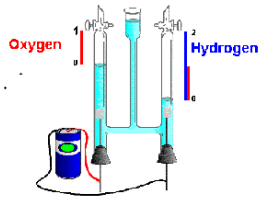
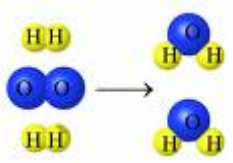
2. What is the meaning of physical change?

3. What is the meaning of chemical change?

4. Match each word, on the left column with the appropriate words on the right column:

Distillation Iron oxidation Combustion Evaporation Condensation Sublimation Ammonia production from nitrogen and hydrogen Water decomposition in hydrogen and oxygen Apple oxidation Decantation Filtration	Chemical change Physical change

Key words:

Physical change		**Chemical change**	
Chemical reaction		**Chemical equation**	$2H_2 + O_2 \rightarrow 2H_2O$
Reactant	H_2 and O_2	**Product**	H_2O
Formula	H_2O	**Balance**	*coefficients* $2H_2 + O_2 \rightarrow 2H_2O$
Combustion		**Precipitation**	
Decomposition		**Synthesis**	
Double displacement	**Anions** and **cations** of **two different molecules** switch places, forming different compounds. These reactions are in the general form: **AB + CD → AD + CB**	**Single displacement**	**One element** trades places with another element in a compound. These reactions come in the general form of: **A + BC → AC + B**
Base	Sodium Hydroxide: **NaOH**	**Acid**	Sulphuric acid: **H_2SO_4**

Exothermic	[1] These are reactions that **transfer energy** to the surroundings.	**Endothermic**	[1] Process or reaction that **absorbs** energy.

[1] Watch a video in web sites: http://www.youtube.com/watch?v=qA_OdwIt_tw&hl=es (endothermic reaction) and http://www.youtube.com/watch?v=-_Q7FCKZmik&feature=related (exothermic reaction)

6.1. Physical and chemical changes

We talk about a **chemical change** when one or more substances are **transformed** into one or more new substances. Energy is released or absorbed, but no appreciable loss in total mass occurs.

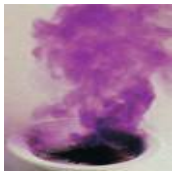
Sometimes a chemical change can be observed because **energy** (heat, light) has been absorbed or released, a change in **colour**, a change in **odour**, formation of a **gas**, formation of a **precipitate**, etc.
Then, we can say that when a **chemical change** is produced:

- One or more **new substances** are produced.
- In many cases an **observable change** is apparent, for example the colour changes, a gas, or a solid precipitate, etc is produced.
- An **energy change** is almost always involved.

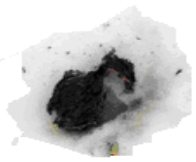
When some change is produced, but the substances are **not transformed**, we are talking about a **physical change**.

Examples:

When iodine sublimates, for example, it becomes vapour. The solid iodine and vapour iodine have the same composition. The only difference is the physical state. This is a physical change:



When paper burns and becomes ash, we are talking about a chemical change because the substances present at the beginning of the change are not present at the end; new substances are formed:



Questions

1. 

a. Look for eight words related to changes

C I Y D B S U B N N F Z Q N N P E Q
L H D P R K Y E G O D X O H D H W O
N T E I R G C E O I K I F G L Y W Q
Q K S M H L X U P T T H N T Q S N V
C A J R I O X I D A T I O N Q I K N
P A U U O C U T R M J V J A T C H N
J N T A P A A T U I K Z J R J A S L
X U T O A E L L F L N M S B L L P A
H L O L N I T S O B E G N A H C O Y
D F Z X F S I A L U I L I C O C M L
M X T W U N R B T S P I Q E I Z G S
S E D F C N T N C I B S B K P F Q U
L S C P P C X T C W P Y O O L T T C
P A X E O X U Y D E Z I O X G R V H
S V E L C T G L Y Q V I C U B Y Y F
A F O V V V K Z O F P I T E C U I C
E U M W A Z P K H D T H R X R T O H
R Z E T R J L X P U Y E Q F M P L K

b. Write by alphabetical order the previous words and define them.

2. 

Read the previous text and fill the following gaps:

In a chemical reaction ---------- substances are made. The ---------- may change or you may see ---------- bubbles. The change is ---------- to reverse. You cannot easily get ---------- the substances you started with. There is an ---------- change at the same time. You may need ---------- or electricity to ---------- the reaction and the mixture may give out heat.

3. Choose the correct answer:

3.1. A variety of observations can indicate whether or not a chemical reaction is happening when chemicals are mixed. Which of the following is most likely to **indicate a chemical change** when a suspected carbonate is added to an acid?

a) There is no colour change
b) The temperature stays the same
c) A clear solution is formed
d) Gas bubbles form

3.2. Chemical changes make new materials and tend not to be readily reversed. Physical changes do not make new materials and tend to be readily reversed. Which of the following is a **chemical change**?

a) Melting butter
b) Ice cracking of a milk bottle
c) Condensation forming on a window
d) Igniting a gas fire

3.3. Which is **TRUE** about physical changes but not chemical changes?

a) New substances are sometimes formed
b) The change is not easily reversed
c) There is rarely visible evidence of the change
d) No new substances are formed

3.4. Which of the following are a **physical change** and not a chemical change?

a) Marble chips dissolving in acid
b) Heated green copper carbonate turns it black
c) Whisky condensing in a distillery
d) Zinc dissolving in hydrochloric acid

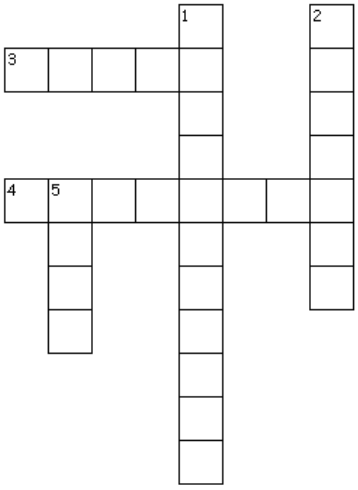
3.5. Which of the following are a **physical change** and not a chemical change?

a) Magnesium dissolving in sulphuric acid
b) Heated green copper carbonate turns it black
d) Adding lemon juice to solid bicarbonate of soda
e) Freezing banana skins in liquid nitrogen

3.6. Which is **TRUE** about chemical reaction changes?

a) The change is not easily reversed
b) No new substances are formed
c) New substances are formed
d) There is rarely visible evidence of the change

4.- Crossword



Across

3. Sometimes is produced in a chemical reaction.
4. Kind of change when the substances are transformed in new ones.

Down

1. Solid that appeared in a chemical reaction.
2. They are observed when a gas is produced inside a liquid solution.
5. It is released in an exothermic reaction.

5.- 

Cryptogram: Write the missing letters and find a sentence related to this topic.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
J			W	I									E					C							

N A E A N , N
Y E J A K I U Y A J M L I J A Q Y V E Y E

A N A S E S E A N S E E
U J E S A J C I C D I A J E V T C I L N I

A N A A E N A N E , E A E
J E J R R J L I E Q A K J E X I Z V L I G J U R M I

E A N S E E A N E , A
D I A J E C I I J E I D A V M V H L J

E A E E S A E
R L I A Y R Y Q J Q I V L T H T T M I C J L I

D E D , E A S E E A S E D ,
R L V W H A I W K I J Q Y C L I M I J C I W

E . A N E S , A A S ,
I Q A A K J E X I C J X J C V L

A S D E A E , E S
J C V M Y W R L I A Y R Y Q J Q I I Q A Y C

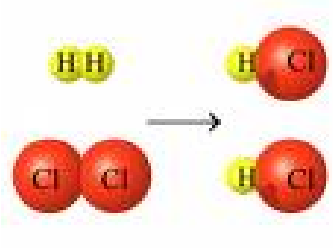
D E D
R L V W H A I W

6.- 

Give 5 examples of chemical changes and 5 examples of physical changes that you have observed in your kitchen, at home.

7.- 

a. Explain what happen in the following diagram:



b. Is it a chemical or a physical change?

6.2. Chemical equations

Chemical reactions are described by an **equation**. In these equations **reactants** (chemicals that react) are represented on the left-hand side of the arrow and **products** (chemicals that are produced) on the right-hand side. Chemicals usually are represented by their chemical symbols.

Example: In the chemical equation: **$C_4H_{10\,(g)} + 13/2\ O_{2\,(g)} \rightarrow 4\ CO_{2\,(g)} + 5\ H_2O_{\,(g)}$** butane ($C_4H_{10}$) and oxygen ($O_2$) are the reactants and carbon dioxide (CO_2) and water (H_2O) are the products.

In a chemical reaction the number of atoms remain the same, for this reason, a chemical equation must be balanced, which means that we have to use coefficients before formulas, if necessary, to change the total number of atoms (not the subscripts in the formulas).

Example: Balance the equation: **a** $C_6H_{6\,(g)}$ + **b** $O_{2\,(g)} \rightarrow$ **c** $CO_{2\,(g)}$ + **d** $H_2O_{\,(g)}$

1. In this equation we have three elements: C, H and O.
2. There are 6 atoms of C in reactants but only 1 atom of C in products, so **c** = 6. There are 6 atoms of H in C_6H_6 and only 2 H in H_2O, so we need to multiplied the coefficient of H_2O by 3 (**d** = 3).
3. Finally, the O coefficient is determined. The total number of O atoms in products is: $2 \cdot 6 + 3 = 15$, then we can deduce that **b** = 15/2.
4. Check your work. If **a** = 1, so the final balanced equation would be written: $C_6H_{6\,(g)}$ + **15/2** $O_{2\,(g)} \rightarrow$ **6** $CO_{2\,(g)}$ + **3** $H_2O_{\,(g)}$

Questions

1. Balance the following equations and write the names of the compounds:

a) __ NH_3 + __ O_2 → __ NO + __ H_2O

b) __ PbO_2 + __ HCl → __ $PbCl_2$ + __ Cl_2 + __ H_2O

c) __ NaOH + __ H_2SO_4 → __ Na_2SO_4 + __ H_2O

d) __ $(NH_4)_2CO_3$ → __ NH_3 + __ CO_2 + __ H_2O

e) __ $Fe_2(SO_4)_3$ + __ K(SCN) → __ $K_3Fe(SCN)_6$ + __ K_2SO_4

f) __ Cu + __ O_2 → __ Cu_2O

g) __ $CaCl_2$ + __ $AgNO_3$ → __ AgCl + __ $Ca(NO_3)_2$

h) __ H_2 + __ O_2 → __ H_2O

i) __ Mg + __ P_4 → __ Mg_3P_2

j) __ $Ca(OH)_2$ + __ HCl → __ $CaCl_2$ + __ H_2O

k) __ CH_4 + __ O_2 → __ H_2O + __ CO_2

l) __ C_4H_{10} + __ O_2 → __ CO_2 + __ H_2O

m) __ C_3H_7OH + __ O_2 → __ CO_2 + __ H_2O

n) __ Fe_3O_4 + __ CO → __ CO_2 + __ Fe

2. In web sites: **http://chemistry2.csudh.edu/newlechelp/rxnbalancing.html** and **http://richardbowles.tripod.com/chemistry/balance.htm** you will find more exercises about balancing equations where checking answers are included.

Hint: web site **http://www.trimen.pl/witek/calculators/wspolczynniki.html** is an interactive site to calculate coefficients to balance chemical equations

6.3. Mol and chemical reaction. Calculations

In chemical reactions, the number in front of the molecule (coefficients) indicates how many molecules participate in the reaction.

As molecules are very small, instead of talking about a single molecule, we talk about moles (remember that one mole is a number referred to 6.02 x 10^{23} units)

It is important too to remember that a mole of molecules is equal to their molecular weight in grams.

Example: We can read the balanced equation: 2 $H_2(g)$ + $O_2(g)$ → 2 $H_2O(g)$ in either of the following ways:

- When 2 molecules of hydrogen react with one molecule of oxygen, two molecules of water are produced.
- When 2 moles of hydrogen react with one mole of oxygen, two moles of water are produced.
- When 4 grams of hydrogen react with 32 grams of oxygen, 36 grams of water are produced.

Questions

1. Which statements are true for the chemical equation: 2 NO + O_2 → 2 NO_2?

a) One mole of NO will produce 1 mol of NO_2
b) One mole of O_2 will produce one mole of NO_2
c) 32 g of O_2 will react with 30 g of NO
d) The reaction of 32 g of O_2 will produce 2 moles of NO_2
e) Two molecules of NO react with two molecules of O_2

Data: Atomic weights: N: 14; O: 16

2. Which statements are true for the chemical equation: 2 H_2S + SO_2 → 3 S + 2 H_2O?

a) The reaction of 64 g of SO_2 will produce 3 moles of sulphur
b) The reaction of 34 g of H_2S will produce 18 grams of water
c) Two moles of H_2S reacts with two moles of sulphur dioxide
d) 34 g of H_2S produce 1,5 moles of sulphur
e) The reaction of 2 molecules of H_2S will produce two molecules of water

Data: Atomic weights: H: 1; S: 32; O: 16

3. Which statements are true for the chemical equation: $6\ Cl_2 + P_4 \longrightarrow 4\ PCl_3$?

a) 4 moles of PCl_3 are obtained from 4 moles of P_4

b) 6 moles of Cl_2 react with 1 mole of P_4

c) 2 moles of PCl_3 are obtained from 3 moles of Cl_2

d) 6 moles of P_4 react with 18 moles of Cl_2

4. Which statements are true for the chemical equation: $3\ H_2 + N_2 \longrightarrow 2\ NH_3$?

a) 6 moles of NH_3 are produced when 3 moles of N_2 react.

b) 3 moles of N_2 react with 6 moles of H_2

c) 1 mole of NH_3 is produced from 2 moles of H_2 and 1 mole of N_2

d) In a reaction between 5 moles of H_2 and 2 moles of N_2, H_2 is in excess.

5. Which statements are true for the chemical equation: $3\ Cl_2 + 2\ FeI_2 \longrightarrow 2\ FeCl_3 + 2\ I_2$?

a) 2 moles of I_2 are produced from 3 moles of Cl_2.

b) In a reaction between 4 moles of FeI_2 and 5 moles of Cl_2, Cl_2 is in excess.

c) In a reaction between 9 moles of FeI_2 and 10 moles of Cl_2, Cl_2 is in excess.

d) When 5 moles of I_2 are produced there also are produced 5 moles of I_2.

6. Calculate the mass of Cl_2 needed to produce 2 moles of PCl_3 in reaction:

$$6\ Cl_2 + P_4 \longrightarrow 4\ PCl_3$$

Data: Atomic weights: P: 31; Cl: 35,5

7. Calculate how many grams of iodine are produced from 1 mol of chlorine in reaction:

$$3\ Cl_2 + 2\ FeI_2 \longrightarrow 2\ FeCl_3 + 2\ I_2$$

Data: Atomic weights: I: 127; Cl: 35,5

8. Tell if the following statements are true or false:

a) 5 moles of N_2 react with 5 moles of H_2 in reaction $2\ H_2 + N_2 \longrightarrow N_2H_4$

b) 1 mole of C_2H_6 is required to react with 7 moles of O_2 in reaction: $C_2H_6 + 7\ O_2 \longrightarrow 4\ CO_2 + 6\ H_2O$

c) When 32 g of O_2 react in reaction $Cu_2S + O_2 \longrightarrow 2\ Cu + SO_2$, 63,5 g of copper are produced.

Data: Atomic weights: Cu: 63,5; S: 32; O:16

d) In reaction: $Fe_2O_3 + 3\ CO \longrightarrow 2\ Fe + 3\ CO_2$, 2 moles of Fe_2O_3 produce 112 grams of iron

Data: Atomic weights: Fe: 56; C: 12; O:16

9. How many grams of potassium chlorate may be produced from 70 grams of chlorine assuming that sufficient potassium hydroxide is available.

$$3\ Cl_2 + 6\ KOH \longrightarrow 5\ KCl + KClO_3 + 3\ H_2O$$

Data: Atomic weights: Cl: 35,5; K: 39; O:16

10. Do the exercises you will find in web site: **http://lrc-srvr.mps.ohio-state.edu/under/chemed/qbank/quiz/bank3.htm** (in this web site you can check your answer).

6.4. Types of chemical reactions

A way of classifying the chemical reactions is to divide them in six categories:

6.4.1. Combustion

A **combustion reaction** of an organic compound takes place when this compound reacts with oxygen and form carbon dioxide and water.

Example: $C_4H_{10(g)} + 13/2\ O_{2(g)} \rightarrow 5\ H_2O_{(g)} + 4\ CO_{2(g)}$

6.4.2. Synthesis

In a **synthesis reaction** two or more elements or compounds combine to form a more complex compound.

Examples: $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

$CaO_{(s)} + CO_{2(g)} \rightarrow CaCO_{3(s)}$

6.4.3. Decomposition

In a **decomposition reaction** a single compound breaks down into two or more elements or simpler compounds.

Examples: $2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$

$2HgO_{(s)} \rightarrow 2Hg_{(l)} + O_{2(g)}$

6.4.4. Single displacement

In this type of reaction, an element replaces another element in a compound.

Example: $Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$

6.4.5. Double displacement

In this type of reaction there is an interchange of elements between two compounds.

Example: $AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$

6.4.6. Acid-base

An **acid-base reaction** is a special kind of double displacement reaction that takes place when an acid and base react and salt and water are produced.

Example: $HBr_{(aq)} + NaOH_{(aq)} \rightarrow NaBr_{(aq)} + H_2O_{(l)}$

$H_2SO_{4(aq)} + 2NaOH_{(aq)} \text{----> } Na_2SO_{4(aq)} + 2H_2O_{(l)}$

Question

List what type the following reactions are:

a) $NaOH + KNO_3 \rightarrow NaNO_3 + KOH$

b) $Fe + S \rightarrow FeS$

c) $NaCl + H_2SO_4 \rightarrow Na_2SO_4 + HCl$

d) $NaOH + HCl \rightarrow NaCl + H_2O$

e) $NaOH + FeCl_3 \rightarrow NaCl + Fe(OH)_3$

f) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

g) $Na_2CO_3 \rightarrow Na_2O + CO_2$

h) $Na_2O + H_2O \rightarrow 2\ NaOH$

i) $AgNO_3 + Na_2CrO_4 \rightarrow Ag_2CrO_4 + NaNO_3$

j) $Cu + 2AgNO_3 \rightarrow 2Ag + Cu(NO_3)_2$

k) $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

l) $2\ Fe + 6\ NaBr \rightarrow 2\ FeBr_3 + 6\ Na$

m) $2\ KClO_3 \rightarrow 2\ KCl + 3\ O_2$

n) $2\ Mg + O_2 \rightarrow 2\ MgO$

o) $CaSO_4 + Mg(OH)_2 \rightarrow Ca(OH)_2 + MgSO_4$

p) $NH_4OH + HBr \rightarrow H_2O + NH_4Br$

q) $Pb + O_2 \rightarrow PbO_2$

r) $CuCO_3 \rightarrow CuO + CO_2$

s) $2\ H_2O \rightarrow 2\ H_2 + O_2$

6.5. Energy in a chemical change

Chemical reactions involve a change in substances but they also are accompanied by a **change** in **energy**.

When energy is required for the reaction to occur we are talking about **endothermic** reactions, but if energy is released to the surroundings, this reaction is called **exothermic**.

Examples: Any combustion reaction of an organic compound is an **exothermic** reaction. Reaction between sulphuric acid and sodium hydroxide is also exothermic.

$$C_6H_{6\ (l)} + 15/2\ O_{2\ (g)} \rightarrow 6\ CO_{2\ (g)} + 3\ H_2O_{\ (l)} + \text{heat}$$

$$H_2SO_{4\ (aq)} + NaOH_{\ (aq)} \rightarrow Na_2SO_{4\ (aq)} + H_2O_{\ (l)} + \text{heat}$$

An example of an **endothermic** reaction is the reaction between ammonia nitrate and barium hydroxide or urea and ammonium chloride (cold pack).

$$2\ NH_4NO_{3\ (s)} + Ba(OH)_2.8H_2O_{\ (s)} + heat \rightarrow NH_{3\ (g)} + Ba(NO_3)_{2\ (aq)} + 10\ H_2O_{\ (l)}$$

Hot and cold packs are used by athletes to treat injuries. In these packs, reactants are separated in different compartments. When pack is needed, the compartments are broken and the chemical reaction takes place absorbing or releasing heat.

Watch the videos in the following web pages:

1. http://www.youtube.com/watch?v=DPjDO7IlXKI&feature=related (video about a sobresaturated solution of sodium acetate (hot pack)). In hot packs, calcium chloride or magnesium sulphates are also used, along with water, they release heat when the compartments are broken and the chemicals dissolve in the water.

2. http://www.youtube.com/watch?v=5RJLvQXce4A&hl=es (video about reaction: ammonia nitrate + barium hydroxide (cold pack)). In cold packs, ammonium nitrate is also used because it absorbs a lot of heat when it dissolves in water. The water and ammonium nitrate are initially in separate compartments in the pack.

3. Videos with a lot of information about endothermic and exothermic reactions, theory and experiments are found in the following web site: http://www.yteach.co.uk/page.php/resources/view_all?id=reaction_endothermic_exothermic_energy_bond_enthalpy_transmition_activation&from=search. Very interesting additional resources about mathematics and science are in homepage: http://www.yteach.co.uk/.

Questions

1. Choose the right answer:

1.1. What type of chemical reaction absorbs energy and requires energy for the reaction to occur?

a) Endothermic
b) Exothermic
c) Double displacement
d) Single displacement

1.2. What type of chemical reaction releases energy when the reaction is produced?

a) Endothermic
b) Exothermic
c) Double displacement
d) Single displacement

1.3. Which of the following are examples of an exothermic chemical reaction? Check all that apply.

a) Burning butane.
b) Photosynthesis.
c) Burning a piece of paper
d) Reaction between sulphuric acid and sodium hydroxide

1.4. Any type of reaction that involves burning (combustion) can be classified as which of the following types of reactions?

a) Endothermic

b) Exothermic

c) Double displacement

d) Single displacement

1.5. When ammonium chloride crystals are dissolved in water the temperature of the water decreases. What does this temperature change indicate about the dissolving of ammonium chloride in water?

a) It is an endothermic reaction because it absorbs heat.

b) It is an endothermic reaction because it releases heat.

c) It is an exothermic reaction because it absorbs heat.

d) It is an exothermic reaction because it releases heat.

2. Classify the following reactions in endothermic or exothermic processes.

a) Burning sugar.

b) Rusting of iron.

c) Electrolysis of water.

d) Baking bread.

3. Can a chemical reaction be both exothermic and endothermic?

4. Fill in these missing words:

In an _____ reaction energy is released. On the other hand, in an _____ reaction, _____ is taken. One example of an endothermic reaction is the dissolving of ammonium _____ in water. When this happens the heat taken in by the mixture causes the _____ to change.

_____ are used to measure temperature.

When in a chemical reaction temperature decreases, an _____ reaction is produced.

5. Many cold packs are used in athletics for treating sprains and aches. Some cold packs contain ammonium nitrate and water in separated compartments. When an athlete or sportsperson hurts themselves they mix the contents of the bag together and put it on the painful part of their body. What kind of reaction is been produced, endothermic or exothermic? Why?

6.

a) What kind of reaction is been produced in hot packs, endothermic or exothermic? Why?

b) Give an example of reactants used in hot packs.

Experiments:

Experiment 1: Heating Copper Sulphate

OBJECTIVE

Observe the changes produced in a chemical reaction.

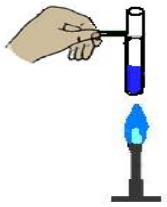
EQUIPMENT

Bunsen burner	Test tube
Spatula	Test tube tongs
Balance	

MATERIALS

Copper (II) sulphate

PROCEDURE



1. Weigh the test-tube and copper sulphate.
2. Put copper sulphate in a test-tube.
3. Light the Bunsen burner.
4. Heat the test tube gently.
5. Stop when it changes colour.
6. Cool the test-tube.
7. Weigh the test-tube and copper sulphate again.

QUESTIONS

1. Write a report of what you did.

Change the instructions to past tense (e.g. Heat the test-tube……. **We** heat**ed** the test-tube). Add some of these words: **first**; **then**; **after that**; **finally**.

2. Complete your report by saying what happened. Write these sentences choosing ONE word from each underlined pair:

Copper sulphate crystals are blue/black. When we heated them we saw steam/smoke at the top of the test-tube. The crystals slowly turned into a red/white powder/liquid. We found they had lost/gained mass. This was because the crystals had lost colour/water.

Experiment 2: Chemical Reactions. Microscale Experiments

OBJECTIVE

Observe the changes produced in different chemical reactions. Save chemicals.

EQUIPMENT

Spatula

Microplates

Pipette

MATERIALS

Diluted sulphuric acid
Copper carbonate
Sodium hydroxide solution
Vinegar
Sodium hydrogen carbonate
Copper oxide
Lead nitrate
Potassium iodide
Copper
Magnesium
Iron filings
Copper sulphate solution
Water

PROCEDURE and QUESTIONS

a. In the following table are written the chemical reactions you have to do.

b. Put a small quantity of the chemicals you have to use to do the reaction in each well of microplates.

Wear safety glasses

Use small amounts of chemicals

c. Record your observations and ideas in the table below:

Chemicals used	Observations	Is it a chemical change? Give reasons
Diluted sulphuric acid + Copper carbonate		
Diluted sulphuric acid + Sodium hydroxide solution		
Vinegar + Sodium hydrogen carbonate		
Water + Copper oxide		
Lead nitrate + Potassium iodide		
Diluted sulphuric acid + Copper		
Diluted sulphuric acid + Magnesium		
Water + Iron filings		
Copper sulphate solution + Iron filings		

Experiment 3: Burning candles

OBJECTIVE

To predict and observe what happen in a combustion reaction when the quantity of oxygen changes.

EQUIPMENT

250 cm^3 beaker 500 cm^3 beaker

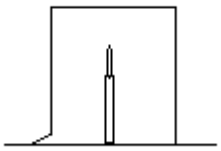
Chronometer

MATERIALS

Two candles same size Matches

PROCEDURE

1. Light a candle. Cover it with a 250 cm^3 beaker. How long does it take the candle to extinguish? A



Prediction: I think the candle will …… because …….. in the beaker ……

Observation: ……
……

2. Light the other candle. Cover it with a 500 cm^3 beaker. How long does it take the candle to extinguish?

Prediction: *I think the candle in the big beaker will …….. because ……..*

Observation: ……
……

QUESTIONS

1. Complete the following paragraph*: A candle contains molecules made of carbon and hydrogen. When it burns these elements combine with ..... in the air. Carbon ....., water and energy in the form of ..... and ..... are made.*

2. What will happen if the candles were of different size?

Experiment 4: Burning copper

OBJECTIVE

To predict and calculate the mass of product obtained when copper is heated directly over the flame of a Bunsen burner.

EQUIPMENT

Balance	Bunsen burner	Tongs
Ruler	Scissors	

MATERIALS

Copper foil

PROCEDURE

1. Cut a rectangular piece of copper foil and weigh it accurately on a balance. Record the mass[1] in the table.

2. Look carefully at the surface of the piece of copper and write down what it looks like[2] (colour, shine, texture).

3. Measure the size of your piece of copper metal in cm^2 and record it in the table.

4. Hold the piece of metal in a pair of metal tongs, and heat it strongly in the flame of a Bunsen burner for about 3 minutes. Write down what it looks like[3] (colour, shine, texture).

Prediction: *I think that if I weigh a piece of copper and then I heat it strongly in the air, the mass of the piece of metal will ..... (stay the same/go up/go down). I think this because .....*

5. After 3 minutes, let the piece of copper cool down.

6. When it is cool, find the new mass[4] of the copper metal and write the result on the table.

Mass[1]	Appearance[2]	Size (cm^2)	Appearance[3]	Mass[4]

Wear safety glasses

QUESTION

1. Complete the following paragraph*: From my results I can see that after I had heated the copper metal the mass had ..... (gone up/stayed the same/gone down). I think this happened because .....*

Experiment 5: Displacing metals in salts

OBJECTIVE

Prove how more reactive metals displace less reactive metals in salts. Know if these reactions are endothermic or exothermic. Save chemicals.

EQUIPMENT

Spatula
Thermometer
Microplates

MATERIALS

Magnesium
Iron
Copper
Zinc
Zinc sulphate
Magnesium sulphate
Iron sulphate
Copper sulphate

PROCEDURE

1. In the following table are written the chemical reactions you have to do.
2. Put a small quantity of the chemicals you have to use to do the reaction in each well of microplates.

Wear safety glasses

Use small amounts of chemicals

QUESTIONS

Remember that more reactive metals displace less reactive metals in salts. Magnesium is more reactive than zinc, zinc reacts better than iron and iron is more reactive than copper.

1. Complete the following sentence: Most reactive ..... least reactive.
2. Predict whether there will be a reaction:
   - Magnesium + zinc sulphate ..... Yes/No
   - Iron + magnesium sulphate ..... Yes/No
   - Copper + Iron sulphate ..... Yes/No
   - Zinc + copper sulphate ..... Yes/No
   - Magnesium + copper sulphate ..... Yes/No

3. Knowing the reactivity of metals, fill each box in this table, with the predictions you can make for possible reactions between metal and salt. In case reaction is produced, write **yes**, if not, write, **no**.

	Magnesium sulphate (aq)	**Zinc sulphate (aq)**	**Copper sulphate (aq)**	**Iron sulphate (aq)**
Magnesium				
Zinc				
Copper				
Iron				

4. Now, perform in the lab the twelve reactions you have predicted. Record with a (**Yes**) or (**No**) whether you observe a reaction.

	Magnesium sulphate (aq)	**Zinc sulphate (aq)**	**Copper sulphate (aq)**	**Iron sulphate (aq)**
Magnesium				
Zinc				
Copper				
Iron				

5. Copy and complete using the words in the box:

metals; oxygen; sometimes; more; reaction; cannot; compound

If we heat a metal with a metal oxide there is ..... a reaction. E.g. Magnesium can take ..... from copper oxide because magnesium is ---------- reactive then copper. But if we heat copper with magnesium oxide there is no ..... The copper ..... take oxygen from the magnesium. More reactive ..... displace less reactive metals in a .....

6. Write the equations for the chemical reactions that have been produced. For example:

Magnesium + copper oxide → Copper + magnesium oxide

7. Tell if the previous chemical reactions are endothermic (absorb heat) or exothermic (release heat). How do you do to know the answer of this question?

Experiment 6: Rate of reaction

OBJECTIVE

Know the influence of size of particles in the rate of reaction.

EQUIPMENT

Spatula	Balance
Erlenmeyer flask	Cotton wool
Graduated cylinder	Chronometer

MATERIALS

Diluted hydrochloric acid	calcium carbonate chips
Powder calcium carbonate	

PROCEDURE

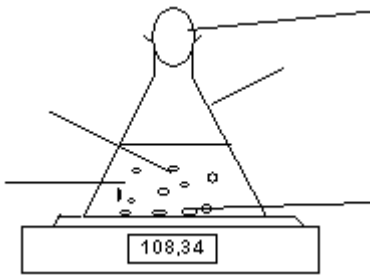
1. In an Erlenmeyer flask put 3 or 4 chips of calcium carbonate.
2. Add 50 mL of diluted hydrochloric acid.
3. Put the mixture on a balance.
4. On the following table annotate the mass that the balance indicates.

Time (s)																
Total mass of flask (g)																

Wear safety glasses

QUESTIONS

1. Label the diagram. Use the following words: *cotton wool; diluted hydrochloric acid; calcium carbonate chips; balance; Erlenmeyer flask; bubbles of carbon dioxide*



2. Using the following statements:

The reaction is fast at the start.
The reaction has finished. No more carbon dioxide is formed.
The mixture is still reacting quickly
The mixture is reacting slowly.

Write a report about what happen in this chemical reaction

3. Match the beginning of the sentence in the left side of table with their corresponding end in right side of the table.

The flask and contents lose mass	the mass stops going down.
The reaction becomes slower	because carbon dioxide went into the air.
Using more diluted acid would	make the reaction go slower.
When the reaction has finished	by using limestone powder.
Stronger acid would	as the acid or limestone is used up
You could speed up the reaction	make the reaction go faster.

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

Chemical change	☐	Physical change	☐
Chemical reaction	☐	Chemical equation	☐
Reactant	☐	Product	☐
Combustion Reaction	☐	Acid-base reaction	☐
Precipitation	☐	Energy	☐
Exothermic reaction	☐	Endothermic reaction	☐
Synthesis reaction	☐	Decomposition reaction	☐
Single displacement	☐	Double displacement	☐

2.- Tick the one you think is your answer:

	I know very well	I need some revision	I need some more help
I know that in a physical change no change of matter is produced.			
I know how that in a chemical change, substances are transformed into new ones.			
I know how to balance a chemical reaction			
I know the difference between a synthesis reaction and a decomposition reaction			
I know the difference between a single displacement reaction and a double displacement reaction			
I know the difference between an acid and a base and which products are produced when they react.			
I known to distinguish an exothermic reaction from an endothermic reaction			

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.

UNIT 7: ACIDS, BASES AND SALTS

Content:

Unit 7 Acids, Bases and Salts

7.1. Definition of acids and bases
7.2. Indicators and pH
7.3. Sulphuric acid, hydrochloric acid and nitric acid
7.4. Acid rain. The effects of acid rain
7.5. Sodium hydroxide and ammonium hydroxide
7.6. Salts

Learning Aims:

At the end of the unit, the student will know:

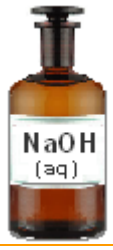
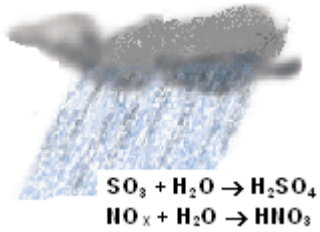
- What an acid and a base are.
- The characteristics and the difference between and acid and a base.
- The concept of pH.
- When indicators are used.
- What a neutralization reaction is.
- How to write and balance a neutralization reaction.
- How acid rain is produced.
- The causes and effects of acid rain.

Initial Activities

1.  Scale of pH goes from 0 to 14. What is the pH of a neutral substance?
2.  Tell if the following statements are true or false:
   - **a.** Acids have a pH lower than 7.
   - **b.** Bases have a pH higher then 7.
   - **c.** Running water is neutral.
   - **d.** All salts are neutrals.
   - **e.** pH of lemon is higher than 7.
3.  Write the formula of sodium chloride and give another name for this compound.

Key words:

Acid 	Substance that can **accept a pair of electrons** to form a covalent bond. Substance that yields hydrogen ions when dissolved in water is an **acid**.
Base 	Substance that can **donate a pair of electrons** to form a covalent bond. A substance that yields hydroxyl ions when dissolved in water or can act as a proton acceptor is a **base**.
Salt 	Chemical compound formed by **replacing** all or part of the **hydrogen ions** of an acid with **metal ions** or **electropositive radicals**.
pH $\log[H^+]$	**pH** is a **logarithmic** measure of **hydrogen ion concentration**: $\mathbf{pH = -\log[H^+]}$
Neutral $pH = 7$	A solution is neutral when the **pH** value is **7**.
Strong acid 	**Acid** that is **completely ionized** when dissolved in water.

Weak acid 	**Acid** that is **partially ionized** when dissolved in water.
Strong base 	**Base** that is **completely ionized** when dissolved in water.
Weak base 	**Base** that is **partially ionized** when dissolved in water.
Neutralization $H^+_{(aq)}Cl^-_{(aq)} + Na^+_{(aq)}OH^-_{(aq)} \rightarrow Na^+_{(aq)}Cl^-_{(aq)} + H_2O$	**Neutralization reactions** occur when a strong acid and a strong base solution are mixed, and a salt is produced.
Acid rain 	Rain resulting from the combination of **nitrogen or sulphur oxides** emissions and **water** in the atmosphere.

7.1. Definition of acids and bases

Definition of **Arrhenius**: **acid** is a substance that **releases protons** or **hydrogen ions** (H^+) in water solutions. **Base**, or alkali, is a substance that **donates** a **hydroxide ion** (OH^-) in water solutions.

Example: $HNO_3 \longrightarrow NO_3^- + H^+$

$NaOH \longrightarrow Na^+ + OH^-$

Arrhenius definition has limited use; a broader definition is given by the **Lowry-Brønsted** theory. **Acids** are **electron pair acceptors** and **bases** are **electron pair donors**.

Acids are paired with bases; the acid accepts the electrons donated by the base. This theory is also called the **conjugate acid-base**.

Example: $HCl + H_2O \longrightarrow Cl^- + H_3O^+$

acid **base** **conjugate base** **conjugate acid**

Hydrogen ion or proton combine with water, a very polar material, attracted by the negative charge of oxygen of a water molecule and the ***hydronium ion***, H_3O^+, is produced.

Acids and bases that **completely ionize** in water solution are called **strong acids** and **bases**, but when they **ionize only partially**, they are called **weak acids** or **bases**.

strong acid: $HCl + H_2O \longrightarrow Cl^- + H_3O^+$

strong base: $NaOH \longrightarrow OH^- + Na^+$

weak acid: $CH_3COOH + H_2O \leftrightarrows CH_3COO^- + H_3O^+$

weak base: $NH4OH \leftrightarrows NH_4^+ + OH^-$

The common acids that are almost one hundred percent ionized are:

HNO_3: nitric acid
HCl: hydrochloric acid
H_2SO_4: sulphuric acid (only the first ionization)
$HClO_4$: perchloric acid
HBr: hydrobromic acid
HI: hydroiodic acid
$HMnO_4$: permanganic acid
$HClO_4$: perchloric acid

All the hydroxides of the elements of Group 1 and Group 2 of Periodic Table, except for beryllium are strong bases. The bases of Group II metals, magnesium, calcium, barium, and strontium are strong, but all of these bases have somewhat limited solubility. Magnesium hydroxide has a particularly small solubility.

LiOH: lithium hydroxide

NaOH: sodium hydroxide

KOH: potassium hydroxide

RbOH: rubidium hydroxide

CsOH: cesium hydroxide

$Mg(OH)_2$: magnesium hydroxide

$Ca(OH)_2$: calcium hydroxide

$Sr(OH)_2$: strontium hydroxide

$Ba(OH)_2$: barium hydroxide

PROPERTIES OF ACIDS

For the properties of acids and bases we will use the Arrhenius definitions.

- Acids release a hydrogen ion into water solutions.
- Acids react with bases and salt and water are produced.
- When an acid react with a metal, usually salt and hydrogen are produced.
- Acids turn blue litmus to red.
- Acids taste sour.

PROPERTIES OF BASES

- Bases release a hydroxide ion into water solution.
- Bases react with acids and salt and water are produced.
- Bases turn red litmus to blue.
- Bases taste bitter.

Questions

1. Which of the following statements are true?

a) Acids and bases don't react with each other.
b) Reaction between an acid and a base produces salt and water.
c) Reaction between acid and base releases hydrogen.
d) Acids have sour taste and change litmus from blue to red.
e) Bases are slippery and change litmus from red to blue.
f) When bases ionize, the release hydrogen ions.

2. Tell if the following statements are true or false:

a) Strong acids are totally dissociated in water solutions.
b) Bases are sometimes called alkalis.
c) Bases are electron pair acceptors.
d) Vinegar, lemon juice and chloride acid are examples of strong acids.
e) In the manufacture of soap sodium hydroxide is used.
f) A common element to all acids is oxygen.
g) Vinegar contains an acid called acetic acid.
h) Lemon juice contains citric acid.
i) When bases are dissolved in water they release hydronium ions.
j) The acid used in the storage battery in your car is nitric acid.

In questions **1** and **2** change the false statements for the correct one.

3. Complete the following sentences:

a) Acids and bases _____ when they dissolve in water.
b) HCl and HI are _____ acids.
c) Hydroxides of metals of Group 1 of the Periodic Table are strong _____.
d) A(n) _____ turns blue litmus red, carries a current and is corrosive with active metals.
e) Another name for hydrogen ion is _____
f) A(n) _____ turns phenolphthalein pink.
g) A hydrogen ion is the same as a _____.
h) An acid tastes _____.
i) OH^- ions are called _____.
j) Bases are _____ donors.

7.2. Indicators and pH

An **acid-base indicator** is a weak acid or a weak base that changes colour over a range of hydrogen ion concentrations, pH. This range is known as **colour change interval**.

Equilibrium equation: $HInd^-_{(aq)} + H_20_{(l)} \leftrightarrows Ind^-(aq) + H_2O_{(l)}$

An example of a **natural indicator** is red cabbage. The colour of fresh red cabbage or boiled with water is blue, but when we add vinegar or lemon, the colour turns red. This is because the pH turns acid. The change of colour is due to a pigment in the red cabbage which acts as a pH indicator.

Question

Consult the website http://www.ch.ic.ac.uk/vchemlib/course/indi/indicator.html and complete the following table:

Indicator	pH Range	Acid colour	Base colour
Thymol Blue (1st change)			
Methyl orange			
Bromocresol Green			
Methyl red			
Bromthymol blue			
Phenol red			
Thymol Blue (2nd change)			
Phenolphthalein			

pH ("p" stands for "potenz" (this means the potential to be) and the "H" stands for Hydrogen) is a logarithmic measure of hydrogen ion concentration. This concept was originally defined by Danish biochemist Søren Peter Lauritz Sørensen in 1909.

pH is defined as the negative logarithm to the base 10 of molar concentration of hydrogen ions:

$$pH = -\log[H^+]$$

pH Scale

The **pH scale** ranges from **0** to **14**. pH of distilled water is **7**, this is **neutral**. Any solution with a pH **below 7** is an **acid** and any solution with a pH **above 7** is an **alkali**:

H_3O^+	OH^-	pH	Acidity/alkalinity
$> 10^{-7}$	$< 10^{-7}$	0 - 7	Acidic
10^{-7}	10^{-7}	7	Neutral
$< 10^{-7}$	$> 10^{-7}$	7 - 14	Basic

Aqueous solutions, acidic, alkaline or neutral, contain both H_3O^+ and OH^- ions. The product of their concentrations is always equal to 10^{-14} at 298 K.

Example: Solution of sodium chloride is neutral (pH =7), lemon juice is acid (pH < 7) and bleach is basic (pH > 7).

Questions

1. Tell if the following sentences are true or false:

a) Pure water has a pH of 7.
b) Orange juice has a pH of about 5. It is a strong acid.
c) Acids have a pH more than 7.
d) A liquid with a pH of 12 is a strong alkali.
e) Toothpaste has a pH of about 9. It is a weak acid.
f) A concentrated sulphuric acid solution has a lower pH than orange juice.
g) Neutral means that it is neither acid nor alkali.
h) A sodium hydroxide solution has a high pH.
i) Alkalis have a pH higher than 7.
k) Water has a higher pH than lemon juice.
l) A cleaner has a pH of 10 or above, it is acid.
m) Soaps and shampoos have pH values between 6 and 8.
n) Some drinks are acid. Drinks which are acid have pH of 1-3

Write the correct answer for the false sentences.

2. Choose the right answer:

2.1. When we add an acid to an alkali solution, pH

a) increases.
b) decreases.
c) remains the same.

2.2. A solution has a pH of 5, so the molar concentration of H_3O^+ is:

a) 10^{-9} mol · dm^{-3}.
b) 5 mol · dm^{-3}.
c) 9 mol · dm^{-3}.
a) 10^{-5} mol · dm^{-3}.

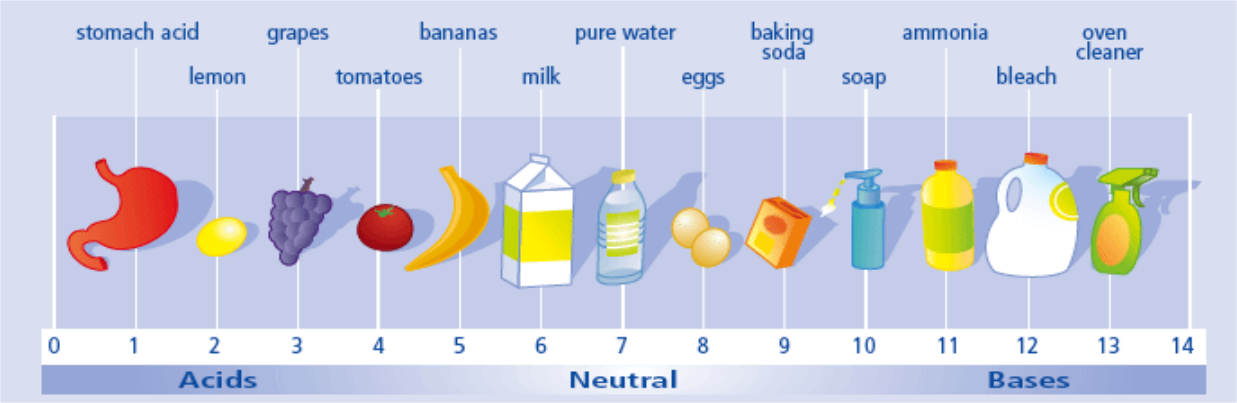
2.3. Which of the following solutions has the lowest PH?

a) bleach
b) sulphuric
c) sodium hydroxide
d) tomato juice

2.4. Pure water has a pH

a) more than 7
b) 7
c) less than 7
d) depend on the place

3. Look the following tables and then answer the questions:



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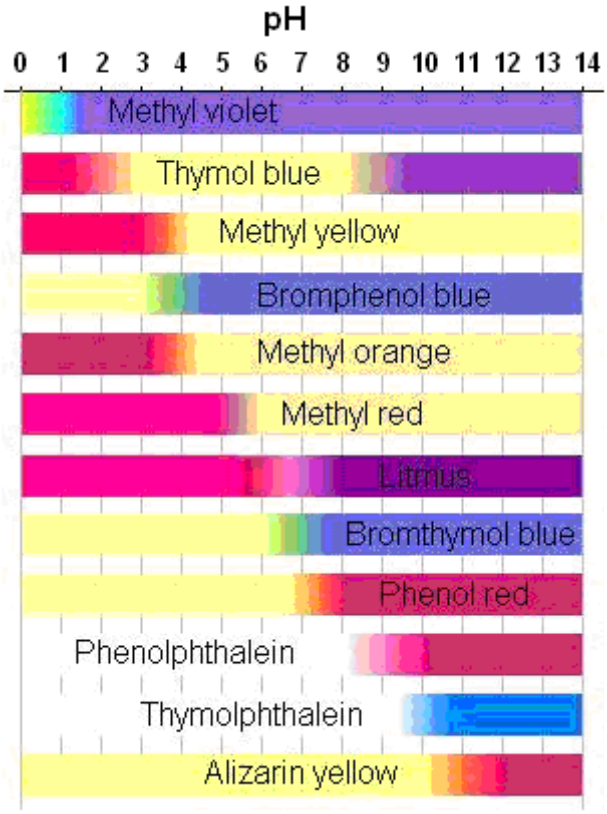


http://www.carlton.srsd119.ca/chemical/equilibrium/Images/indicators.jpg

a) Which substances of the first table turn phenolphthalein pink? Why?

b) What colour would methyl orange indicator be in a solution with a pH of 2?

c) What colour would litmus be in bleach?

d) What colour would thymol blue indicator be in natural lemon juice?

e) Draw a new table similar to the previous one, wit the colours of a universal indicator made with a mixture of the indicators that appear in that table in the same proportion.

4. Match a sentence from the first box with a sentence from the second box.

1. Vinegar has a pH of about 4

2. Sodium hydroxide is a strong alkali

3. Sulphuric acid and hydrochloric acid have a pH of 1-2

4. Toothpaste has a pH of 8 and sodium carbonate has a pH of 9

5. Nitric acid has a pH of 1-2 and vinegar has a pH of about 4

6. Sodium hydroxide has a pH of 12, but sodium carbonate has a pH of 9

7. Water has a pH of 7

8. The pH of a liquid

9. A very acid solution

10. A very alkaline solution

11. When acid is added to an alkali

12. When alkali is added to an acid

a. Therefore sodium hydroxide is a stronger alkali than sodium carbonate.

b. So, they are both strong acids.

c. So, they are both weak alkalis.

d. So, it is a fairly strong acid.

e. Therefore it is neutral.

f. Therefore nitric acid is a stronger acid than vinegar.

g. Has a pH of 12-14.

h. it has a high pH (13 or 14).

i. The pH goes down.

j. Has a low pH (1 or 2).

k. Tells how acidic or alkaline it is.

l. The pH goes up.

5. Calculate the pH of the following solutions and tell if they are acids, bases or neutrals: $[H_3O^+]$: 10^{-5}; $10^{-12.5}$; $10^{-3.2}$; $10^{-4.8}$; $10^{-10.5}$.

7.3. Sulphuric acid, hydrochloric acid and nitric acid

Sulphuric acid (H_2SO_4), **hydrochloric acid** (HCl) and **nitric acid** (HNO_3) are strong acids widely used in industries and laboratories.

Questions

With support of **Wikipedia** website, complete the following table and answer the questions:

1.

	H_2SO_4	HCl	HNO_3
Scientific name			
Other names			
Discoverer			
Synthesis			
Molecular Weight			
State			
Appearance			
Toxicity. Safety			
Uses			

2. Choose the right answer:

2.1. Acid that reacts with proteins in your skin leaving a yellow colour is:

a) hydrochloric acid
b) sulphuric acid
c) nitric acid
d) acetic acid

2.2. When an aqueous solution of an acid is prepared,

a) acid has to be added over the water.
b) water has to be added over the acid.
c) acid and water have to be mixed in the same proportions.
d) none of the previous answers.

2.3. When an acid spill over your clothes or skin, on the affected area

a) add a strong base.
b) add a weak base.
c) flush with water
d) add an adequate ointment.

2.4. An acid that reacts with water in the skin and can cause burned tissue is:

a) hydrochloric acid
b) sulphuric acid
c) nitric acid
d) acetic acid

7.4. Acid rain. The effects of acid rain

There is **Natural Acidity of Rainwater** when carbon dioxide reacts with water to form carbonic acid. Carbonic acid then dissociates to give hydronium ions (H_3O^+) and hydrogen carbonate ions (HCO_3^-).

$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$H_2CO_3 + H_2O \leftrightarrows HCO_3^- + H_3O^+$$

Nitric oxide (NO), which also contributes to the natural acidity of rainwater, is formed during lightning storms by the following reactions:

$$N_{2(g)} + O_{2(g)} \xrightarrow{h\nu} 2\ NO_{(g)}$$

$$NO_{(g)} + \tfrac{1}{2}\ O_{2(g)} \rightarrow NO_{2(g)}$$

$$3\ NO_{2(g)} + H_2O \rightarrow 2\ HNO_{3(aq)} + NO_{(g)}$$

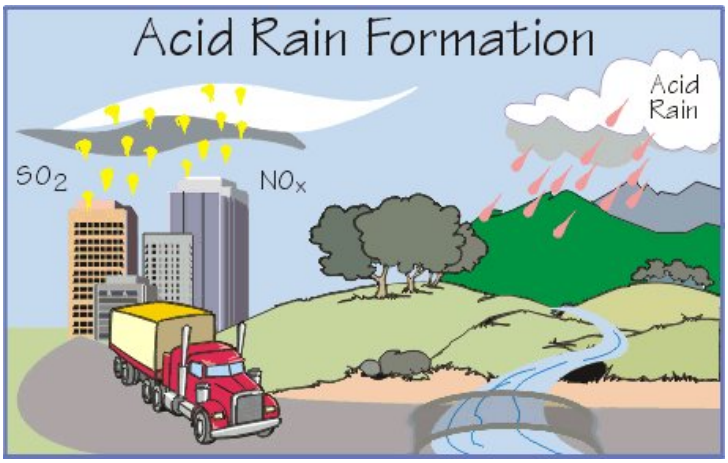
But there are additional processes that produce **Polluted Rainwater**: car engines and power plants produce large amounts of NO gas; this gas then forms nitric acid. Level of nitric acid in rainwater increases and can harm the environment.

25% of acid rain is due to nitric acid, most of the other 75% of the acidity of rain is accounted for by the presence of sulphuric acid (H_2SO_4) in rainwater. Small quantities of sulphuric acid are produced naturally from biological decay and volcanic activity, but human activity produced a lot of quantities of sulphur oxides. These oxides are usually produced in the combustion of fossil fuels in power plants. When fossil fuels containing sulphur are burned, the following reactions are produced:

$$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$$
$$SO_{2(g)} + ½\ O_{2(g)} \rightarrow SO_{3(g)}$$
$$SO_{3(g)} + H_2O \rightarrow H_2SO_4$$

Sulphuric acid is an acid, so it dissociates in water, to give an $H30^+$ ions, HSO_4^- ions and SO_4^{2-} ions:

$$H_2SO_4 + H_2O \rightarrow HSO_4^- + H_3O^+$$
$$HSO_4^- + H_2O \rightarrow SO_4^{2-} + H_3O^+$$



http://www.epa.gov/bioindicators/images/acid.jpg

The effect of acid rain is important and destructive in industrial areas. It have been studied a big area in the North of Europe where the acid rain has damaged forests and harvests, eroded structures and damaged the life in the lakes of sweet water.

In 1988, as a part of the Agreement about contamination at the United Nations Convention (1979), twenty five nations ratified a protocol in witch they froze the emissions of nitrogen oxides. The amendments of 1990 to the US Clean Air Act of 1967 introduced rules to reduce the sulphur dioxide emission to 10 million tons a year before the first of January of 2000.

Apart from the smoke of the industries also it is very important the emissions of cars.

We have to be aware about this problem because when the acid rain drops over a forest, leaves don't do the chlorophilical function well and the roots don't take minerals from the earth. After some years, the forest dies.

Effects of Acid Rain

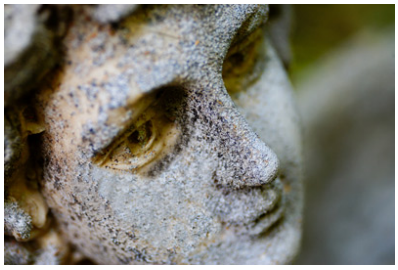
Surface Waters

Surface waters and their ecosystems are victims of acid rain. Most of precipitation that enters a lake, river, stream or marsh, must first pass through soil. All soil has a **buffering capacity**, or ability to resist changes in acidity and alkalinity. If the capacity is low, or has reached its limit, acid rain can increases considerably the pH of soil.

Acid deposition weakens trees and pollutes surface waters.

Acid rain also dissolves helpful minerals and nutrients like calcium, magnesium and potassium before trees can absorb them. Nutrient deprivation and exposure to toxins make trees more likely to fall in storms or die in cold weather.

Materials and Finishes



Acid rain reacts with calcium carbonate stones and metals. It accelerates the natural weathering reactions due to rain, sun snow and wind.

Acid rain reacts with stones and metals. Old buildings, monuments and tombstones bear the smooth signs of acidic corrosion and deterioration such as India's Taj Mahal, the mausoleum built by the Mughal Emperor Shah Jahan for his beloved wife Mumtaz Mahal. Acid rain also spoils automotive paint.

Acid Rain and the Taj Mahal

Health

Since acid rain can kill aquatic animals, weaken trees and dissolve stone, it is also dangerous ford humans, it produce scalds or burns, but the effect it is not so harmful. Sulphate and nitrate particulates of dry deposition can cause asthma, bronchitis and heart problems. The NOx in acid deposition also reacts with **volatile organic compounds** (VOCs) to form ground-level ozone. Ozone, or **smog**, aggravates and weakens the respiratory system.

One strategy for limiting the amount of acid pollution in the atmosphere is *scrubbing.* In particular, calcium oxide (CaO) is injected into the combustion chamber of a power plant, where it reacts with the sulphur dioxide produced, to yield solid calcium sulphite.

Questions

1. Name the top 3 substances found in air and list in order of abundance.

2. Where are produced the nitrogen and sulphur oxides?

3. When rain turns acid, how is the value of the pH, smaller or higher?

4. Write the equation for formation of carbonic acid from carbon dioxide and water.

5. When temperature increases, concentration of carbon dioxide in water increases or decreases? Why?

6. Explain the reason for decrease in acidity of soda with increase in temperature.

7. Describe the causes and effects of acid rain. 

8. Complete the following paragraphs using the words from the box:

Acids, buildings, pollution, great, slightly, polluting, carbon dioxide, nitrogen, clouds, snow, increase, sulphur dioxide, water, pH

Acid rain is a result of air …….. Power stations, factories and cars all burn fuels and therefore they all produce …….. gases. Some of these gases (especially …….. oxides and …… ……..) react with the tiny droplets of …… in clouds to form sulphuric and nitric …….. The rain from these …….. then falls as very weak acid - which is why it is known as "acid rain".

Rain is always …….. acidic because it mixes with naturally occurring oxides in the air (such as …….. ……..). Unpolluted rain would have a ……..value of between 5 and 6. When the air becomes more polluted, with nitrogen oxides and sulphur dioxide, the acidity can …….. to a pH value of 4. Some rain has even been recorded as being pH = 2.

Acid rain can be carried ……..distances in the atmosphere, not just between countries but also from continent to continent. The acid can also take the form of……., mists and dry dusts. The rain sometimes falls many miles from the source of pollution but wherever it falls it can have a serious effect on soil, trees, …….. and water

http://ypte.org.uk/docs/factsheets/env_facts/acid_rain.html

9. What can we do to reduce emissions to the atmosphere? Give at least four examples.

10. 

Build a rain gauge with a plastic bottle. If you need some help, consult the web page: **http://www.rcn27.dial.pipex.com/cloudsrus/measurerain.html**

a) Collect rainwater different days, measure the pHs and complete the following table:

Date / Time	Rainfall (mm)	Rain pH

b) Plot a rainfall/pH graph.

c) Is there any relationship between the rainfall and the rain's pH? Give a reason for your answer.

d) What relationship do you observe between rainfall, pH and the date the observations are made?

7.5. Sodium hydroxide and ammonium hydroxide

Sodium hydroxide (NaOH) is a strong base and **ammonium hydroxide** (NH_4OH) is a weak base. Both chemicals are widely used in industries and laboratories.

Questions

With support of **Wikipedia** website, complete the following questions and table:

1. Phenolphthalein turns _____ in contact with ammonium hydroxide.
2. Sodium hydroxide is a strong base and ammonium hydroxide is a _____ base.
3. Sodium hydroxide is _____ at room temperature, but ammonia is a gas at room temperature.
4. pH of a solution of sodium hydroxide or ammonia hydroxide is _____ than 7.

5.

	NaOH	**NH_3**
Scientific name		
Other names		
Discoverer		
Synthesis		
Molecular Weight		
State		
Appearance		
Toxicity. Safety		
Uses		


NaCl

7.6. Salts

When an acid and a base react, a **salt** is obtained.

Example: $HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$

When an acid reacts with a metal, a **salt** is also obtained.

Example: $Mg_{(s)} + HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

pH of solution depend on the strength of acid and base. Strong acids and bases give a neutral salt; strong acid and weak base give and acid salt and weak acid and strong base give a basic salt.

Example:

- pH of a NH_4NO_3 solution is smaller than 7 because NH_4OH is a weak base and HNO_3 is a strong acid.
- pH of a CH_3COONa solution is higher than 7 because CH_3COOH is a weak acid and NaOH is a strong base.
- pH of a NaCl solution is 7 because HCl and NaOH are strong acid an base, respectively.

Questions

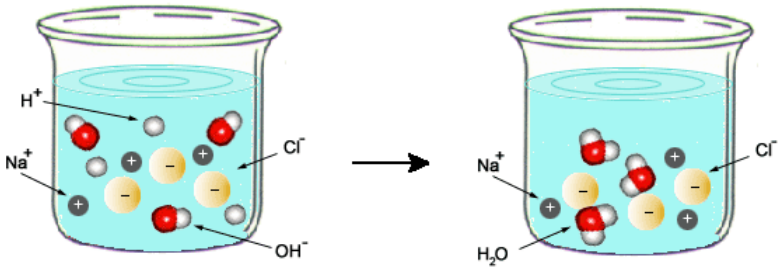
1. Name the salt produced in the following chemical reactions:

a) Sodium hydroxide reacts with sulphuric acid.
b) Barium hydroxide reacts with nitric acid.
c) Magnesium reacts with hydrochloric acid.
d) Iron (III) hydroxide reacts with sulphuric acid.
e) Potassium hydroxide reacts with hydrobromic acid.
f) Hydrofluoric acid reacts with zinc hydroxide.
g) Calcium hydroxide and phosphoric acid.

2. Tell if the following statements are true or false. If some statement is false, change it to the correct one.

a) When magnesium and hydrochloric acid react, magnesium chloride and water are produced.
b) When water solutions of an acid and base are mixed, a salt and hydrogen are produced.
c) When zinc reacts with sulphuric acid, zinc sulphate and hydrogen are obtained.
d) When a metal reacts with sulphuric acid, hydrogen is released.

3. Acids, bases and salts are dissociated in aqueous solutions (look the following diagram):



http://www.geocities.com/jtwsaddress42/Chemistry/Chem1ABChem2Chem30A_TOC.html

Are these solutions electricity conductors or not? Why?

4. The substances that appear in the following table are the only strong acids and bases.

a) Write and name in each square the formula of the salt obtained when the acid and base react.

Acid / Base	**HCl**	**HBr**	**HI**	**H_2SO_4**	**HNO_3**	**$HClO_3$**	**$HClO_4$**
LiOH							
NaOH							
KOH							
RbOH							
$Ca(OH)_2$							
$Sr(OH)_2$							
$Ba(OH)_2$							

b) Write the equation of the different chemical reactions.

5. Use different web sites to solve the following questions:

- **a)** Give another name for sodium chloride.
- **b)** Describe the appearance of sodium chloride.
- **c)** Why sodium chloride is important to life?
- **d)** What is the composition of a physiological solution?
- **e)** Define the term isotonic.
- **f)** Where sodium chloride is obtained of?
- **g)** Write five uses of sodium chloride.

Experiments:

Experiment 1: Making and testing cabbage indicator

OBJECTIVE

Make a pH indicator from red cabbage and test the change of colour when pH changes.

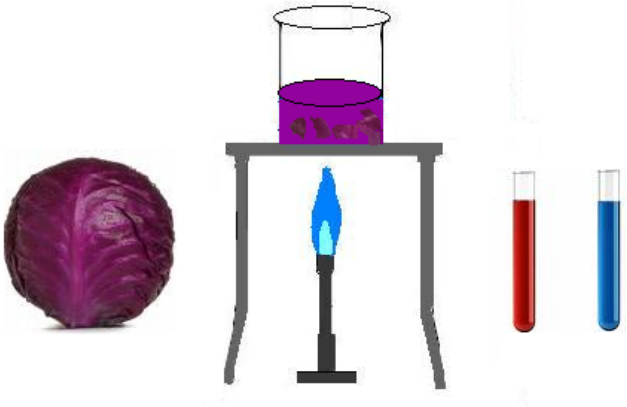
EQUIPMENT

Beaker	Bunsen
4 test tubes	5 pipettes
Stirring rod	knife

MATERIALS

Sliced red cabbage	Vinegar, lemon juice... (an acid)
Water	Ammonia, bleach, baking soda … (a base)
Two unknown solutions	

PROCEDURE



1. Boil cabbage in the beaker for about 30 minutes.
2. Let cool before removing the cabbage.
3. Pour about 1 mL of cabbage juice into each test tube.
4. Add 0.5 mL of ammonia or other base to one test tube and stir with a clean stirring rod.
5. Add 0.5 mL of vinegar or other acid to a second test tube, stir the mixture.
6. Add about 2 mL of the unknown solutions in the other two test tubes.

QUESTIONS

1. What colour change took place when you add vinegar or other acid to the cabbage juice? Why?

2. Did the ammonia or other base turn the cabbage juice pH indicator red or blue? Why?

3. What happens to the colour if you pour the contents of the acid test tube into the ammonia test tube?

4. If you gradually add acid to the test tube containing the base and cabbage juice, what do you think would happen to the colour of the indicator? Try it, stirring constantly.

5. The unknown solutions contain an acid or a base? Why?

Experiment 2: Neutralizing Acids or Bases Using a pH meter

OBJECTIVE

Observe the variation of pH in an acid-base reaction. Titrate a measured volume of HCl with a solution of NaOH, according to the equation:

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

EQUIPMENT

Erlenmeyer flask	Burette
Beaker	Stand
Clamp	pH meter

MATERIALS

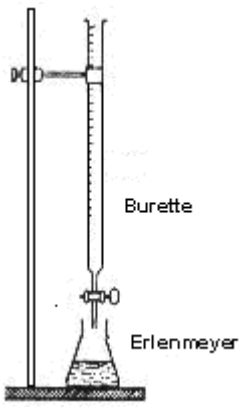
HCl 0,1 mol · dm^{-3} NaOH 0,1 mol · dm^{-3}

Distilled water

PROCEDURE

Watch these videos before starting the experiment:
http://www.youtube.com/watch?v=g8jdCWC10vQ&feature=channel_page and
http://www.youtube.com/watch?v=r1uEXOOR2nU

1. Set the apparatus up according to the setup specified below.



2. Pour 10 mL of HCl 0,1 mol · dm^{-3}, 20 mL of distillate water and 3 or 4 drops of phenolphthalein in the Erlenmeyer flask.

3. Put the pH meter inside the Erlenmeyer.

4. Add NaOH 0,1 mol · dm^{-3} from the burette little by little the first 9 mL, then drop by drop, and stir the mixture constantly.

5. Measure the pH, annotate their value on the table that appear in the questions and compare with the indicator colour.

Repeat this experiment using the Multilog Pro equipment and the Multilab program. In web site: **http://www.gwahak.com/pdfs/chemistry/acid_base_titration.pdf** you will find all the information to carry out the experiment and also different questions related to the titration process.

QUESTIONS

1. Complete the following table with the titration data:

mL of $NaOH_{(aq)}$	pH	Indicator colour
1		
2		
3		
4		
5		
6		
7		
8		
9		
9,5		
9,6		
9,7		
9.8		
9,9		
10		
10,1		
10,2		
10,3		
10,4		
10,5		
11		
12		

2. Plot a graph of mL of NaOH added versus pH

3. What happens to the pH?

4. What was the pH at equivalence point for this titration?

5. What is an indicator? Why was phenolphthalein used as an indicator for this titration?

Experiment 3: Amphoteric properties of Zinc. Gold Pennies

OBJECTIVE

Show the amphoteric character of zinc.

EQUIPMENT

Beaker	Bunsen
2 test tubes	Pipette
Spatula	Tongs
Goggles	

MATERIALS

$NaOH_{(aq)}$	$HCl_{(aq)}$
Zinc	Distilled water
Vinegar	Saltz
Coin (5 cents)	

PROCEDURE

In chemistry, some substances have an amphoteric character, they can react with either an acid or bases, as for example amino acids, water and many metals, such as zinc, tin, aluminium and beryllium, have amphoteric oxides.

Wear safety glasses

Use small amounts of chemicals

Work with chemicals on the hood

1. Reaction of zinc and hydrochloric acid:

1. In a test tub put a small quantity of zinc and add diluted hydrochloric acid.

2. Repeat the process using concentrated hydrochloric acid.

2. Reaction of zinc and sodium hydroxide. Gold penny:

Watch this video before starting the experiment:
http://www.metacafe.com/watch/1262456/make_a_gold_penny/

1. Clean 5 cents coin in a mixture of vinegar and salt for about ten minutes.

2. Drop the coin into a boiling solution of sodium hydroxide and zinc mixture. Let it sit for about two minutes.

3. Pull the coin out of the water with a pair of crucible tongs and let it cool and dry on a paper towel. DO NOT TOUCH THE PENNY WITH YOUR BARE HANDS!

Record the appearance of the coin:

4. With the crucible tongs, hold the coin over the Bunsen burner until you observe a colour change (about 20 seconds). Once the colour has changed, immediately remove the coin from the heat and let it cool in water. Don't put it on a paper towel (the paper towel would catch fire).

Record the appearance of the coin:

Explanation: Zinc reacts with sodium hydroxide and sodium zincate is produced: $Zn + 2\ OH^- \rightarrow ZnO_2^{2-} + H_2$. When coin is added to solution, a redox reaction take place and zincate ion is reduced to metallic zinc (silver colour). Finally, when coin is heated over the Bunsen burner, zinc coating diffuses into the copper of the coin and an alloy called brass (gold colour) is obtained.

QUESTIONS

1. Write the reaction between hydrochloric acid and zinc.

2. What difference do you observe when using diluted hydrochloric acid and concentrated hydrochloric acid?

3. Watch the video: **http://www.youtube.com/watch?v=HxiW2iPUZiw&feature=related.** Which reaction is produced between hydrogen and oxygen when the balloon blows up?

4. Formation of brass from copper and zinc is a chemical reaction? Why?

5. Consult a web site, for example Wikipedia, and explain some properties and applications of brass.

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

Acid	☐
Base	☐
Strong acid	☐
Weak acid	☐
Strong base	☐
Weak base	☐
Salt	☐
pH	☐
Neutralization reaction	☐
Acid rain	☐

2.- Tick the one you think is your answer:

	I know very well	**I need some revision**	**I need some more help**
I understand the concept of acid.			
I understand the concept of base.			
I understand the theory of Lowry-Brønsted theory and why is also called the conjugate acid-base theory.			
I know what pH means.			
I know the intervals of pH in an acid, a base and a neutral substance.			
I know why an acid-base indicator is used.			
I understand the variation of pH in an acid-base titration.			
I know some properties and uses of hydrochloric acid			
I know some properties and uses of sulphuric acid.			
I know some properties and uses of nitric acid			
I know how acid rain is produced.			
I know the effects of acid rain			
I know some strategies for limiting the amount of acid pollution in the atmosphere.			
I know some properties and uses of sodium hydroxide.			
I know some properties and uses of ammonium hydroxide.			
I know how to write the equations of chemical reactions between and acid and an hydroxide.			
I know how to write the equations of chemical reactions between and acid and a metal.			

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.

Project: At the end of chemistry students have to do a written report about "Chemistry, society and environment" In this interdisciplinary work a lot of emphasis will be made in the study of the environment: natural resources, waste and pollution, the water as a resource, the greenhouse effect, etc proposing the students a work in group and making debates to put in common the measures they think can be taken.

UNIT 8: RADIOACTIVITY AND THE ATOM

Content:

Unit 8 Radioactivity and the atom

8.1. Nuclear Reactions.
8.2. Types of radiations.
8.3. Ionization by radiation.
8.4. Half-life
8.5. Nuclear fission.
8.6. Nuclear fusion
8.7. Radiation effects.
8.8. Applications of radioactive nuclei

Learning Aims:

At the end of the unit, the student will know:

- To identify a nuclear reaction.
- The difference between an alpha and beta particles.
- The characteristics of gamma rays.
- How to solve questions related to the half-life of an isotope.
- The difference between nuclear fission and fusion.
- Some applications of radioactive isotopes.
- To use the appropriate language to answer questions and to communicate with teacher and classmates.

Initial Activities

1.  Choose the right answer:

1.1. Isotopes have the same number of

a) Protons
b) Neutrons
c) Electrons
d) Ions

1.2. A nuclear fusion is:

a) An endothermic reaction.
b) An exothermic reaction.
c) A displacement reaction.
d) An acid-base reaction.

1.3. Beta particles are

a) Protons
b) Neutrons
c) Electrons
d) Ions

1.4. Alpha particles are

a) Protons
b) Helium nucleus
c) Electrons
d) Neutrons

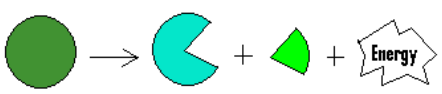
1.5. An isotope used in nuclear powers plants is

a) ^{27}Al
b) ^{235}U
c) ^{23}Na
d) ^{207}Pb

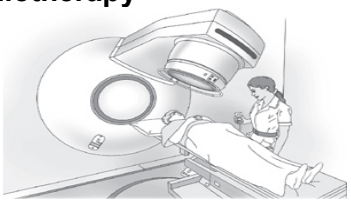
2.  What is the difference between fusion and fission reactions? 

3.  What is the difference between nuclear reactions and "normal" chemical reactions? 

Key words:

Radiation α *alpha* β *beta* γ *gamma*	**Particles** or electromagnetic **waves** emitted by the atoms of a radioactive substance as a result of nuclear decay.
Half-life *2 grams of* ^{229}Ra *after 4 minutes becomes* *1 gram of* ^{229}Ra	**Time** required for **half the nuclei** in a radioactive isotope to undergo radioactive decay.
Nuclear reaction 	Process in which an atomic **nucleus** release **energy** by either a combination of light atoms or the splitting of heavy atoms.

Alpha particles α $^{4}_{2}He^{2+}$	**Helium nucleus**, positively charged particle, composed of two protons and two neutrons.
Beta particles β e^{-}	**Electron** emitted from nucleus of a radioactive isotope.
Gamma rays γ $h\nu$	**High energy** electromagnetic **radiation** emitted by a nucleus undergoing radioactive decay.
Ionization $A + n\ e^{-} \rightarrow A^{n-}$ $B - n\ e^{-} \rightarrow B^{n+}$	Process in witch an **atom** becomes positive or negative **charged**.
Fission $^{235}_{92}U + {}^{1}_{0}n \rightarrow$ $^{140}_{56}Ba + {}^{93}_{36}Kr + 2\ {}^{1}_{0}n + \gamma$	Nuclear reaction in which a nucleus **splits** into two or more lighter nuclei.
Fusion $^{2}_{1}H + {}^{2}_{1}H \rightarrow$ $^{3}_{2}He + {}^{1}_{0}n + energy$	Nuclear reaction in which a two light nucleus **combine** and a heavier nucleus is formed.

Positron 	Antiparticle of electron, positron has the same mass of an electron, but a **positive charge** equal to the electron charge.
Decay $^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$	**Nuclear decay** is the spontaneous disintegration of a radioactive nucleus. This disintegration is accompanied by the emission of alpha or beta particles or gamma rays.
Radiotherapy  http://www.cancerbackup.org.uk/Cancertype/Testes/Treatment/Radiotherapy	**Treatment** of **disease** with radiation.

8.1. Nuclear Reactions.

Nuclear reactions result from the spontaneous decay of naturally occurring or artificially produced radioactive nuclei, from the fission of unstable heavy nuclei, from the fusion of light nuclei, and from the bombardment of nuclei with other nuclei or with other fast moving particles.

Example:

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\ {}^{1}_{0}n$$

8.2. Types of radiations.

In nuclear reactions are involved different kinds of particles. These particles include:

- **Alpha particles** ($^{4}_{2}He$, or α): consist of two neutrons and two protons and are identical to helium nuclei. The energy of alpha particles varies, with higher energy alpha particles being emitted from larger nuclei, but most alpha particles have energies of between 3 and 7 MeV (12.000 km/s and 18.360 km/s). As these particles are relatively large and heavy, they are not very penetrating (a sheet of paper or a 3-cm layer of air is sufficient to stop them) and will not penetrate the outer layer of our skin, but is dangerous if inhaled or swallowed. Its energy is transferred within a short distance to the surrounding media.

- **Beta particles** ($_{-1}^{0}e$, or β): they are high-speed electrons coming from the nucleus. These particles are produced when the nucleus of an unstable atom, with an excess of neutrons, spontaneously decays, and the extra neutron is transformed into a proton, an electron and an antineutrino:

$$n \rightarrow p + e^{-} + \bar{\nu}_e$$

  These particles can leave the nucleus at a speed of 270,000 km/s. They can be stopped, for instance, by an aluminium sheet a few millimetres thick or by 3 metres of air.

- **Positrons** ($_{+1}^{0}e$, or β^{+}) are particles with the same mass as an electron but one unit of positive charge. These particles are produced when the nucleus of an unstable atom, with an excess of protons, spontaneously decays, and the extra proton is transformed into a neutron, a positron and a neutrino:

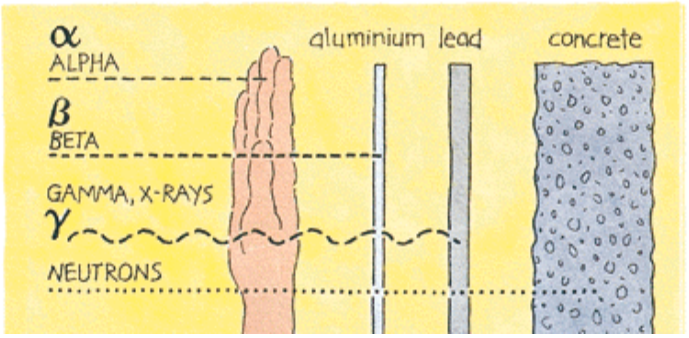
$$p \rightarrow n + e^{+} + \nu_e$$

- **Protons** ($_{1}^{1}H$, or p), which are nuclei of hydrogen atoms.

- **Neutrons** ($_{0}^{1}n$, or n), which are particles with a mass approximately equal to that of a proton but which bear no charge.

Nuclear reactions also often involve **gamma rays** (γ). They are electromagnetic radiation, somewhat like X rays in character but of higher energies and shorter wavelengths. **Gamma rays** are emitted from the nucleus during radioactive decay and occasionally accompanying the emission of an alpha or beta particle. These rays are harmful, capable of damaging living cells as it slows down by transferring its energy to surrounding cell components.

An example of gamma emitter is cobalt-60.



Examples:

$^{254}_{99}Es + {}^{4}_{2}He \rightarrow {}^{256}_{101}Md + 2\ {}^{1}_{0}n$

Alpha Decay: $^{238}_{92}U \rightarrow {}^{4}_{2}He + {}^{234}_{90}Th$

Decay: Beta Emission (Beta-minus): $^{228}_{88}Ra \rightarrow {}^{0}_{-1}e + {}^{228}_{89}Ac$

Decay: Positron Emission: $^{93}_{44}Ru \rightarrow {}^{0}_{1}e + {}^{93}_{43}Tc$

K-Capture (capture beta-minus): $^{22}_{11}Na + {}^{0}_{-1}e \rightarrow {}^{22}_{10}Ne + \nu_e$

A nuclear reaction has to be balanced; that is, both the total nuclear mass and the total charge balance. The total number of protons and neutrons in the reactants must be equal to the total number of protons and neutrons in the products

Questions

1.- What is the change in the nucleus that gives rise to an α particle?

2.- What is the change in the nucleus that gives rise to a β particle?

3.- How do nuclear reactions differ from ordinary chemical changes?

4.- Complete the following equations:

a) $^{7}_{3}Li + {}^{1}_{1}H \rightarrow {}^{4}_{2}He + \ldots\ldots$

b) $^{3}_{1}H + {}^{2}_{1}H \rightarrow {}^{1}_{0}n + \ldots\ldots$

c) $^{14}_{6}C \rightarrow {}^{14}_{7}N + \ldots\ldots$

d) $^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + \ldots\ldots$

e) $^{26}_{12}Mg + {}^{1}_{0}n \rightarrow {}^{0}_{-1}e + \ldots\ldots$

5.- Write the equation that represent the following nuclear reactions:

a) lead-214 decays by beta emission.

b) bismuth-214 decays by beta emission

c) polonium-214 decays by alpha emission

8.3. Ionization by radiation.

When radioactive particles streak through air they are able to remove electrons from some of its atoms. Every **type of radiation** (alpha, beta, gamma, neutrons) has a different damaging potential:

Alpha particles are the most ionizing ones because they are much heavier than the electrons and carry a positive charge. Because alpha particles are charged and relatively heavy, they interact intensely with atoms in materials they encounter, giving up their energy over a very short range. In air, their travel distances are limited to no more than a few centimetres.

Beta particles are lighter and less charged than alpha particles and so are no so good at removing electrons from atoms. They interact less intensely with atoms in the materials, which give them a longer range than alpha particles. Depending on the amount present, they can be harmful for skin and dangerous if inhaled, ingested or absorbed into the body.

Beta particles can produce a secondary radiation called **bremsstrahlung** (X-rays produced when beta particles or other electrons decelerate while passing near the nuclei of atoms). The intensity of bremsstrahlung radiation is proportional to the energy of the beta particles and the atomic number of the material through which the betas are passing. So, lower energy beta emitters, such as ^{14}C, do not produced this kind of

radiation, but the higher energy beta emitters such as ^{32}P can produce it, especially when passing through shielding materials such as lead.

Gamma rays are electromagnetic radiations, then have no mass or charge and interact less intensively with matter than ionizing particles and so are no so good at removing electrons from atoms. As gamma radiation loses energy slowly, it is able to travel significant distances. Dense materials, such as lead, are used to stop these radiation (the denser the material, the more chance that a gamma ray will interact with atoms in the material). This radiation is dangerous to the body.

When radiation enters our bodies it **ionizes atoms** or **breaks chemical bonds**, causing chemical changes. Alpha particles cause most damage because they produce large number of ions within a short distance. Beta and gamma rays penetrate further because they produce fewer ions along their tracks and take longer to use up their energy.

A physical shape or a chemical change of a protein can irreversibly stop its biological function. Most mutations are harmful to the living beings.

The **quantity** of radioactive material present is generally measured in terms of **activity**, number of radioactive disintegrations an amount of material undergoes in a given period of time. Activity is related to mass because the greater the mass of radioactive material, the more atoms are present to undergo radioactive decay.

The two most common units of activity are the **Curie** or the **Becquerel** (in the SI system).

1 Becquerel (Bq) = 1 disintegration per second (dps).

1 Curie (Ci) = 3,7 x10^{10} disintegrations per second (dps)

1 Curie is a large amount of activity while 1 Becquerel is a small amount, then, the units millicurie (mCi) and microcurie (μCu) are used:

1 mCu = 2,2 x 10^9 disintegrations per minute (dpm) = 3,7 x 10^7 Bq = 37 MBq

1 μCi = 2,2 x 10^6 dpm = 3,7 x 10^4 Bq = 37 kBq

Questions

1.- Which radiation:

a) gets rid of its energy quickest?
b) could not get trough skin very easily?
c) could go furthest through the air?

2.- Complete next table, putting a $\surd$ in the square if the radiation can get through and a X if it cannot:

Type	Paper	3 mm aluminium	3 cm lead
Alpha			
Beta			
Gamma			

3.- $^{131}_{53}I$ is a radioactive isotope used in nuclear medicine both diagnostically (to know if the thyroid gland works correctly) and therapeutically (treatment of thyrotoxicosis and thyroid cancer) with a half-life of 8.02 days. This isotope decays with beta and gamma emissions.

a) How many protons and neutrons does it have a nucleus of $^{131}_{53}I$?

b) Write the nuclear equation for the decay of $^{131}_{53}I$.

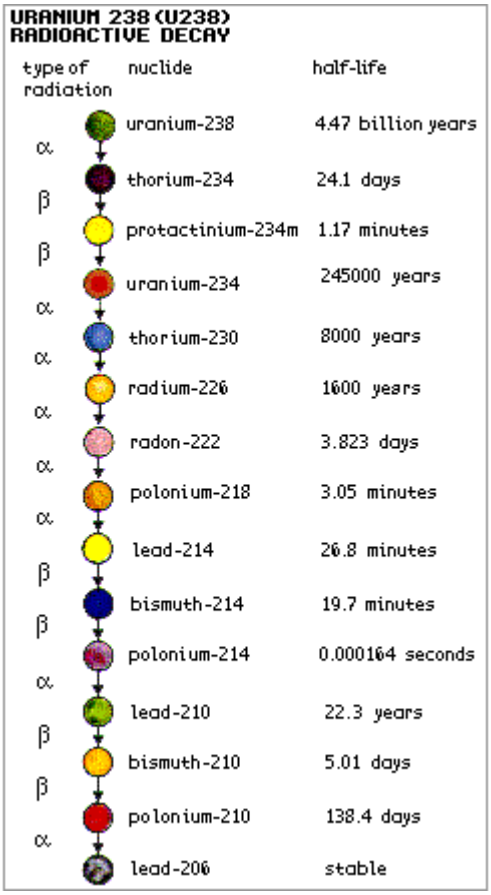
c) The usual sodium iodide (iodine-131) dose to treat hyperthyroidism ranges from 4-10 mCi. Doses to treat thyroid cancer are individualized and are usually 10-27 times greater than for hyperthyroidism. Sodium iodide iodine-131 is available as a capsule or as a liquid in vials.

d) A vial contains $^{131}_{53}I$ with an activity of 3,5 mCi/mL; if a patient need a radiation of 10 mCi, what volume of the vial is required?

8.4. Half-life

Half-life is the time it takes for half of the number of atoms in a sample to decay.

Next, is represented a radioactive series (chains of successive disintegrations, or "decays"), and the half-life of each nuclide. There are three natural series: the **uranium series**, ^{238}U, the **actinium series**, ^{235}U, and the **thorium series**, ^{232}Th. The **neptunium series**, ^{237}Np, does not occur naturally, its members are produced artificially.



Example:

If half-life of a radioactive isotope is 5 days, if we have 8 grams of this isotope, the remain quantity of this isotope after 5 days will be 4 grams, 2 grams after 10 days, 1 gram after 15 days, and so on.

1.- **http://www.colorado.edu/physics/2000/isotopes/radioactive_decay3.html:** Applet with different isotopes with a half-life of a few seconds. There are two pictures, in the top picture, you'll see the atoms change colour as they decay and in the lower picture is a graph showing the number of atoms of each type versus time.

2.- **http://www.lon-capa.org/~mmp/applist/decay/decay.htm:** Another applet to study radioactive decay. You can select the half-life of a nucleus; watch the decay as a function of time and a histogram indicating the number of nuclei remaining at a given time.

3.- **http://lectureonline.cl.msu.edu/~mmp/kap30/Nuclear/nuc.htm**: Interactive Chart Z-N of isotopes, distribution of elements by numbers of neutrons and protons, where the half-life of each element is given.

Questions

1.- Half-life of ^{11}Be is 13.81 seconds. Calculate the mass of 20 grams of ^{11}Be after four half-lives.

2.- Half-life of ^{63}Ni is 100 years. If you had 10^{20} atoms of this isotope, how much would be left after 400 years?

3.- Approximately what percentage of parent isotopes remains after 2 half-lives have passes:

a) 50% **b)** 25% **c)** 12,5% **d)** 6,25%

4.- If a rock initially contained 10 mg of a radioactive parent when it first crystallized, how much remains after 4 half-lives?

a) 4mg **b)** 2,5 mg **c)** 0,625 mg **d)** 0,05 mg

5.- What % parent remains after 10 half-lives?

a) 10% **b)** 1% **c)** 0,1% **d)** 0,01

6.- If a mineral contains 1,56% of its original parent isotopes, how many half-lives have passed?

a) 6 **b)** 7 **c)** 8 **d)** 9 **e)** 1.56

8.5. Nuclear fission.

Nuclear fission was discovered in 1938 by the German chemists, Otto Hahn and Fritz Strassman. They observed that when bombarding a sample of uranium-235 with neutrons, barium, krypton and other lighter elements than uranium were obtained.

Chemical equation: $^{0}_{1}n + ^{235}_{92}U \rightarrow ^{141}_{56}B + ^{92}_{36}Kr$

This kind of reactions is called **nuclear fission**. In these reactions the number of protons and neutrons remains the same; then, the previous reaction is not written correctly, three neutrons are also given out:

$$^{0}_{1}n + ^{235}_{92}U \rightarrow ^{141}_{56}B + ^{92}_{36}Kr + 3\ ^{0}_{1}n$$

Another characteristic of nuclear reactions is that mass of products is smaller than mass of reactants, this loss of mass is changed to energy according to Einstein's equation: $E = mc^2$. The amount of energy released during this process is about one million times more per atom than in a chemical reaction.

We can also observe that when a fission reaction of ^{235}U takes place more neutrons are released, these neutrons are able to split three more atoms and produce more energy, the process continues and a chain reaction might begin.

These reactions are used in **nuclear power plants** to produce electricity.

http://lectureonline.cl.msu.edu/~mmp/applist/chain/chain.htm: In this Java applet you will find a nuclear chain reaction. Start the reaction by releasing a neutron.

8.6. Nuclear fusion

Nuclear fusion is the opposite process to nuclear fission in which light atomic nuclei join together to form a heavier nucleus.

When low mass nuclei combine, great quantity of energy is released due to the loss of mass.

Nuclear fusion occurs naturally in stars. The firs artificial fusion of light nuclei (hydrogen isotopes) was observed by Mark Oliphant in 1932. Research into fusion for military purposes began in the early 1940s, as part of the Manhattan Project (development of the first atomic bomb during World War II). Researches for civilian purposes began in the 1950s, and continue to this day.

The energy released by fusion is greater than the energy released by fission, because the amount of mass transformed into energy is much greater in a fusion reaction than in a fission reaction.

Example:

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}n + 3{,}27\ MeV$$

Questions

1.- What is the difference between nuclear fission and nuclear fusion?

2.- Where a large amount of energy is released, in a nuclear fission reaction or in a nuclear fusion reaction?

3.-
a) The reaction of $^{3}_{1}H$ and $^{2}_{1}H$ to form $^{4}_{2}He$ and a neutron is an example of a nuclear fission reaction or a nuclear fusion reaction?

b) Write the equation of the previous reaction.

4.- In the combustion reaction of 1 gram of coal, 34 kJ are released. 200 MeV are produced in the fission of a nuclide of ^{235}U. Calculate the mass of coal needed to generate the same quantity of energy than the energy produced in the fission of 1 gram of ^{235}U.

Data: 1eV = 1,6 · 10^{-19} J; atomic mass of ^{235}U = 235,05 g/mol; N_A = 6,02 · 10^{23} mol^{-1}.

5.- Compare the energy released in the fission of 1 gram of ^{235}U (use the result of the previous exercise) with the energy obtained in the fusion of 1 gram of deuterium ($^{2}_{1}H$): $^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n + 3{,}27$ MeV.

Data: 1eV = 1,6 · 10^{-19} J; atomic mass of ^{2}H = 2,01 g/mol; N_A = 6,02 · 10^{23} mol^{-1}.

6.- We already know that the energy obtained in a fission nuclear reaction and in a fusion nuclear reaction is due to the loss of mass (Einstein's equation: $E = mc^2$). Calculate the loss of mass needed to produce:

a) 1 eV
b) 1 kJ
c) 1 cal
d) 1 MeV

Data: 1eV = 1,6 · 10^{-19} J; 1 cal = 4,18 J; c = 3 · 10^{8} m/s

8.7. Radiation effects.

The main danger from radioactivity is the damage it does to the cells in our body and leaving beings.

Although **alpha particles** are slow and can be stopped easily (remember a sheet of paper can stop these particles and they can't go through the skin), when α particles go inside your body (through food or drink), they produce ionisation of cell's atoms mutations of DNA occur.

β-particles are more difficult to stop than α particles, but their power to ionise atoms is much less strongly than α particles due to their mass and charge. These particles can get through the human skin and affect cells inside the body.

Gamma rays hardly ionise atoms, but are very difficult to stop. Gamma rays are absorbed by living tissue and cause serious damage because when this radiation interacts with an atom, the atom can emit subatomic particles.

Questions

1.- The main danger to us from radioactivity is damage to our ……

2.- The type of radiation that causes most damage by ionisation is ……

3.- What might happen if a cell's DNA is damaged by radiation?

4.- Can beta radiation penetrate your skin?

5.- Which type of radiation causes twenty times much damage to you as beta particles?

6.- Which type of radiation does not directly damage you by ionisation?

7.- Lab coats and gloves protect you from:

a) Alpha particles?
b) Beta particles?
c) Gamma rays?

8.8. Applications of radioactive nuclei

Radioactive nuclei have multiple uses:

Americium-241 is used as smoke detector. Am-241 emits alpha particles that ionise the air, then the air conducts electricity and a small current flows. When smoke enters the alarm, the alpha radiation is absorbed by smoke particles, the current reduces, and the alarm sounds.

Beta emitters with a long half-life (to avoid a regular maintenance) are used for testing paper or cardboard, thickness. For metal thickness a gamma emitter is used.

Gamma radiation emitters with a short half-life are used to check welds or to find leaks

For **sterilising food** (kill bacteria, mould and insects) is used gamma radiation. ^{60}Co is widely used in this process.

Carbon-14 (half-life of 5.700 years) is used for radioactive dating of matter.

To understand chemical and biological processes are used **radioactive tracers**. For example, to know how plants use phosphorus to grow, the isotope ^{32}P is used.

Medical purposes

In medicine, radioisotopes are used to sterilize of surgical equipment, to provide diagnosis information about a specific organ, to treat some medical conditions, and to research.

Iodine-131 is used in diagnosis and treatment of thyroid disease

A common tracer used in medicine to detect tumours is ^{99}Tc, this radioisotope is a safe gamma emitter because has a short half-life of six hours.

Gamma rays are used to kill cancer cells. In this technique, called **Radiotherapy**, healthy cells are also killed, but they can be repair and cancer cells can not.

Questions

1.- Choose the right answer. Radioisotopes used for diagnosis in nuclear medicine

a) Have short half-lives
b) Are usually gamma emitters.
c) Travel quickly through tissue.
d) All the above answers.

2.- Technetium-99 is used in diagnosis to detect tumours. How many grams of 0,1 grams sample of ^{99}Tc will remain in the organism after 24 hours if this nuclide has a half-life of 6 hours.

3.- Look for information in your computer and do the following questions:

3.1. Enrico Fermi was an Italian physicist who worked in the United States on the Manhattan Project for the development of nuclear energy and the atomic bomb. Write an abstract about the biography of Fermi (where he was born, studied, his work, etc.)

3.2. When did Fermi get the Nobel Prize?

3.3. What a Geiger counter is used for?

3.4. Explain how a chain fission nuclear reaction is produced.

3.5. Where and when was the first atomic bomb detonated? Name the Japanese cities where the Americans threw the two atomic bombs in the Second World War.

3.6. Did Fermi participate in fusion reactions?

3.7. Explain the symptoms of radio toxicity.

4.- Explain, in ten lines, all what you think about the advantages and disadvantages of nuclear energy.

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

- Nuclear reaction ☐
- Alpha particles ☐
- Beta particles ☐
- Gamma particles ☐
- Ionization ☐
- Half-life ☐
- Nuclear fission ☐
- Nuclear fusion ☐

2.- Tick the one you think is your answer:

	I know very well	I need some revision	I need some more help
I understand why a nuclide is unstable.			
I know how to balance a nuclear equation.			
I know the characteristic of alpha and beta particles and gamma rays.			
I know how a beta particles is produced in a nucleus.			
I know the difference between a particle and an electromagnetic wave.			
I understand why alpha particles are more ionizing than beta particles and gamma rays.			
I understand the concept of half-life.			
I know how to solve questions related to half-life.			
I know the difference between fission and fusion nuclear reaction.			
I understand why in a fission or fusion reaction great quantity of energy is released.			
I know how to calculate the energy obtained in a nuclear reaction from the loss of mass.			
I know why some radioactive nuclides are used in industries.			
I understand why some radioactive nuclides are used in diagnosis or to treat diseases.			

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.

UNIT 9: ELECTRICITY

Content:

Unit 9 Electricity

9.1. The electric charge
9.2. Types of electrification
9.3. Conductors and non-conductors
9.4. Electroscope
9.5. Electrophorus
9.6. The van der Graaff generator

Annex: History of electricity

Learning Aims:

At the end of the unit, the student will know:

- The different kinds of electricity and how are produced.
- The differences between conductors and non-conductors of electricity.
- How to describe some devices used in electrostatics.
- How an electroscope works.
- How an electrophorus works.
- How the van der Graaf generator works
- To use the appropriate language to answer questions and to communicate with teacher and classmates.

Initial Activities

1.  Choose the right answer:

1.1. Substance in witch charges move easily are called:

a) Insulators
b) Conductors

1.2. Negative charges _____ each other.

a) Attract
b) Repel

1.3. A positive charge and a negative charge _____ each other.

a) Attract
b) Repel

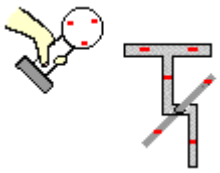
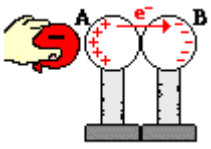
1.4. A particle with excess of electrons is

a) Negatively charged
b) Positively charged
c) Neutral

2. Which particle of an atom is responsible for electric conduction?

3. If we approach two balloons, after rubbing then with our hair, they repel each other, why?

Key words:

Electric charge + −	**Negative** or **positive** charge in particles is due to an excess or deficiency in **electrons**.
Friction electrification 	**Friction electrification** occurs when two surfaces are rubbed together
Conduction electrification 	Electrification by **contact** between a charged object and a neutral object. Charges of the charged object distribute between the two objects
Induction electrification 	An insulating conductor object is charged by another charged object **without contact** between the two objects

Conductor 	Material where **electrons** or **ions** have freedom to **move** around
Insulator 	In insulators **electrons** or **charged particles do not** have freedom to **move** around
Electroscope 	Instrument for **detecting** the presence of **static electricity**.
Electrophorus 	Insulated rod and a metal plate, used to **store up** static electricity by induction.
Van der Graaff generator 	Electrostatic machine which uses a moving belt to accumulate **very high voltages** on a hollow metal globe

9.1. The electric charge

In unit 1 we talked about the composition of matter, we already know that the tiniest particle of an element is the atom, but an atom has protons, neutrons and electrons. A **proton** has **positive charge** and an **electron** has the same, but **negative**, charge of a proton. Now we can say that a substance has charge when the number of electrons and protons is different.

When atoms **lose electrons** they become **positively charged**, but when the atoms **gain electrons**, their charge is **negative**. If the number of electrons is equal to the number of protons, substances are neutral.

Like charges **repel** each other but opposite charges **attract** one another.

We talk about **static electricity** when the net electric charge is non-zero and motionless, but when charge is flowing in a particular direction, the phenomenon is known as electric current.

Questions

1. Which of the following statements are true? If the statement is false, write the correct one.

a) A neutral object becomes positively charged when electrons are removed.

b) Like charges attract each other.

c) Protons and electrons repel each other.

d) In a neutral atom the number of protons is equal to the number of neutrons.

e) A negatively charged object must have an excess of protons.

2.- What is the difference between a positively charged object and a negatively charged object?

3.- What is the characteristics of charges to be attracted?

9.2. Types of electrification

We define electrification as the process by which matter lose or gain electric charges. There are three main **types of electrification**: **Friction**, **Conduction**, and **Induction**.

1. **Friction:** The frictional charging process results in a transfer of electrons between two insulating objects which are rubbed together. In this process, an object take electrons (it becomes negatively charged) from the other object (it becomes positively charged).

Example:

When a rubber balloon is rubbed with animal fur or hair, the rubber balloon gains electrons and the animal fur loses electrons. A transfer of electrons takes place. When you rub the balloon, it becomes negatively charged, it has taken some of the electrons from the animal fur and left the fur positively charged.

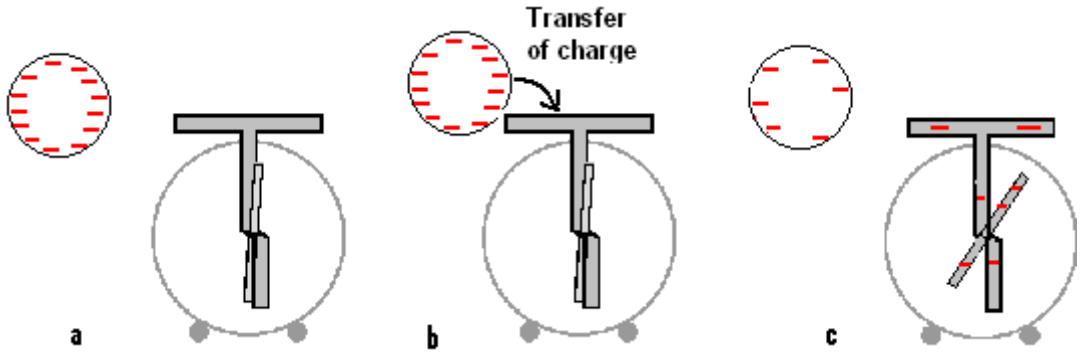
Different materials have different affinities for electrons and they can be ordered according to their affinity for electrons. In the following series, materials are ordered by their capacity to gain electrons. Materials shown highest on the table tend to have a greater affinity for electrons (gain electrons) than those below it:

Celluloid
Sulphur
Rubber
Amber
Wood
Cotton
Silk
Cat fur
Wool
Glass
Rabbit fur

2. **Conduction:** This process involves the contact between a charged object and a neutral object. Because charging by conduction involves contact, it is often called **charging by contact**. In this case, charges of the charged object distribute between the two objects.

Example:

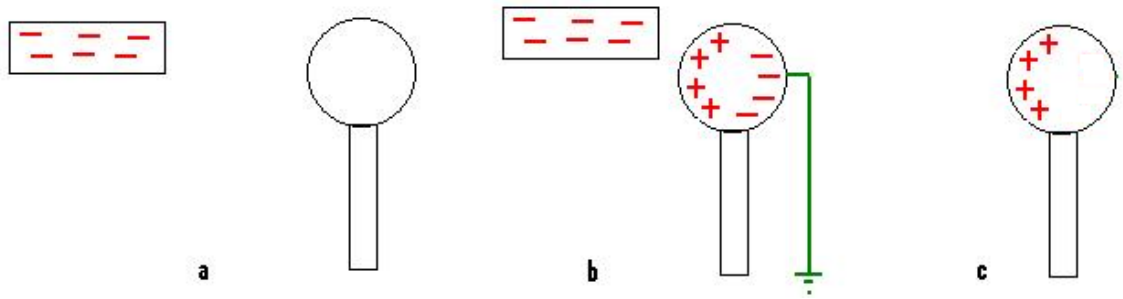
Initially we have a charged metal object and an uncharged metal on an insulating support stand (let's think of an electroscope) (**a**). If we touch the electroscope with the charged object (**b**), some of the charge will transfer over to the uncharged metal object and charge distributes the charged object and the uncharged metal (**c**).



http://www.ddart.net/science/physics/physics_tutorial/mmedia/estatics/esn.gif:
Simulation about the distribution of charges by conduction.

Induction: In this method an insulating conductor object is charged by a charged object without contact between the two objects (only approaching it) (**a**). If we approach the charged object to the insulating conductor object, a separation of charges in the insulating conductor occurs (**b**). A ground wire is used to transport negative charges (in this figure from the objet to ground) (**c**).

Note: When the object we approach is positively charged, electrons would come up the grounding wire to be closer to the object. Observe that that when an object is charged by induction, their charge is opposite to the charged object.



In webpage http://www.glenbrook.k12.il.us/GBSSCI/PHYS/CLASS/estatics/u8l2c.html you will find a curious way of charging by induction.

Questions

1.- Tell if the following statements are true or false. Change the false statements for the correct ones:

a) When a neutral object is charged by friction, there is a transfer of protons between the two insulating objects.

b) If we want to charge an object negatively with only the help of a positively charged object, the induction method is the more appropriate to do it.

c) A negatively charged balloon sticks to the wall because there is a distribution of charges in the wall and negative charges of balloon attract the positive charges of wall.

d) If we use a negatively charged plastic rod to charge a metal plate by induction, the charge on the metal plate will be positive.

e) In the process of charging an object by friction, charged acquired by the two objects have the same magnitude but the sign is different.

2.- What is the name of the process of charging a neutral body by touching it with a charged body?

3.- If you comb your hair and the comb becomes negatively charged, how is the charge of the hair?

4.- What is the difference between charging an object by conduction and charging by induction?.

5.- If glass is rubbed against silk, which would end up with a negative charge? Why?

6.- Why a rubber rod becomes negatively charged when rubbed with fur?

7.-.
a) Two neutral metallic cans are touching each other. A negatively plastic rod is approached (without touching) to one of the cans, once the cans are charged, they are separated. Explain what happen to both cans.

b) The previous process is repeated but this time, approaching a positively glass rod. Explain what happen in this case.

8.- Explain the process to charge positively an insulating metallic sphere.

9.-
a) What happen with charges of a negatively charged rod when touching an insulated neutral metal?

b) What happen if rod in question (**a**) is positively charged?

9.3. Conductors and non-conductors

Materials can be divided in **conductors** or **non-conductors** (insulators) of electricity.

Conductors: In **conductors**, electrons or ions have freedom to move around.

Example:

Metals are good conductors of electricity because the outermost electrons in the atoms are loosely bound to the nucleus.

When salts are dissolved in water their ions (cations and anions) can move freely through the solution.

Non-conductors (insulators): When electrons o charged particles do not have freedom to move around the material, we are talking about **non conductors** or **insulators**.

Example:

Glass, cotton, plastic are examples of insulators (resistant to electron motion).

Questions

1.- What is the difference between a conductor and an insulator?

2.- Explain why solid salts do not conduct electricity but they do in aqueous solution.

3.- Why metals are good conductors of electricity?

9.4. Electroscope

An **electroscope** is an instrument for detecting the presence of static electricity. The basic electroscope consists of two thin metal leaves suspended from a metal hook. When a charged object is approached to the hook, metal leaves acquire the same charge as the object. As the two leaves have the same charge, they repel each other.

Electroscopes are used to know if and object is charged (**a**) or to find the sign of a charged object (**b**).

a) We know if an object is charged when the electroscope's leaves separate when the object touches the hook of the uncharged electroscope.

b) To know the sign of a charged object, we need to approach the object to a charged electroscope; if the deflection decreases the charge of the object has opposite sign than the electroscope charge, but if the deflection increases, then the charge is the same as the electroscope.

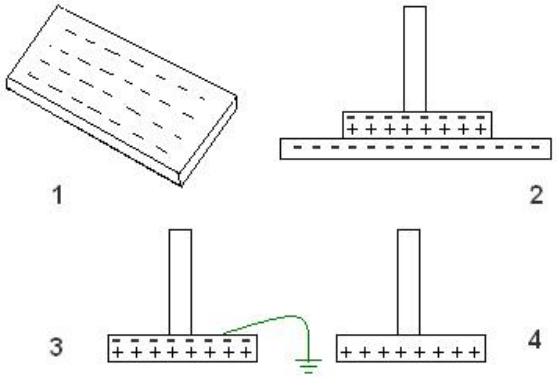
http://www.kalipedia.com/fotos/electroscopio.html?x=20070924klpcnafyq_355.les

9.5. Electrophorus

An **electrophorus** is a simple, high-voltage electrostatic generator. It consists of a metallic disc and an insulated handle. This apparatus is charged by **induction**. Steps to charge an electrophorus:

1. With an animal fur rub a plastic surface (this surface becomes negatively charged).
2. Place the metallic disc of electrophorus onto the negatively charged plastic. Charges in metal will be distributed, the positive charges will be attracted by the negative charges of plastic and the electrons in the metal will occupy the opposite place.
3. Remove the electrophorus from the plastic surface, then eliminate the negative charge with a ground wire or touching the metal disc briefly (the negative charges will flows to earth through the wire or your body)

4. The electrophorus will be charged positively.



You can use an electrophorus to:

- Produce small sparks.
- Deflect the leaves of an electroscope
- Blink a small neon bulb.
- See the initial attraction of soap bubbles and their final repulsion (once they become charged, they float away due to repulsion off the same sign charges).
- Pick up small pieces of paper, lint, etc.

9.6. The van der Graaff generator

The **Van der Graaff generator** is also a static electricity machine that can generate very high voltages.

It consists of a large hollow metallic sphere supported by an insulating column. Electric charges of the same type (either positive or negative) are put onto a moving belt, carried upwards by the belt and put into the hollow sphere by sharply pointed combs, and left there. This is a continuous process, the belt collects charge at the bottom and this charge is stored at the top sphere. As the amount of charge on the dome increase, its voltage also increases.

Potential differences in Van de Graaff generators can be of 5 megavolts. The larger radius of the sphere is, the higher the potential.

One of the largest Van de Graaff generators, built by R. J. Van der Graaff, is found at Boston's Museum of Science. It has two joined spheres of 4,5 m each and. This generator can reach a voltage of 2 megavolts.

The **voltage** is very high, but the current is tiny, therefore it is quite safe to use this generator.

In cold and dry days, the Van der Graaff generator works better because discharge is more difficult.

There are many web sites with experiments related to Van der Graaff generator. In the following web sites you will find videos simulations:

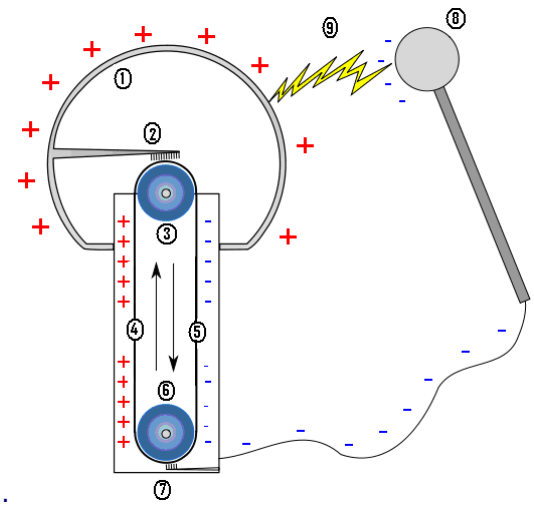
1.- http://www.youtube.com/watch?v=AhLbYaloxsE&hl=es: a good video, explaining how the generator works, production of sparks and why an electric whirl spins rapidly in a direction that is away from the points.

2.- http://www.youtube.com/watch?v=xhvc-z0anB0: This video contains different experiments: spinning of an electric whirl, movement of Styrofoam balls inside a glass jar, pulling apart sheets of paper.

3.- **http://www.physics.ucla.edu/demoweb/demomanual/electricity_and_magnetism/electrostatics/van_der_graaff_experiments.html**: This is a very interesting web site with explanations and simulations using different accessories: electric whirl, electroscope, smoke precipitator (when smoke is blown into a tube (for example, from a cigarette) rapidly disappears when the electrodes on the ends of the tube are connected to the generator), Styrofoam balls, etc.

4.- **http://teleformacion.edu.aytolacoruna.es/FISICA/document/fisicaInteractiva/sacaleE_M2/Triboelecetricidad/vanderGraff/GeneradorEVG_Trabajo.htm:** In this Spanish webpage there is a good explanation of van der Graaf generator.

5.- http://en.wikipedia.org/wiki/Van_de_Graaff_generator: Explanation and history of Van der Graaff generator. This web page also includes a picture of the components of Van der Graaff generator:



1. Hollow metallic sphere.
2. Electrode connected to the sphere, a brush ensures contact between the electrode and the belt.
3. Upper roller.
4. Side of the belt with positive charges
5. Opposite side of the belt with negative charges
6. Lower roller
7. Lower electrode (ground)
8. Spherical device, used to discharge the main sphere
9. Spark produced by the difference of potentials

Questions

1. Which of the following statements are true? Change the false statements for the correct ones.

a) A neutral electroscope is charged by touching it with a positively charged glass rod. The leaves of electroscope acquires a positive charge

b) An electroscope, positively charged, is touched by a negatively charged balloon. The leaves of electroscope separate more.

c) We discharge a negatively charged electroscope touching it because electrons go to ground through our body.

d) We discharge a positively charged electroscope touching it because protons go to ground through our body.

e) The leaves of a charged electroscope will deflect even more when we touch it with a charged rod, independently of the sign of charges.

2.- Explain the process to charge an electrophorus.

3.- A balloon is rubbed with an animal fur. Then, we touch a negatively charged electroscope with the balloon. What is the charge of the balloon? Why?

4.- After watching the videos or simulations on the previous web pages related to the Van der Graaff generator, answer these questions:

- **a)** Why sparks are produced between the two spheres?
- **b)** Why the electric whirl spins in a direction that is away from the points?
- **c)** Why Styrofoam balls jump inside the glass jar?
- **d)** Why the sheets of paper are pulling apart?
- **e)** What happen if the sphere is touched with an electroscope?
- **f)** Why does the smoke disappear inside the tube?
- **g)** What happen to hair when an insulated person touches the sphere? Why?

Annex: History of electricity

It was known by the Greek philosopher **Thales of Miletus** (640-546 B.C.) that when amber was rubbed acquired the property of attracting light objects. The word electricity comes from ***electron***, Greek word for amber. The first static Electric generator was invented in 1675 by **Otto von Guericke**, but except for some medicinal applications, electricity had little use.

Later, in 1729 **Stephen Gray** tested that electricity can move through conducting wires and that charges of electrified objects are located on their surfaces.

Discovery that there are two kinds of charges, negative (**resinous**) and positive (**vitreous**) was made by **Charles Francois du Fay** in 1733.

In 1745, **Pieter van Musschenbroek**, from Leiden, Netherlands, invented the **Leyden jar**. The Leyden jar[1] is a device that stores static electricity between two electrodes on the inside and outside of a jar.

It was in 1752 when **Benjamin Franklin** proved that lightning (flow of electrons between the ground and the clouds) had an electrical nature. He flew a silken kite with a metallic skeleton, holding the end of the kite silken string with an iron key, during a thunderstorm. When lightening occurred, a spark was produced from the key to his wrist. With this experiment B. Franklin proved that lightning had electrical nature.

Throughout the next years, there were many experiments related to electricity, but we have to point out the invention of the incandescent filament bulb in 1878 by the British scientist, **Joseph Swan**, and, a year later by the American **Thomas Edison**. This is one of the first practical uses of electricity.

Among other inventions related to the uses of electricity we have to stand out:

- In1786, **Luigi Galvani** found that legs of a dead frog moved quickly when they were touched by a metal knife. Galvani thought that legs of frogs contained electricity.

- In 1792, **Alessandro Volta** tested that movement of leg's frog was due to the movement of charges between the two metals (the steel knife and the tin plate where the frog was lying) separated by a moisture material. Volta invented the first **electric battery**, in 1800, it was made from alternating discs of zinc and copper with pieces of cardboard soaked in brine between the metal discs.

- In 1831, **Michael Faraday** discovered how to produced electricity moving a magnet inside a coil of copper wire, (**electromagnetic generator**).

- The first motor that allows generating **alternating current** was inventing in 1882 by **Nikola Tesla**. AC, rather than DC, enables the transmission of large quantity of electrical power using higher voltages via transformers

Westinghouse Electric, founded in 1886 by **George Westinghouse**, was the first company that constructs the **hydroelectric power station** at Niagara Falls to transmit electricity to long distances.

The first power plants used **water** power or **coal** as sources of energy to make electricity commercially. In the 1950's **gas**, **oil** and **nuclear power** were introduced.

[1] Your teacher will show you a video explaining the construction of a Leyden jar, how to charge it with a screen TV and how to discharge the Leyden jar (a spark is produced).

Project:

The following projects are thinking to work individually or in groups of two. Choose one of them, or any other related to electrostatics:

1. Build a Leyden jar: Consult the web pages:

http://video.google.com/videoplay?docid=-7547972370900128124

http://www.alaska.net/~natnkell/leyden.htm

http://home.earthlink.net/~lenyr/stat-gen.htm

2. Build an Electroscope: Consult the webpage:

http://www.charlesedisonfund.org/Experiments/HTMLexperiments/Chapter9/9-Expt3/p1.html

3. Build a Van der Graaf generator: Consult the webpage:

http://scitoys.com/scitoys/scitoys/electro/electro6.html

Experiments:

Experiment 1: Conductors and insulators

OBJECTIVE

Test the electrical conductivity of different materials.

EQUIPMENT

Battery	Light bulb
Three Cables	Multimeter

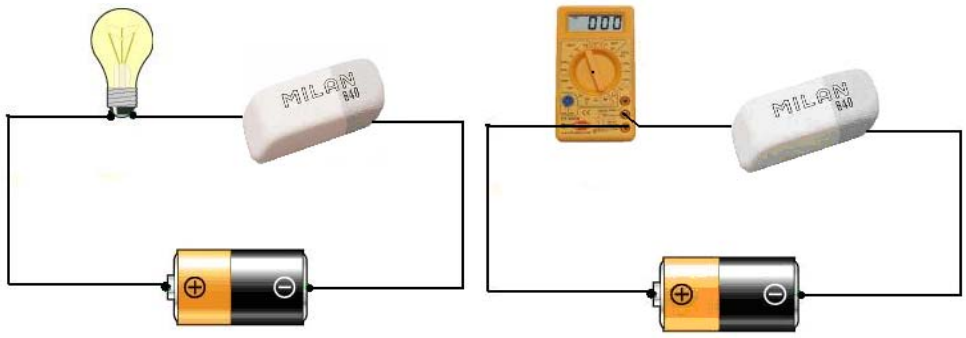
MATERIALS

Paper clips	Aluminium foil
Sulphur	Running water
Distilled water	Rubber
Plastic	Copper
Etc.	

PROCEDURE

The figure shows the circuit you have to do:

1. Use two cables to connect either terminals of the battery. A cable has to connect the battery to the light bulb and the terminal of the other one has to be free to be connected to the different materials.
2. A terminal of the third cable has to be attached to the other pole of the bulk and leave the other terminal free for the different materials to be attached to it.
3. Once the circuit is prepared, connect the different materials to the free terminals and observe the bulb brightness.
4. Change the bulb by a Multimeter and record the results.



QUESTIONS

1. Annotate your observations in the below table:

Material	Bulk's Brightness

2. Divide the materials you have used in good conductors, poor conductors and insulators. Which criterion have you used to do this classification?

3. Record the data (in volts) indicated by the multimeter:

Material	Voltage

Experiment 2: Attraction and repulsion of charges

OBJECTIVE

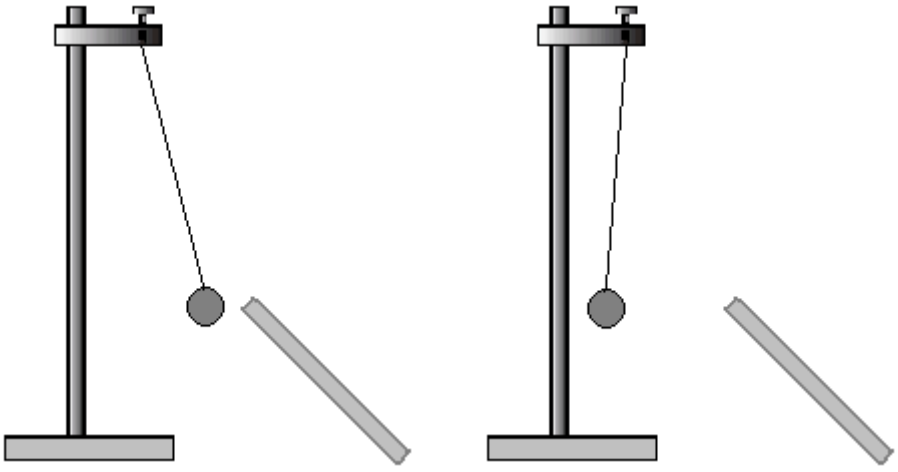
Observe the attraction between opposite charges and repulsion between like charges.

EQUIPMENT

Electroscope	Pith ball pendulum
Animal fur	Ebonite or plastic rod
Silk cloth	Glass rod
Balloon	Comb

PROCEDURE

1. Rub a plastic rod with animal fur. Touch the electroscope and record what you observe.
2. Rub a balloon on your hair and touch the electroscope previously charged. Record what you observe.
3. Repeat part (**2**) but touching the electroscope with a comb.
4. Rub a glass rod with silk cloth. Touch the electroscope and record what you observe.
5. Approach the plastic rod rubbed with animal fur to an uncharged pith ball pendulum. Observe that the pith ball is first attracted and then repelled.



6. Do the same that in part (**5**) but with a glass rod rubbed with silk cloth. Annotate your observations.
7. Approach the plastic rod rubbed with animal fur to the charged pith ball pendulum of part (**6**). Annotate your observations.
8. Approach the glass rod rubbed with silk cloth to the charged pith ball pendulum of part (**5**). Annotate your observations

QUESTIONS

1. Tell if the following statements are true or false. Change the false statements to the correct ones.

a) When the plastic rod is rubbed with animal fur the plastic rod and the animal fur became positively charged.

b) When the electroscope is touched with the charged plastic rod, their leaves separate because they both acquire positive charges.

c) When the balloon is rubbed with the animal fur, it acquires the same kind of charge that the plastic rod because the leaves of electroscope repel even more.

d) The type of charging that occurs when a glass rod is rubbed with a silk cloth is called electrification by contact.

e) The type of charging that occurs when a charged rod is brought close to a neutral pith ball is called electrification by induction.

f) In electrification by friction objects acquired the same kind of charge.

2. What type of charge acquire the comb when is rubbed with fur? Why?

3. Explain why the pith ball is first attracted and then repelled when approaching the rubbed plastic rod or the rubbed glass rod.

4. Have the rubbed glass rod and the rubbed plastic rod the same kind of charges? Explain the reasons for your answer.

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

Electrostatics	☐
Negative Charge	☐
Positive Charge	☐
Friction electrification	☐
Conduction electrification	☐
Induction electrification	☐
Conductor	☐
Insulator	☐
Electroscope	☐
Electrophorus	☐
Van der Graaff generator	☐

2.- Tick the one you think is your answer:

	I know very well	**I need some revision**	**I need some more help**
I understand the concept of electrical charge.			
I know that like charges repel one another and unlike charges attract one another.			
I Know that when an object is charged by friction, the object acquires different charge than the material used to charge it.			
I Know that in the process of charging a neutral object by conduction, charges go from the charged to the uncharged object.			
I understand why an object charged by conduction has charges of the same sign that the charge object used to charge it.			
I understand the process used to charge an object by induction.			
I know the differences between conductors and insulators. .			
I know why a substance is conductor of electricity.			
I understand how an electroscope works.			
I know how to make an electroscope.			
I know how to guess the sign of unknown charges by using an electroscope.			
I understand how an electrophorus works.			
I know how to make an electrophorus.			
I know how a Van der Graaf generator works.			

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.

UNIT 10: ELECTRIC CURRENT

Content:

Unit 10 Electric Current

10.1. Coulomb's law
10.2. Electric current intensity
10.3. Voltage
10.4. Resistance. Ohm's law
10.5. Joule's law
10.6. Electric circuits
10.7. Parallel and series circuits

Learning Aims:

At the end of the unit, the student will know:

- How to calculate forces between charges from Coulomb's law.
- The meaning of electric current intensity.
- How to calculate voltage, current and resistance using Ohm's law.
- The relationship between resistance and heat.
- How to analyze circuit diagrams for series circuits and parallel circuits.
- The different parts of an electric circuit.
- How to assemble components in an electric circuit.
- To use the appropriate language to answer questions and to communicate with teacher and classmates.

Initial Activities

1.  Choose the correct answer.

1.1. Which of these materials is the best conductor of electricity?

a) Glass
b) Wood
c) Copper
d) Sugar

1.2. What is the difference between a series circuit and a parallel circuit?

a) A series circuit has one path; the parallel circuit splits into branches.
b) A parallel circuit only works with batteries.
c) A parallel circuit has one path, the series circuit splits into branches.
d) A series circuit always has a resistance and a switch.

1.3. In a circuit, batteries

a) are the generators of electric energy.

b) are the receptors of electric energy.

c) never work in a parallel circuit.

d) never work in a series circuit.

1.4. Materials that allow electricity to flow through them easily such as copper are called

a) Conductors.

b) Semiconductors.

c) Insulators.

1.5. Materials that only conduct electricity under certain circumstances are called

a) Conductors.

b) Semiconductors.

c) Insulators.

1.6. The device used to open and close a circuit is called

a) Resistor.

b) Battery.

c) Switch.

d) Motor

2.  Tell if the following statements are true or false:

a) Two particles with the same charge repel each other.

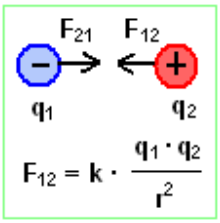
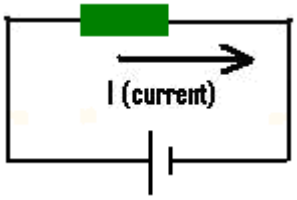
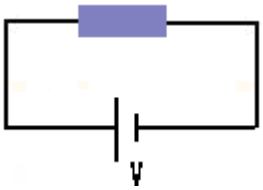
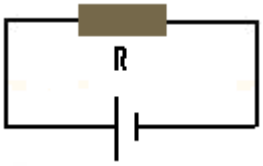
b) Two particles with opposite charges will be attracted to each other.

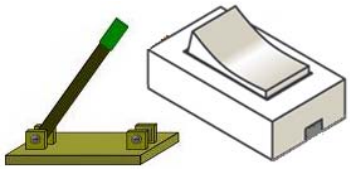
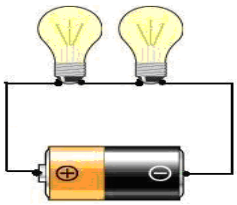
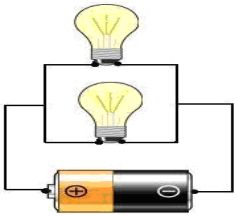
c) Ohm's law states that $\mathbf{I = V \cdot R}$

3.  Match the magnitude with their corresponding unit:

Force	joule
Charge	ampere
Electric current	coulomb
Heat	volt
Resistance	newton
Voltage	ohm

Key words:

Coulomb law 	The electric **force** between two point electric charges is directly proportional to the product of the magnitudes of each of the **charges** and inversely proportional to the square of the total **distance** between the two charges.
Electric current intensity 	**Electric current intensity** is rate of movement of charge per unit time in an electric circuit.
Voltage 	**Voltage** is the electric potential energy per unit charge.
Resistance 	**Opposition** of a material to current passing through it.
Ohm's law $V = I \cdot R$	The potential difference or **voltage** between two points of the conductor is proportional to the **current** passing through it and to the **resistance**.
Joule's law $Q = I^2 \cdot R \cdot t$	The amount of **heat** per second that is generated in a conductor carrying a current is proportional to the **resistance** of the conductor and the square of the **electric current intensity**.

Generator 	**Generators** are the Power Source needed to supply the flow of electrons (electricity).
Transmission lines 	**Transmission lines** provide the connexion between power resources and receivers.
Receiver 	**Receivers** transform the electricity into work.
Switch 	**Switches** are used for making, breaking or changing the connections in a circuit.
Series circuit 	In **series circuits**, resistors, or other type of receivers, are arranged in a chain.
Parallel circuit 	In a **parallel circuit** current flows at least in two independent paths to get back to the source.

10.1. Coulomb's law

Coulomb's law states that: **"**The magnitude of the electrostatic force between two point electric charges is directly proportional to the product of the magnitudes of each of the charges and inversely proportional to the square of the total distance between the two charges":

$$F = k \cdot \frac{q_1 \cdot q_2}{r^2}$$

where

r is the distance between the two charges

$\mathbf{q_1}$ and $\mathbf{q_2}$ are the two point electric charges (the SI unit of charge is the coulomb, C) and

k is a proportionality constant.

If the bodies are oppositely charged, one positive and one negative, they are attracted toward one another (positive force); but if the bodies are similarly charged, either positive or negative, the force between them is repulsive (negative force).

The value of the proportionality constant, **k**, called *Coulomb's constant* is dependent upon the medium that the charged objects are immersed in. In the case of air, the value is approximately $9{,}0 \cdot 10^9\ N \cdot m^2 \cdot C^{-2}$.

Questions

1. Match the magnitudes with their corresponding units in the International System:

Force	Meter
Charge	Newton
Distance	Coulomb

2. The charge of one electron is $1{,}6 \cdot 10^{-19}$ C. How many electrons are in a charge of 1 C?

3. An object, A, has a negative charge of $2 \cdot 10^{-8}$ C, and another object, B, situated 20 cm away has a positive charge of $3 \cdot 10^{-7}$ C.

a) Is there an attraction or repulsion force between these two objects?

b) Calculate the value of force

Data: $K = 9{,}0 \cdot 10^9\ N \cdot m^2 \cdot C^{-2}$

4. An object, A, positively charged has two negative charges nearby, B and C, situated at the same distance from A. Which charge exerts the biggest force?

a) A, B and C have the same charge.

b) A has double charge than B and B has double charge than C.

5. There is an electrical force between two charges, A and B. What happen to the force if one of the charges is tripled?

6. There is an electrical force between two positive charges of 10^{-5} C each. Charges are 20 cm apart. Calculate the value of this attraction force.

Data: $K = 9{,}0 \cdot 10^{9}\ N \cdot m^2 \cdot C^{-2}$

7. There is an electrical force of 20 N between two positive charges of 10^{-5} C each.

a) Calculate the distance between these two charges.

b) What happen to the force exerted between the two charges when they are situated twice as far apart?

Data: $K = 9{,}0 \cdot 10^{9}\ N \cdot m^2 \cdot C^{-2}$

8. Two charges of $2 \cdot 10^{-11}$ C and $-1.5 \cdot 10^{-11}$ C are separated 2 mm. Which force exerts the positive charge over the negative charge?

Data: $K = 9{,}0 \cdot 10^{9}\ N \cdot m^2 \cdot C^{-2}$

9. Two charged objects repel each other. How is the charge of these two objects?

a) Both are positive charged.

b) Both are negatively charged.

c) One is negatively charged and the other one is positively charged.

10. How will the force between two objects change if the distance between them doubles?

a) Double

b) Quadruple

c) One half

d) One forth

11. What happen to the force exerted between two charges when:

a) The two charges duplicates

b) The distance is reduced to one half the initial distance.

10.2. Electric current intensity

Electric current intensity (**I**) measure the rate of movement of charge (**Q**) per unit time (**t**) in an electric circuit:

$$I = \frac{Q}{t}$$

The SI unit of electric current intensity is the ampere (**A**). A current of 1 ampere means that there is 1 coulomb of charge passing through across a section of a wire every 1 second:

$$1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}}$$

The particles which carry charge through wires in a circuit are mobile electrons. The electric field direction within a circuit is by definition the direction which positive test charges are pushed. Thus, these negatively charged electrons move in the direction opposite the electric field

Questions

1. Tell if the following statements are true or false. Change the false statements for the correct ones.

a) Electric current intensity is a measure of movement of electric charge.

b) A charge of 5 mC takes to flow through a copper 0,1 seconds if the current intensity is 0,5 mA.

c) The current intensity unit in the International System is the coulomb.

d) The devise used to measure intensity is called voltmeter.

e) The amount of charge flowing through a wire increases when the current intensity also increases.

2. A current of 10 mA flows through a wire for 2 seconds. Calculate the total electric charge flowing through the wire.

3.
a) Calculate the current intensity when 10^{19} electrons are circulating through a wire in 2 seconds.

b) How many electrons are necessary to generate a current of 5 mA in 10 μs?

Data: Charge of 1 electron: $1,6 \cdot 10^{-19}$ C.

4. A current of 8 μA flows through a wire for 3 minutes. Calculate the total electric charge flowing through the wire

10.3. Voltage

The voltage in a point of an electric field created by a charge, **Q**, is the electric potential energy per unit charge:

$$V = k \cdot \frac{Q}{r}$$

where

r is the distance between the charge and the point of the electric field.

k is a proportionality constant.

The SI unit of voltage is the volt, V.

$$1 \text{ volt} = \frac{1 \text{ joule}}{1 \text{ coulomb}}$$

10.4. Resistance. Ohm's law

Ohm's law, applied to an ideal conductor, states that "The potential difference or voltage, **V**, between two points of the conductor is proportional to the current, **I**, through it and to the resistance, **R**".

This law can be expressed by the mathematical equation:

$$V = I \cdot R$$

The SI unit of resistance is ohms, **Ω**.

$$1 \text{ ohm} = \frac{1 \text{ volt}}{1 \text{ ampere}}$$

Materials that obey Ohm's Law are called "**ohmic**" or "**linear**" because the potential difference across it varies linearly with the current.

The electrical resistance of a wire depends on wire length, the cross sectional area, the material wire is made and the temperature. Resistance can be expressed by the formula:

$$R = \rho \cdot \frac{l}{S}$$

where

R: resistance

ρ: resistivity (depend on the kind of material and temperature)

l: length

S: cross sectional area

Questions

1. Calculate the voltage required to produced a current of 0,15 A in a resistor of 100 Ω.

2. Calculate the resistance of circuit which under a voltage of 1,5 V allows a current of 0,1 A.

3. What is the voltage required to produced a current of 0,5 A in a resistor of 1,5 Ω.

4. Calculate the current produced when a voltage of 3 V is applied to a resistor of 9 Ω.

5. What current goes through a circuit if voltage is 4,5 V and resistance is 1,5 Ω?

6. Tell if the following statements are true or false. Change the false statements to the correct ones.

a) The formula that relates intensity and resistance is: I = V. R

b) The current flow in a conducting wire will increase as the length of that wire is increased.

c) The resistance of a wire increases as the length of the wire increases.

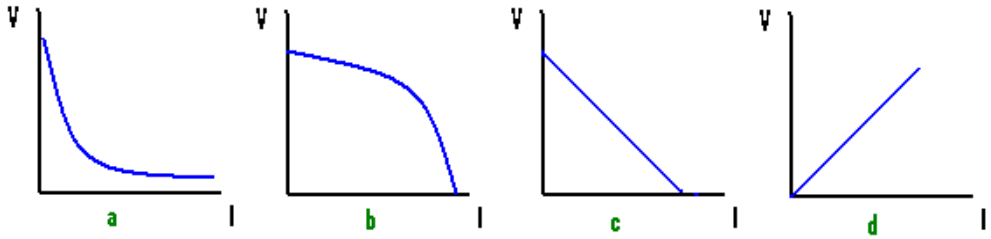
d) The resistance in a conducting wire will increase as the diameter of that wire is increased.

e) A devise used to measure resistance is called ohmmeter.

f) Unit of voltage in the IS is ampere.

g) Unit of resistance in the IS is ohm and it is symbolized by an "O"

7. In the following graphs, voltage is represented on the vertical axis and intensity on the horizontal axis.



Which graph represents the Ohm's law? Why?

8. Anna investigated variation of intensity respect to voltage setting up a circuit with a resistor, a variable voltage power supply and an ammeter. She put her results in a table.

Voltage (V)	Intensity (mA)
1	0,21
2	0,40
3	0,59
4	0,80
5	1,01
6	1,20

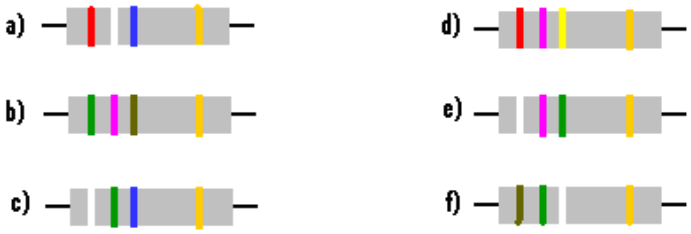
a) Plot these results in a graph.
b) Calculate the value of the resistance.

When Anna changed the resistance, she obtained the results given on the following table:

Voltage (V)	Intensity (mA)
1	0,51
2	1,00
3	1,49
4	2,01
5	2,51
6	3,00

c) Plot these results in another graph.
d) Calculate the value of the new resistance

9. Resistors have incorporated colour bands to know their resistance. Consult the web page: **http://www.kpsec.freeuk.com/components/resist.htm** to calculate the resistance of:



There are different web pages with applets to calculate the total resistance. For example in pages:
http://www.resistor-color-code.com/ or
http://www.dannyg.com/examples/res2/resistor.htm

10.5. Joule's law

Joule's first law, or *Joule effect*, describes the rate at which resistance in an electric circuit transforms the electric energy into heat. This law states that the amount of heat per second generated in a conductor is proportional to the resistance of the conductor and the square of the electric current intensity going through the conductor.

This law can be expressed by the mathematical formula:

$$E = I^2 \cdot R \cdot t$$

Where

E is the heat generated

I is the electric current intensity

R, is the resistance and

t is the time.

The IS unit of heat is joule, **J**.

Knowing that: **Q = I · t** and **V = I · R**, other expressions for the Joule's law are:

$$E = V \cdot I \cdot t$$

$$E = Q \cdot V$$

We can also define another magnitude, known as **Power**. **Power** indicates the energy supplied each second, therefore, it can be calculated by the expression:

$$P = \frac{E}{t} = I^2 \cdot R = V \cdot I = \frac{Q \cdot V}{t}$$

The IS unit of power is watt, **W**.

Questions

1. Choose the right answer

1.1. A 60 W light bulb is connected to a 220 V supply. Intensity current going through the bulb is.

a) 3,67 A
b) 0,27 A
c) 2,70 A
d) 367 mA

1.2. When the current in a resistor is doubled, the heat produced by the resistor is:

a) Double
b) A half
c) Four times
d) One fourth

1.3. A resistor produces energy of 10 J in 2 seconds. What is the power loss of the resistor?

a) 5 W
b) 20 W
c) 5 kWh
d) 20 kWh

1.4. Kilowatt-hour, **kWh**, is a unit of

a) Power
b) Energy
c) Voltage
d) Current

2. Two light bulbs, 100 W and 60 W each, are connected to a 230 V light socket.

a) Which bulb has the highest resistance?
b) Which bulb carries the greatest current?
c) Which bulb is brighter?

3. An electric heater of 1.500 W, connected to a 230 V supply, is on for 2 hours.
a) Calculate the energy used by the heater.
b) Calculate the intensity going through the heater.

4. Transform 2 kilowatts-hour to IS units, joules.

5. Fill the table below with symbol an IS units of different magnitudes.

Magnitude	**Symbol**	**IS unit** (name and symbol)
Voltage		
Electric charge		
Current intensity		
Resistance		
Energy / Heat		
Power		

6. An electric motor develops 5 J of work for 1,5 seconds, how much power does it produce?

7. If an electric motor is powered by a 4,5 V battery and produces 3 W of power, how much current is the motor drawing?

8. How much power produces an electric apparatus powered by a 6 V battery if it is drawing 0.1 A of current for 10 s? How much work does the apparatus do?

9. How much chemical energy will a 4,5 V battery convert to electrical energy in 1 minute if the current is 2 A?

10.6. Electric circuits

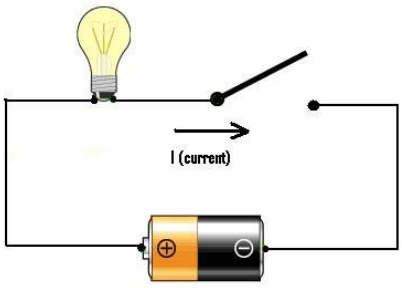
An **electrical circuit** is a closed loop of interconnected electrical elements, generators, transmission lines, switches and receivers, in order to make electricity practical. Electrons must flow from and return to the power source.

Generators are the Power Source needed to supply the flow of electrons (electricity).

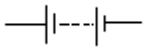
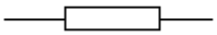
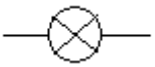
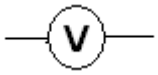
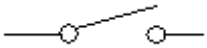
Transmission lines provide the connexion between power resources and receivers.

Receivers transform the electricity into work.

Switches are used for making, breaking or changing the connections in a circuit.



Symbols used to represent a circuit:

Battery		Resistor	
Lamp		Voltmeter	
Motor		Ammeter	
Switch		Ohmmeter	

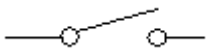
 http://www.andythelwell.com/blobz/ (interesting web site of interactive guide of electric circuits)

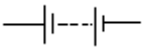
Questions

1. When connecting a source of electricity such as a battery and a resistor by a metallic wire, one has created an electric _____.

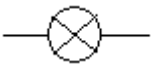
a) circuit
b) light bulb
c) switch
c) motor

2. Match one word in the left column with their corresponding symbol in the right column:

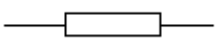
Battery 

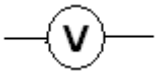
Lamp 

Voltmeter 

Motor 

Resistor 

Ammeter 

Switch 

Ohmmeter 

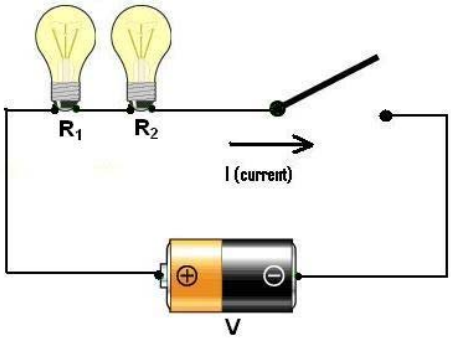
10.7. Parallel and series circuits

There are two basic ways in which to connect more than two circuit components: **series** and **parallel**.

In a **series circuit** there is only one path for electrons to flow. In this kind of circuit if, for some reason, current cannot pass through one of the elements of circuit, the current cannot flow in the circuit at all.

In series circuits, resistors, or other type of receivers, are arranged in a chain. The current is the same through each resistor and the total resistance of the circuit (equivalent resistance, **R**) is the sum of the resistance values of the individual resistors:

$$\mathbf{R} = R_1 + R_2 + R_3 + ...$$



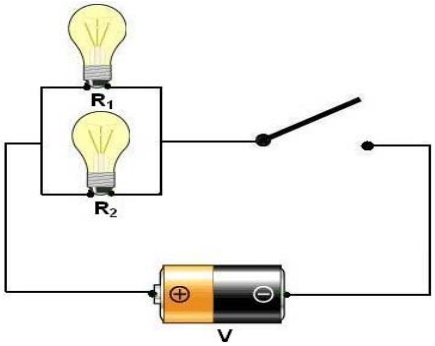
In a **parallel circuit** the current can pass simultaneously through each resistor, or other receiver, and the energy of the current is available to each resistor. In this case if current cannot pass through a receiver, it can continue to flow through the rest of the circuit.

The current in a parallel circuit breaks up, with some flowing along each parallel branch and re-combining when the branches meet again. The voltage across each resistor in parallel is the same. There are many paths for electrons to flow, but only one voltage across all components.

The total resistance (**R**) of a set of resistors in parallel is found by adding up the reciprocals of the resistance values, and then taking the reciprocal of the total:

$$\frac{1}{\mathbf{R}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

The amount of current going through each resistor depends on the resistance.

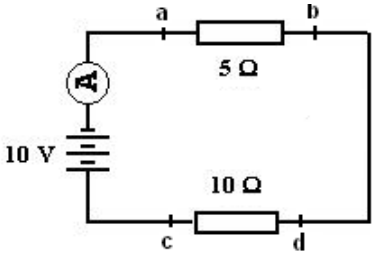


For resistors in series, the current is the same for each resistor, and for resistors in parallel, the voltage is the same for each one.

Example 1

In the circuit below, calculate:

a) The reading on ammeter **A**.
b) The potential difference between **a** and **b** and the potential difference between **c** and **d**.



Solution

a) This is a series circuit, so that, the total resistance, **R**:

R = 5 Ω + 10 Ω = 15 Ω

If we substitute the values of voltage and resistance in Ohm's law:

I = V / R

We obtain a current intensity of 10 /15 = 0,67 A

Now we know that the reading of ammeter will be **0,67 A**

b) The current through resistors in series circuits is the same, so that, potential difference across the ends of each resistor will be:

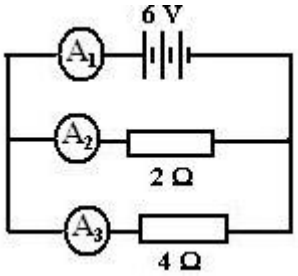
$V_a - V_b$ = 5 Ω · 0,67 A = **3,33 V**

$V_a - V_b$ = 10 Ω · 0,67 A = **6,66 V**

Example 2

In the circuit below, calculate:

a) The total resistance.
b) The reading on ammeter A_1, A_2 and A_3.



Solution

a) This is a parallel circuit, so that, the total resistance, **R**:

$$\frac{1}{R} = \frac{1}{2\,\Omega} + \frac{1}{4\,\Omega} = 0{,}75 \Rightarrow \mathbf{R = 1{,}33\ \Omega}$$

b) The potential difference across the ends of resistor connected in parallel is the same, so that, if we substitute the values of voltage and resistance in Ohm's law:

I = V / R

We obtain the following readings:

Ammeter A_2: I_2 = 6 V / 2 Ω = **3 A**

Ammeter A_3: I_3 = 6 V / 4 Ω = **1,5 A**

Ammeter A_1: $I_1 = I_2 + I_3$ = 3 A + 1,5 A = **4,5 A**

Questions

1. Choose the right answer:

1.1. When batteries are connected in series,

a) The positive terminals of the batteries are wired together and the negative terminals are wired together.

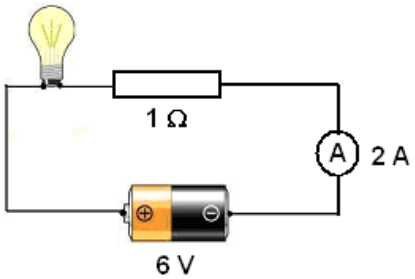
b) The positive terminals of the batteries are wired to the negative terminals.

1.2. When batteries are connected in parallel,

a) The positive terminals of the batteries are wired together and the negative terminals are wired together.

b) The positive terminals of the batteries are wired to the negative terminals.

1.3. A resistor and a bulb are connected to a battery of 6 V. The ammeter indicates a current of 2 A. Resistance of bulb is:



a) 1 Ω

b) 2 Ω

c) 3 Ω

d) 5 Ω

1.4. Batteries produce

a) Alternating current

b) Direct current.

1.5. A 3 Ω resistor, a battery, and an ammeter are connected in series in a circuit. If the resistor is replaced by a 6 Ω resistor, then

a) The voltage of the battery will decrease by a factor of two.

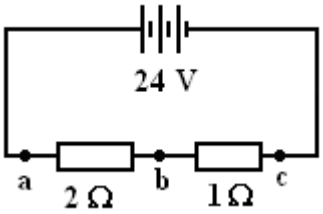
b) The voltage of the battery will increase by a factor of two.

c) The ammeter reading will decrease by a factor of two.

d) The ammeter reading will increase by a factor of two.

e) Both the current and the resistance will remain constant.

1.6. In the circuit diagram below



1.6.1. The electric current through the 2 Ω resistor is

a) 0.1 A

b) 2 A

c) 4 A

d) 8 A

1.6.2. The electric current through the 1 Ω resistor is

a) 0.1 A

b) 2 A

c) 4 A

d) 8 A

1.6.3. The potential difference between a and b is

a) 8 V

b) 16 V

c) 12 V

d) 24 V

1.6.4. The potential difference between b and c is

a) 8 V

b) 16 V

c) 12 V

d) 24 V

1.6.5. The equivalent resistance of the circuit is

a) 1,5 Ω

b) 0,5 Ω

c) 3 Ω

d) 24 Ω

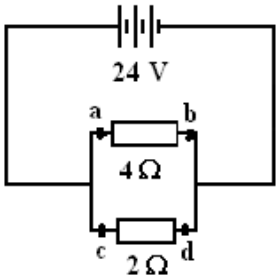
1.7. Two resistors connected in series in a circuit

a) Draw a larger current from a battery than connected in parallel.

b) Draw a smaller current from a battery than connected in parallel.

c) Draw the same current from a battery than connected in parallel.

1.8. In the circuit diagram below



1.8.1. The electric current through the 2 Ω resistor is

a) 6 A

b) 12 A

c) 24 A

d) 8 A

1.8.2. The electric current through the 4 Ω resistor is

a) 6 A

b) 12 A

c) 24 A

d) 8 A

1.8.3. The potential difference between a and b is

a) 8 V

b) 16 V

c) 12 V

d) 24 V

1.8.4. The potential difference between c and d is

a) 8 V

b) 16 V

c) 12 V

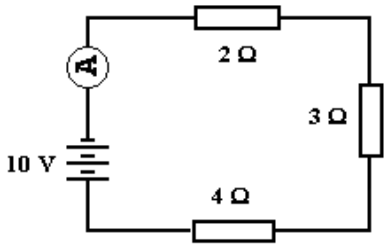
d) 24 V

1.8.5. The equivalent resistance of the circuit is

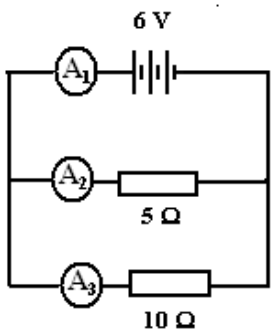
a) 1,3 Ω
b) 0,75 Ω
c) 1,5 Ω
d) 24 Ω

2.
a) Calculate the equivalent resistance in the circuit diagrams below.

a.1)



a.2)



b) Calculate the current indicated by the ammeters A, A_1, A_2 and A_3.

3. Match these electric devices to their descriptions

Resistor	It is used to measure resistance
Motor	It provides direct current
Ammeter	It transforms electric energy into kinetic energy
Voltmeter	It control current by providing resistance
Battery	It is used to measure current intensity
Ohmmeter	It breaks or opens an electric circuit
Switch	It is used to measure voltage

4.

a) Try to find eleven words related to circuits.

G	X	N	F	F	Y	W	D	Y	D	K	Y
H	S	C	U	R	R	E	N	T	W	D	F
B	X	Y	D	C	E	L	I	I	I	P	C
R	E	S	I	S	T	A	N	C	E	H	J
C	E	H	K	W	T	I	F	I	A	C	P
I	N	S	U	L	A	T	O	R	S	T	P
R	X	E	A	Z	B	N	G	T	W	I	D
C	Q	M	J	C	T	E	E	C	U	W	W
U	P	M	X	E	G	T	V	E	P	S	E
I	F	M	M	O	T	O	R	L	N	D	J
T	A	E	P	C	X	P	N	E	R	T	Q
J	Z	E	G	A	V	N	Y	C	I	D	D

b) Use these words to fill in the blanks in the following sentences.

- - - - - - - - - - - is the flow of - - - - - - around a - - - - - - - carrying energy from the - - - - - - - (or power supply) to components such as a - - - - or a - - - - -.

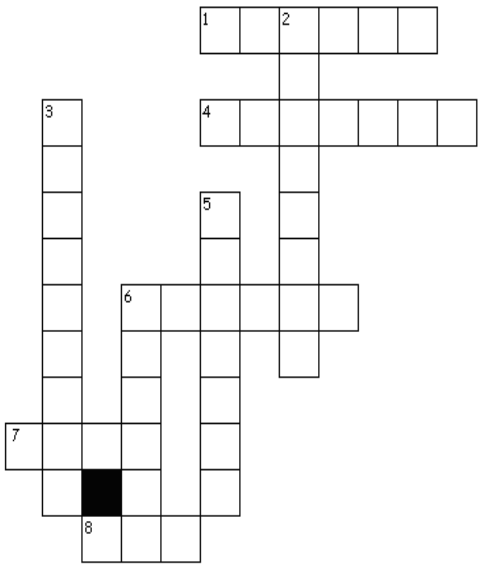
We say that - - - - - - - - - - - flows from the positive (+) terminal of a - - - - - - - to the negative (-) terminal of the - - - - - - -.

This flow of electric - - - - - - is called conventional- - - - - - -.

In a - - - - - - - there is at least a - - - - - -. If the - - - - - - is opened the - - - - - - is broken, so - - - - - - - - - - - cannot flow, but if the - - - - - - is closed the - - - - - - - is complete, allowing - - - - - - - - - - - to flow.

Opposition of a - - - - - - - to the flow of electric - - - - - - - is called - - - - - - - - - - . Ohm's law states that the - - - - - - -, **I**, flowing in a - - - - - - - is proportional to the applied - - - - - - - - - difference, **V**. - - - - - - - - - -have extremely high - - - - - - - - - - to the flow of - - - - - - through them.

5. Crossword



Across

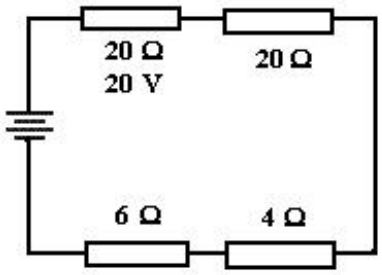
1. Unit of current in the International System
4. Closed loop of conductors through which charges can flow
6. All components are placed one after the other
7. Unit of voltage in the International system
8. Unit of resistance in the International System

Down

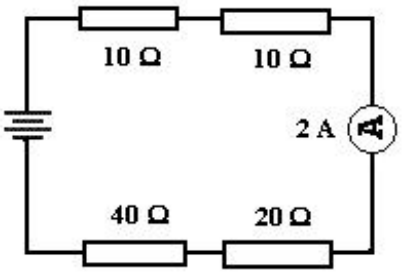
2. Current divides and goes through several branches at once
3. Substance through which electrical charges can easily flow
5. Flow of electrical charges
6. Device that closes or opens a circuit

6. Calculate the current passing through each resistor, the potential difference across the ends of each resistor and the total voltage in the following circuits:

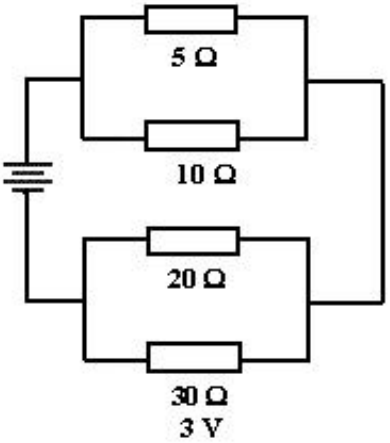
a)



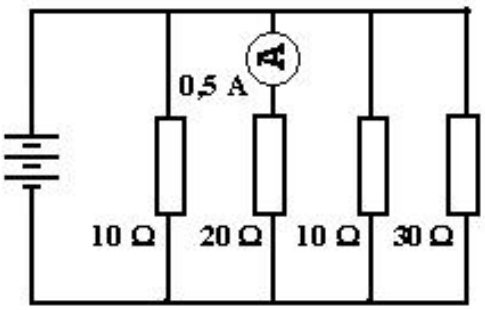
b)



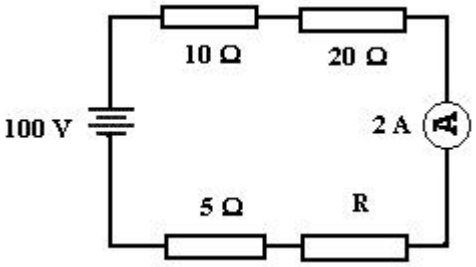
c)



d)



7. Calculate the current passing through each resistor, the potential difference across the ends of each resistor and the resistance of the unknown resistor, R:



Web sites

There are many web sites with applets related to electricity. You can practice doing your own circuits with the following ones:

1.- http://www.walter-fendt.de/ph14e/combres.htm Applet. It is possible to combine resistors and change the total voltage. Voltage and current in each resistor can be known.

2.- http://www.lon-capa.org/~mmp/kap20/RR506a.htm In this applet you can select several configurations of resistors in parallel or in series or in combination of both, change their individual resistances, and know the total resistance.

3.- http://www.hyperstaffs.info/work/physics/child/index.html (In this applet there is a brief introduction to circuits. Interesting

4.- http://www.andythelwell.com/blobz/ Interactive theory and questions about circuits.

In this unit many important topics have not been discussed. Your teacher will tell you what part of these two projects you have to work in.

Project 1: Make a report including one the following items:

1. Natural electrical phenomena
2. Cells, Batteries
3. Power stations: hydroelectric, thermal, solar, nuclear, aeolian
4. Uses of the electrical energy
5. Electricity at home
6. Saving energy

The report has to include:

1st page:

Title
Name
Class/Group
Date

2nd page:

Index

Aim

Introduction

Development of Contents

In this part is important do include diagrams, pictures, concept maps, tables, graphs, etc.

Conclusions

Glossary of terms

References

You also have to prepare **questions directed to your classmates**. Examples of question could be cut a picture as a puzzle to be solved for the rest of the students, texts to be filled with the missing words, texts to underline or circle words related to the topic, tables to be completed, put in order sentences (you can give the sentences written on different cards), word searches, link words with their definitions, etc.

Project 2: Building of an electric devise

 The following projects are thinking to work individually or in groups of two.

1. Build a Burglar Alarm: Consult the webpage:
http://www.charlesedisonfund.org/Experiments/HTMLexperiments/Chapter7/7-Expt4/p1.html

2. Build an electrical motor: Consult the webpage:
http://scitoys.com/scitoys/scitoys/electro/electro4.html

This report has to include:

1st page:

Title
Name
Class/Group
Date

2nd page:

Index

Aim

Introduction

Equipment

Development of the activity: diagrams, pictures, concept maps, etc. have to be included in this part of the activity

Conclusions

Glossary of terms

References

Rules before doing the reports

- Collect and sort the information
- Read and underline the main information
- Group and classify the information
- Think about the steps you have to follow to elaborate the report.
- Sequence the information
- Estimate the Time for each Step

Communication

These reports have to be present to the rest of the class. Posters, leaflets, overhead transparencies, PowerPoint, videos, etc can be made to present the word. Presentation can be recorded; music can be used; etc.

Planning the exposition

1. **Assign roles/tasks to each member**
2. **Organise the global exposition in different parts**

   Introduction,

   Structure,

   etc.

   Sequencing the contents and discussing the main points
3. **It is important to consider the following points:**

- What you are going to explain
- Preparation of resources you need
- Think of time the presentation last (for example teacher can tell you that each member of group have five minutes to explain their part of the project)
- Write everything is important to explain the classmates
- Think of questions your classmates can ask you

4. **Practice**

   It is important that students rehearse the presentation, speaking aloud and clearly, and controlling the time.

Rules for presentations

- Speak clearly and at a moderate speed.
- Control your expressions and movements.
- Control the volume of your voice and speak naturally.
- Look to your mates.
- Transmit enthusiasm to the audience.

Experiments: DC Circuits

Experiment 1: Series batteries

OBJECTIVES

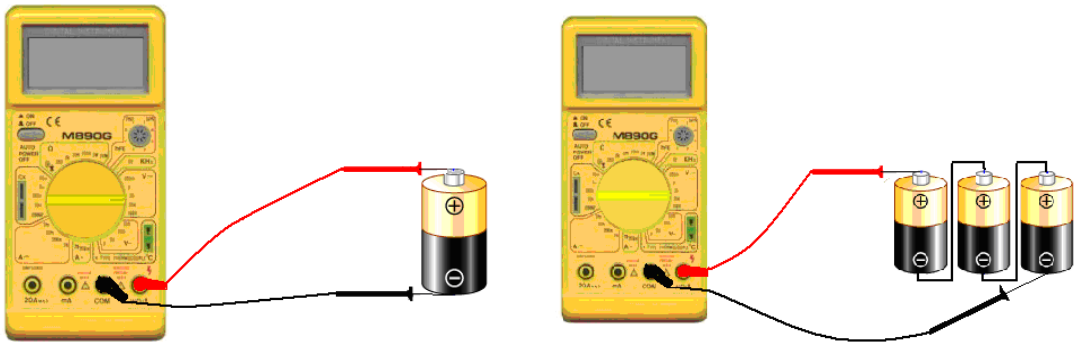
- Learn how to connect batteries in series.
- Calculate the total voltage in series batteries.

EQUIPMENT

Three 1,5 volts batteries
One 4,5 volts battery
Cables
Voltmeter

PROCEDURE

1. Measure the voltage of one 1,5 volts battery (make the connexions as showing in the picture). Annotate the value.
2. Measure the voltage of the 4,5 volts battery. Annotate the value.
3. Connect two 1,5 volts batteries in series (the positive pole of one to the negative pole of the other) and measure the voltage across them both. Annotate the value.
4. Connect three 1,5 volts batteries in series and measure the voltage across them. Annotate the value



QUESTIONS

1. Draw a schematic diagram of each circuit.
2. What happen if the terminal connexions to the batteries are reversed?
3. How is the total voltage of two 1,5 volts series batteries compared to the voltage of the isolated 1,5 volts battery?
4. How is the total voltage of the three 1,5 volts series batteries compared to the voltage of the isolated 1,5 volts battery?

5. How is the total voltage of the three 1,5 volts series batteries compared to the voltage of the isolated 4,5 volts battery?
6. What do you observe when opening a 4,5 volts battery?
7. What is the total voltage of five 1,5 volts batteries connected in series?

Experiment 2: Parallel batteries

OBJECTIVES

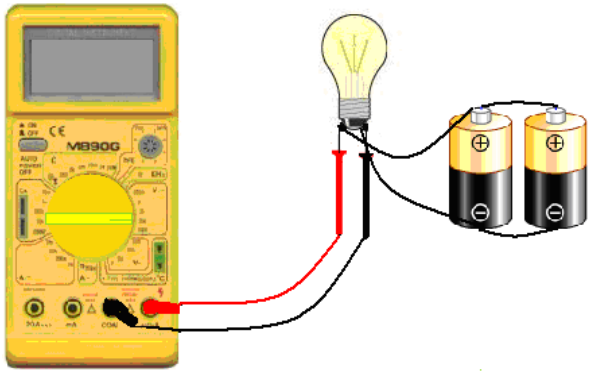
- Learn how to connect batteries in parallel.
- Calculate the total voltage in parallel batteries.

EQUIPMENT

- Two 6 volts batteries
- A 12 volts bulb
- A socket
- Cables
- Voltmeter

PROCEDURE

Connect the 12 volts bulb to the two 6 volts batteries in parallel (the positive pole of one to the positive pole of the other) and measure the voltage across the bulb. Annotate the value.



QUESTIONS

1. Draw a schematic diagram of the circuit.
2. Explain why the lamp glows dimly.
3. How is the total voltage of the two 6 volts parallel batteries compared to the voltage of the isolated 6 volts battery? Why?
4. What is the total voltage of four 6 volts batteries connected in parallel?

Experiment 3: Ohm's law

OBJECTIVES

- To know how to use a voltmeter
- To know how to use an ammeter
- To prove the Ohm's law

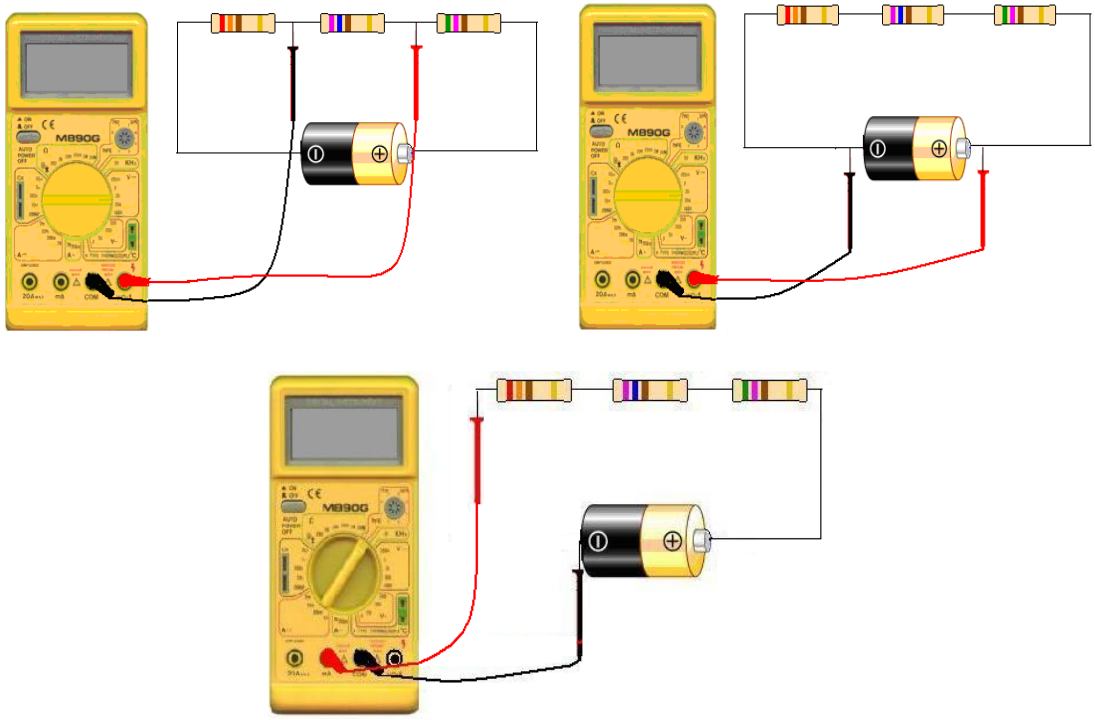
EQUIPMENT

- 6 volts battery
- Different resistors between 100 Ω and 1000 Ω
- Cables
- Polimeter

PROCEDURE

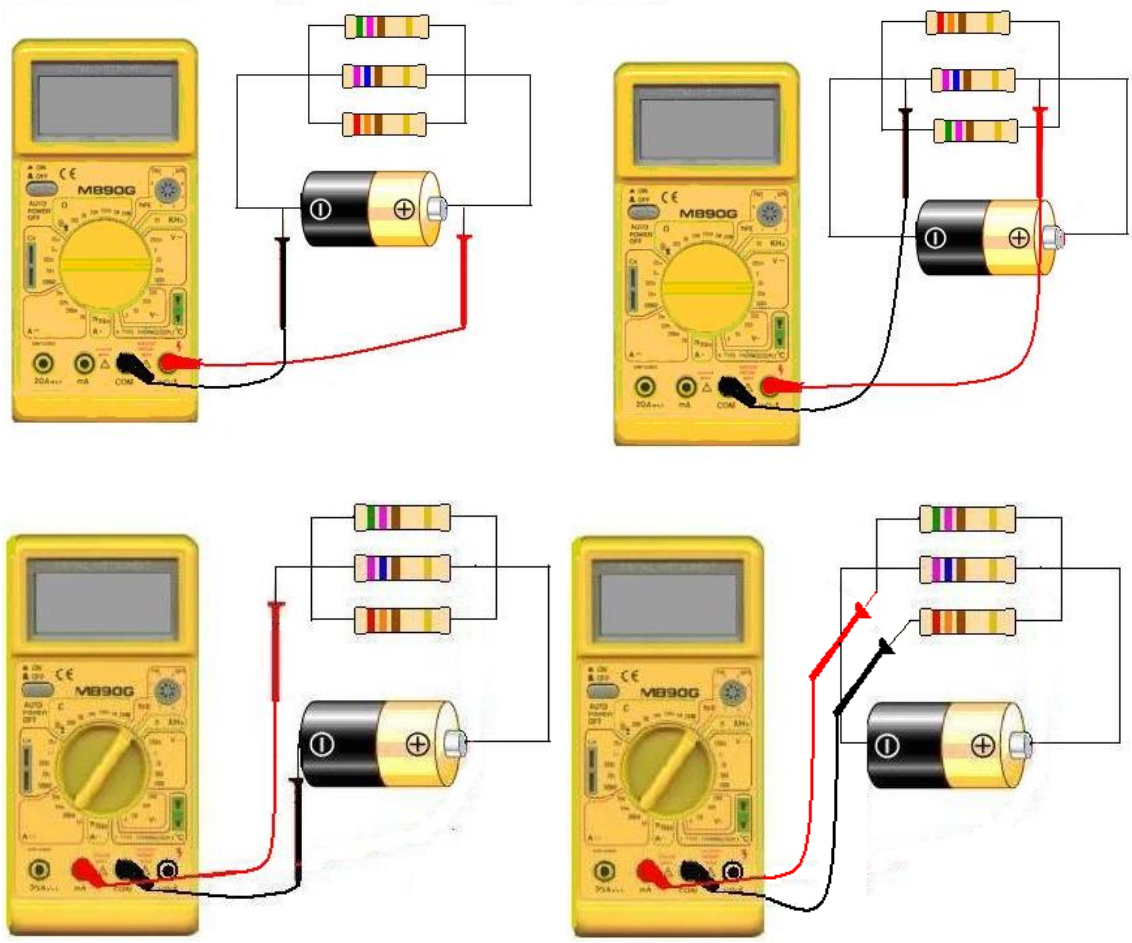
Series circuit

1. Connect three resistors in series to a 6 volts battery as shown in the picture.
2. Measure the voltage across each resistor and the battery voltage, with a voltmeter, after the resistors have been connected to it. Annotate the values.
3. Measure the current with an ammeter. Annotate the values.
4. Prove the Ohm's law



Parallel circuit

1. Connect three resistors in parallel to a 6 volts battery as shown in the picture.
2. Measure the voltage dropped across each resistor and the battery voltage, with a voltmeter, after the resistors have been connected to it. Annotate the values.
3. Measure the current with an ammeter. Annotate the values.
4. Prove the Ohm's law ($V = I \cdot R$)



Remember:

- Switch you multimeter to the "voltage" mode or "current" mode when measuring voltage or current.
- Voltmeter has to be connected in parallel.
- Ammeter has to be connected in series.

QUESTIONS

1. Draw a schematic diagram of each circuit.

2. In the table below annotate the results obtained for each resistance and for the overall circuit in the series connexion and in the parallel connexion:

Series Circuit			
	Resistance (Ω)	Voltage (V)	Current (mA)
1			
2			
3			
Total			
Parallel Circuit			
	Resistance (Ω)	Voltage (V)	Current (mA)
1			
2			
3			
Total			

3. How the total voltage is dropped respect to the voltage in each resistor?

a) In the series connexion.

b) In the parallel connexion.

4. How the total current respect to the current across passing through each resistor?

a) In the series connexion.

b) In the parallel connexion.

5. Calculate the resistance of each resistor using the Ohm's law.

6. Calculate the total resistance in both circuits

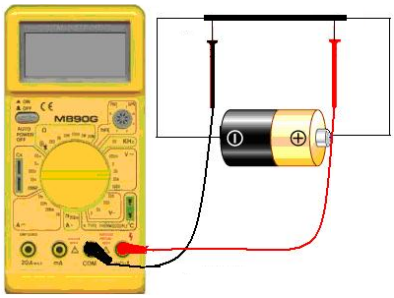
7. What happen to the current if the number of resistors in the series circuit increases?

8. What happen to the voltage if the number of resistors in the series circuit increases?

9. What happen to the current if the number of resistors in the parallel circuit increases?

10. What happen to the voltage if the number of resistors in the parallel circuit increases?

11. Replace the series resistors by a pencil graphite rod. Move the red probe along the length of the rod and explain what you observe. What probe position gives the greatest voltage indication?



Experiment 4: Thermocouples

OBJECTIVE

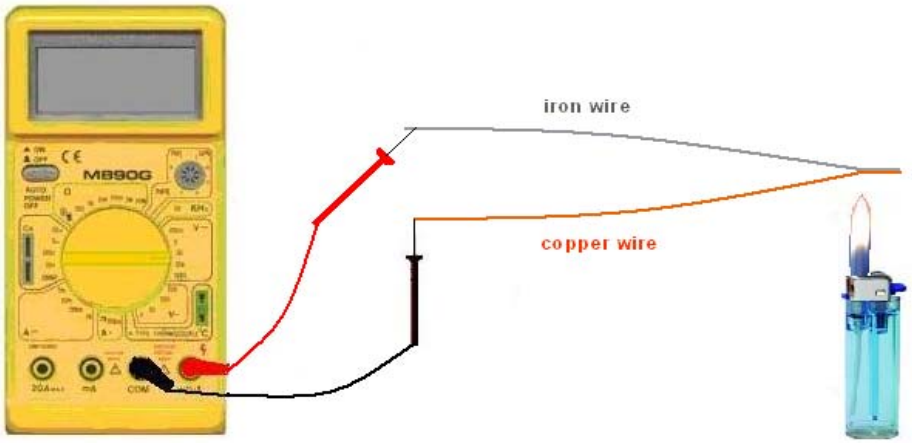
Observe the how a variation of temperature affect conduction in thermocouples.

EQUIPMENT

- Copper wire
- Iron wire
- Voltmeter
- Lighter
- Ice cubes

PROCEDURE

Thermocouples consist of two different metals joined so that a temperature difference between the points of contact produces a voltage difference.



1. Twist one end of the iron wire together with one end of the copper wire.
2. Connect the free ends of the wires to the voltmeter.
3. Set the voltmeter to its most sensitive range. Annotate the voltage.
4. Heat the twister ends of metals with a lighter. Explain what happen to the voltage. Annotate the highest value of voltage.
5. Remove the flame of lighter and let it cool until the voltmeter indication is zero.
6. Touch the wired ends of thermocouple with ice. Explain what happen to the voltage. Annotate the highest value of voltage.

QUESTIONS

1. Explain why the voltmeter indicates a zero voltage when you connect it to the ends of thermocouple in the beginning of the experiment.

2. Compare the maximum values of voltage obtained with the flame and with the ice cubes. Explain the reason for this difference.

3. A thermocouple is an application of the *Seebeck effect.* Explain the Seebeck effect and give examples of its applications.

Experiment 4: Lemon battery

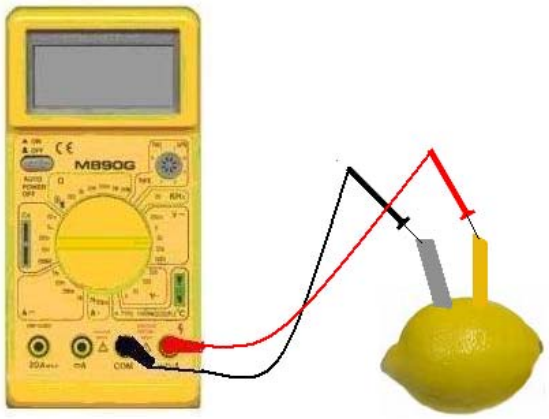
OBJECTIVE

- Prove that some chemical reactions produce electricity

EQUIPMENT

- A lemon
- Lamina of zinc
- Lamina of copper
- Voltmeter

PROCEDURE



1. Insert the two metal laminas (electrodes) inside the lemon and assemble the different parts, as indicated in the previous picture.
2. Set the voltmeter and annotate the voltage.
3. Use different metal laminas as electrodes. Annotate the voltage.
4. Change lemon for other fruit. Annotate the voltage.

QUESTIONS

1. Create a table with the voltage dates you have obtained.
2. Which electrodes give the highest values of voltage?
3. Which electrodes give the lowest values of voltage?

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

Current	☐
Voltage	☐
Resistance	☐
Circuit	☐
Switch	☐
Series circuit	☐
Parallel circuit	☐
Resistor	☐
Resistivity	☐
Battery	☐
Ammeter	☐
Voltmeter	☐
Ohmmeter	☐

2.- Tick the one you think is your answer:

	I know very well	I need some revision	I need some more help
I know that the electric force between two charges is directly proportional to the product of the magnitude of the charges and inversely proportional to the square of the distance between the two charges.			
I know that when materials allow flowing electrons through them, they are conductors of electricity.			
I know that the electric current is the rate of movement of charge per unit time.			
I know that voltage is the electric potential energy per unit charge.			
I know that resistance is the opposition of a material to current passing through it.			
I know the resistance unit in the IS is ohm (Ω)			
I know the current unit in the IS is ampere (A).			
I know the voltage unit in the IS is volt (V).			
I know that Ohm law states the current going through a resistance is proportional to voltage.			
I remember the equation: Power = Current · Voltage			
I know that Joule's law states that the amount of heat per second that is generated in a conductor carrying a current is proportional to the resistance of			

the conductor and the square of the electric current intensity.			
I know that batteries provide direct current.			
I know that in a circuit, generators are the power source needed to supply the flow of electrons.			
I know that in a circuit, transmission lines are needed to provide the connexion between power resources and receivers.			
I know that receivers, such as resistors, bulbs or motors, transform the electricity into work.			
I know that switches are used for making, breaking or changing the connections in a circuit.			
I know that in series circuits, there is only one path for electrons to flow and the current is the same through each receiver.			
I know that in series circuits, the total resistance of the circuit is the sum of the resistance values of the individual resistors.			
I know that in parallel circuits, current flows at least in two independent paths to get back to the source.			
I know that in parallel circuits, the voltage across receivers is the same.			
I know that in parallel circuits, the total resistance of receivers is found by adding up the reciprocals of the resistance values, and then taking the reciprocal of the total.			

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.

UNIT 11: ELECTROMAGNETISM

Content:

Unit 11 Electromagnetism

11.1. Magnets: natural and artificial
11.2. Magnetization
11.3. Poles: magnetic properties
11.4. Magnetic field
11.5. The compass
11.6. Electromagnet
11.7. The electric engine
11.8. The dynamo

Learning Aims:

At the end of the unit, the student will know:

- Different substances that present magnetic properties.
- How a substance can be magnetized.
- Properties of the magnetic poles.
- What happen to iron fillings when they are situated over a magnet.
- What is a compass and what is used for.
- The difference between ferromagnetic, paramagnetic and diamagnetic substances.
- How and electromagnet works.

Initial Activities

1.  Choose the correct answer:

1.1. A magnet has two poles, north and south poles. What happen when the magnet is cut in pieces?

a) A half of pieces are south poles and the other half north poles.

b) All pieces lost the magnetism.

c) Each piece has a north pole and a south pole.

1.2. Lodestone is a mineral used

a) in jewellery.

b) as a magnet.

c) in pharmacy.

1.3. Magnets attract

a) Plastics.

b) Iron.

c) Wood.

1.4. The force of a magnet is strongest

a) At the ends of the magnet.

b) In the middle of the magnet.

c) It is the same in all parts of magnet.

1.5. Like poles _____ each other and unlike poles _____ each other.

a) attract, attract.

b) repel, repel,

c) attract, repel.

d) repel, attract.

1.6. The attraction of a magnet to a coin indicates that

a) The coin is made of metal.

b) The coin contains iron, cobalt or nickel.

c) The coin is also a magnet.

1.7. The Earth is a big magnet?

a) Yes, it is.

b) Depend on the weather.

c) No, it is not.

1.8. The compass needles are magnetized?

a) Yes, they are.

b) Depend on the material they are made of.

c) No, they are not.

2. Give the name of something that can separate iron filings from sawdust.

3. Complete the sentences:

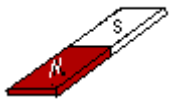
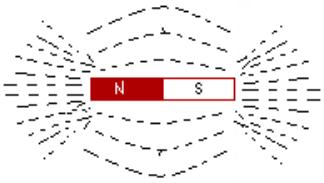
a) The cardinal directions in a compass needle are: Nord 0º, South _____, East _____, West _____.

b) An electromagnet is a kind of magnet that works when it is connected to the _____ current.

4. Choose the right bold word: An electromagnet is a coil of wire usually wound around an **iron / plastic** core. When connected to a **direct / alternating** current a magnetic field is produced. The magnetic field disappears when the current **ceases / flows**.

5. What is the name of a magnet that can be turned on and off?

Key words:

Magnetism 	Property of **attraction** displayed by **magnets** on other materials.
Poles 	Either of two regions of a **magnet**, designated north and south, where the magnetic field is strongest.
Magnetic field 	**Region** around a magnet or an electric current, characterized by the existence of a detectable magnetic force.
Compass 	Device, generally a **magnetic needle**, used to determine geographic direction.
Magnetite 	Brown to black iron oxide mineral, **Fe_3O_4**, that is strongly magnetic.
Ferromagnetic 	Substances such as iron, nickel, or cobalt and alloys that exhibit extremely **high magnetic** permeability.

Paramagnetic 	Materials like aluminium or platinum **become magnetized** in a magnetic field but it disappears when the field is removed.
Diamagnetic 	Substance that is **slightly repelled** by a magnet. Most elements in the periodic table are diamagnetic. Examples of diamagnetic elements are gold, silver and copper.
Electromagnet 	**Magnet** consisting essentially of a coil of insulated wire wrapped around a soft iron core that is magnetized only when **current flows** through the wire.

Magnetism

Magnetism is the property of attraction displayed by magnets on other materials. The main materials that exhibit magnetic properties are **nickel**, **iron**, **cobalt**, **gadolinium**, **samarium**, **neodymium** and their **alloys**.

Electric current creates magnetic fields, so **magnetism** can be explained from the movement of electrons around the nucleus of an atom.

11.1. Magnets: natural and artificial

There are natural and artificial magnets.

Magnetite, also called loadstone (Fe_3O_4), is a natural magnet. Magnetite was discovered by the ancient Greeks, near the city of Magnesia.

When nickel, iron, cobalt, gadolinium, samarium, neodymium and their alloys (ferromagnetic materials) are magnetized, a permanent artificial magnet is obtained.

An artificial magnet, produced by the action of an electrical current going through a wire, is called an electromagnet.

- One of a new application for **gadolinium** is the use for making **magnetic refrigerators**. A magnetic refrigerator works due to the special magnetic properties of gadolinium. Gadolinium heats up when exposed to a magnetic field and cools down when the magnetic field is removed. That means that a magnetic refrigerator requires no so much electrical energy and causes little harm to the environment.

- **Samarium Cobalt** magnets are composed of samarium (Sm), cobalt (Co) and iron (Fe). These magnets are extremely strong for their small size and high resistance to demagnetization. The main disadvantage is that they are expensive. These magnets are used in computer disc drives, sensors, satellite systems, etc.

- **Neodymium** magnets or NIB magnets are made of an alloy of neodymium (Nd), iron (Fe) and boron (B), $Nd_2Fe_{14}B$. They are the strongest type of permanent magnets made, but are also mechanically fragile (it can be crushed with a mixer)

  http://revver.com/video/150990/magnets/ (watch this video about blending of neodymium magnets)

  Neodymium magnets have replaced the resistant Sm-Co magnets in most applications, due mainly to their lower cost. These magnets are used in the music, electronic, automotive, in the toy and jewellery industry amongst other applications.

Magnetic Building set

- **Ceramic** magnets are composed of iron oxide, barium and strontium elements. These magnets are very hard and brittle and have a higher resistance to demagnetization and oxidation compared to other non-rare earth magnets. Another advantage is their low cost, therefore they are widely used.

There are also **plastic** magnets**.** Properties such as high elasticity, flexibility make them favourite candidates for many applications in industry and in home appliances.

There are liquid substances with magnetic properties. These substances are called **ferrofluids**. A **ferrofluid** is a colloidal mixture with about 5% nanoscale particles of magnetic solid, magnetite, hematite or other compound containing iron, 10% surfactant, and 85% carrier, by volume. The carrier could be an organic liquid such as kerosene and an oleic acid can be used as surfactant.

Ferrofluid attracted by a magnet

http://www.metacafe.com/watch/1054847/amazing_ferrofluid/: In this web page you can watch a video about a ferrofluid.

Curie temperature: Temperature above which ferromagnetic materials lose their magnetism.

Examples:

Curie temperature of **iron**, Fe: 1043 K;

.Curie temperature (T_c) of alloys depends on the composition of the alloy:

- **Nd-Fe-B**: $T_c \approx$ 350 ºC but temperatures above about 180 ºC are no recommended.
- **Sm-Co (1:5)**: $T_c \approx$ 750 ºC
- **Sm-Co (2:17)**: $T_c \approx$ 800 ºC

  Sm-Co magnets can operate at temperatures up to 300 ºC.
- **Al-Ni-Co** (**Alnico**) $T_c \approx$ 860 ºC but temperatures above about 540 ºC are no recommended.
- **Ceramic** magnets: $T_c \approx$ 450 ºC but temperatures above about 300 ºC are no recommended.


Consult the following web pages related to magnets:

1. **http://www.stanfordmagnets.com/magnet.html#nfb**: Theory about the different types of magnets. In this web site you can buy magnets.

2. **http://www.bbc.co.uk/schools/scienceclips/ages/7_8/magnets_springs.shtml**: This is an interactive experiment in which you can test which objects can be picked up by a **magnet.**

3. **http://ksnn.larc.nasa.gov/k2/videos/s_magnetsWork_Hcap.html**: This is a cartoon video about how a magnet works, you can also read what they are talking about.

4. In these two videos: **http://www.youtube.com/watch?v=ewx9tEJJlWk&hl=es** and **http://www.youtube.com/watch?v=s1xS-ssfTM8&hl=es** you can watch what happen with neodymium magnets when approaching to a screen TV.

Questions

1. In the previous test

a) Underline in green the elements of the Periodic Table.

b) Ring in green the symbols of the elements.

c) Underline in red the applications of magnets.

d) Underline in orange the physical properties of magnets.

2. Look for some information about magnetic refrigerators: how, who, when and where were discovered, saving of energy, etc.

3. Look for the meaning of words:

Colloidal mixture

Surfactant

Carrier

4. When a magnet is approached to a ferrofluid, does the density of ferrofluid change? Why?

5. Look for applications of ferrofluids.

6. Mafic lava contains a high percentage of iron. When this lava starts flowing, the temperature oscillates between 900 and 1.300 °C. If the Curie temperature of iron is 1043 K;

a) What is the Curie temperature of iron in Celsius degree?

b) What does it mean Curie temperature?

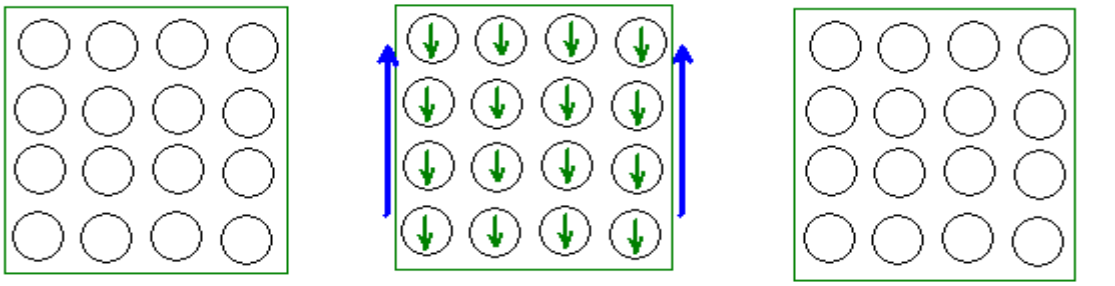
c) Has lava magnetic properties?

11.2. Magnetization

Magnetization is the process of making a substance temporarily or permanently magnetic.

Depending on the magnetization properties of elements, they can be classified in:

- **Diamagnetic**: These substances are **slightly repelled** by a magnet because when they are placed in a magnetic field, a slight magnetic field is produced, but this field is opposed to the main magnetic field. This property makes diamagnetic materials useful for levitation. In these substances all the electrons are paired, that means that a half of electrons spin in a direction and the other half in the opposite direction, therefore, the total magnetic field is zero. Many elements in the periodic table are diamagnetic; examples of diamagnetic elements are gold, silver, copper, zinc, gold, mercury, and bismuth.



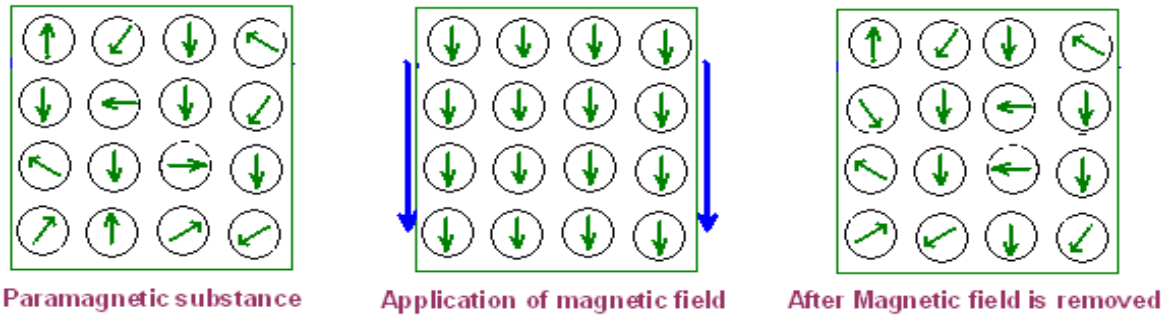
Watch the following web pages:

1. http://www.exploratorium.edu/snacks/diamagnetism_www/index.html: Experiments with diamagnetic substances.

2. http://www.youtube.com/watch?v=2FvWtEdY4sE: Video where you can observe how water is repelled by a magnet.

3. **http://video.google.es/videoplay?docid=-4131097019486262141&ei=c1sVSv2IBYPu-AaE1-j8Aw&q=diamagnetism&hl=es**: Video about levitation of diamagnetic substances.

- In **paramagnetic** substances the atoms have unpaired electrons. Initially, the atom magnetic fields are aligned randomly, and the total magnetic field is zero. When an external magnetic field is applied to this kind of substances, the magnetic field realign in the same direction that the external magnetic field, but these magnetic properties disappear when the external magnetic field is removed. These materials are **slightly attracted** by the external magnetic field. Examples of paramagnetic materials are aluminium, platinum, magnesium, molybdenum and lithium.

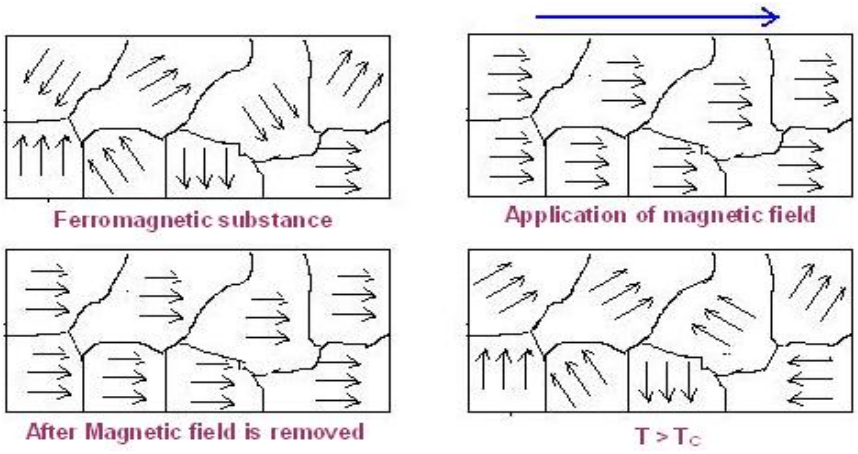


- **Ferromagnetic** substances also have unpaired electrons. They are **strongly attracted** by magnets and can be magnetized by their insertion in a magnetic field. Examples of ferromagnetic substances are iron, cobalt and nickel.

The difference between **paramagnetic** and **ferromagnetic** materials is that in ferromagnetic materials, the atoms are organized in **domains**. A **magnetic domain** is like a small region of material in which the magnetic fields of atoms are aligned. In an unmagnetized material, the domains are organized randomly and total magnetic field is zero, but when the material became magnetized, the magnetic field realign in the same direction that the external magnetic field, and the material becomes magnetic.

Magnetization can be done by placing the material in a strong external magnetic field or by passing electrical current through the material. Depending on how much magnetization last, after the magnetic field is removed, ferromagnetic materials can be classified in **temporary** or **permanent** magnets.

When a magnetized ferromagnetic material is heated, above the **Curie temperature** (Pierre Curie discovered this property in 1895), the material loses its permanent magnet properties.



Look the following web pages:

1. **http://www.ehow.com/video_4756351_what-definition-magnetic-domain.html:** Video. A teacher explains what a domain is.

2. **http://www.ndt-ed.org/EducationResources/HighSchool/Magnetism/fieldcreation.htm**: Simulation of movement of an electron.

3. **http://www.ndt-ed.org/EducationResources/HighSchool/Magnetism/electronpairing.htm:** Simulation of movement of pairing electrons

4. **http://www.ndt-ed.org/EducationResources/HighSchool/Magnetism/magneticdomain.htm:** Applet of magnetic domain

5. **http://www.ndt-ed.org/EducationResources/HighSchool/Magnetism/ferromagmaterials.htm**: Simulation of ferromagnetic materials behaviour.

Questions

1. What is the name of materials that only have magnetic properties when a permanent magnet is closed to them?
2. What is the name of materials that are slightly repelled by a magnet?
3. What is the name of materials that are strongly attracted by a magnet?
4. Explain the two different kinds of movements of electrons around the nucleus.
5. What is the difference between paramagnetic and ferromagnetic materials?
6. Explain the characteristics of a magnetic domain.
7. What happen to a needle if you rubbed a magnet across it?
8. Explain the meaning of the previous figures related to diamagnetic, paramagnetic and ferromagnetic materials. What do the arrows represent?
9. Explain the difference between paired and unpaired electrons.
10. What kind of atoms have magnetic field?
11. Materials that present magnetic properties always have unpaired electrons, but not all materials with unpaired electrons have magnetic properties. Why?
12. Explain the differences between a permanent magnet and a temporary magnet.
13. What happen when a magnet is heated above the Curie temperature?
14. Choose the right answer:

    14.1. Which metals has magnetic properties?

    a) Aluminium
    b) Iron
    c) Copper
    d) Nickel

14.2. The small regions in ferromagnetic materials are called

a) Poles

b) Magnetic fields

c) Domains

d) Cells

14.3. When iron is not magnetized, domains

a) are situated in the same direction.

b) are situated randomly.

c) do not exist.

14.4. When iron is magnetized, domains

a) are situated in the same direction.

b) are situated randomly.

c) do not exist.

15. Look for additional information about domains:

a) Dimensions

b) How they can be detected.

11.3. Poles: magnetic properties

It is very easy to demonstrate that the magnetic force surrounding a magnet is not uniform. This magnetic force is greater at the ends of the magnet and it is weak at the centre. The two ends of a magnet are called **poles** (**north** and **south**).

Properties of magnetic poles:

- Unlike poles are attracted from one another (**north** pole attracts **south** pole and viceversa).
- Like poles are repelled to one another (**north** pole repels **north** pole and **south** pole repels **south** pole).
- The attraction or repelling strength of two magnets depends on
  - How close they are to each other (the closer they are, the greater the magnetic force is).
  - How strong the magnetic force of magnets is.
- When a magnet is broken into pieces, new magnets are obtained, with their corresponding north and south poles.

Look the following web pages:

1. **http://www.ndt-ed.org/EducationResources/HighSchool/Magnetism/twoends.htm**: Simulation of attraction and repulsion between unlike poles and like poles of a magnet.

2. **http://www.ndt-ed.org/EducationResources/HighSchool/Magnetism/magneticproperties.htm**: Applet about how a magnet behaves when it is cut.

Questions

1. Tell if the following statements are true or false. Change the false statements to the correct one:

a) Magnets attract one to another with a force called magnetic.

b) A magnet has two poles called east and west.

c) Like poles attract each other.

d) Opposite poles repel one to another.

e) The magnetic force between two magnets is stronger the further apart the magnets are from one another.

f) When magnets are broken into small pieces, each piece is a magnet.

g) The ends of magnets are called electric poles.

h) Magnetic materials can be made of iron, copper or nickel.

2. We have 3 magnets, A, B and C. Magnet A can hold 3 paper clips, magnet B can hold 6 paper clips and magnet C can hold 4 paper clips. Which magnet is the strongest?

3. What are the similarities between electric charges and magnetic poles?

4. A magnet is cut in 5 pieces.

a) How many poles will each piece have?

b) How many poles there will be in total?

5. Choose the right answers:

5.1. Which objects are not attracted by a magnet?

a) A nail

b) A plastic spoon

c) A key

d) A piece of paper

5.2. The north pole of a magnet attracts

a) The south pole of another magnet.

b) The north pole of another magnet.

c) Any ferromagnetic substance.

d) Both poles of a magnet.

5.3. The north pole of a magnet repels

a) The south pole of another magnet.

b) The north pole of another magnet.

c) Any ferromagnetic substance.

d) Both poles of a magnet.

6. We have 3 magnets in a rectangular shape, A, B and C. Magnet A attracts magnet B and magnet B repels magnet C.

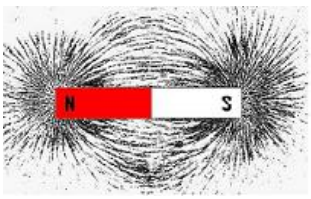
a) Draw the magnets, indicating the name of poles. Explain the drawing you do.

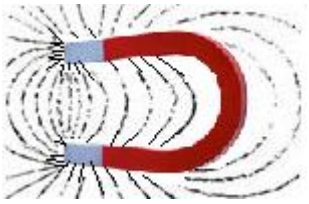
b) Is it possible to do another drawing changing the position of magnetic poles? If it is possible, do it.

11.4. Magnetic field

Magnetic field is the region surrounding a magnet or an electric current (it is produced whenever an electrical charge is in motion) where a ferromagnetic material or a moving electric charge experiment a magnetic force. **Magnetic field** is represented by **magnetic lines of force**.

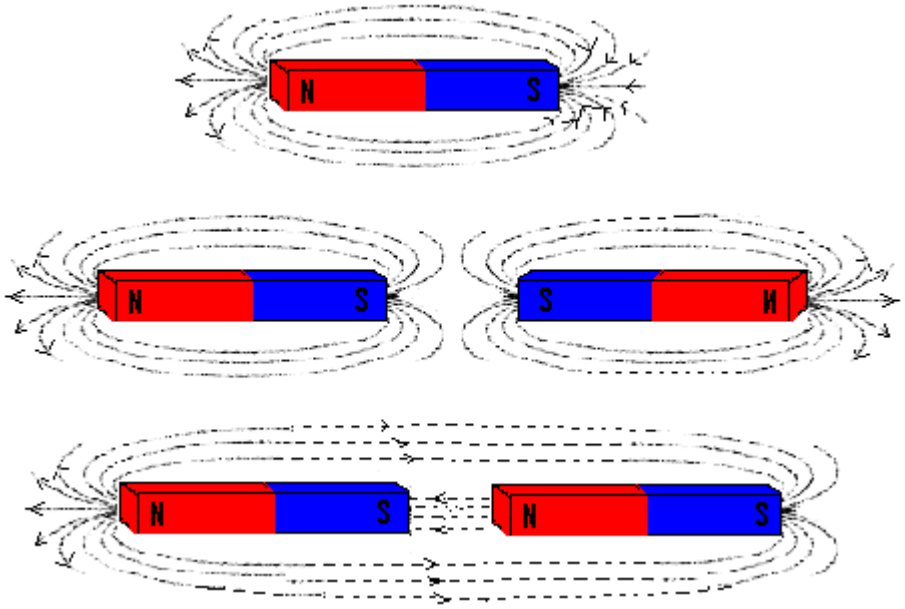
Magnetic lines of force can be visualized (magnetograph) by sprinkling iron filings or putting small compasses over a magnet (iron filings also have two poles, north and south). The particles align themselves with the lines of magnetic force produced by the magnet:





Properties of Magnetic Lines of Force

- They go from the north pole to the south pole in the air and from the south pole to the north pole within the magnet.
- They are more concentrated at the two poles, where the force of the magnet is stronger.
- Concentration of magnetic lines decreases when the distance to poles increases.
- They never cross one another.
- They all have the same strength.



Magnetic lines of force

 Look the following web page:

http://www.ndt-ed.org/EducationResources/HighSchool/Magnetism/linesofforce.htm:

Simulation of how magnetic lines of force act upon ferromagnetic objects.

Questions

1. Explain the differences you observe in the magnetic lines of force (observe the previous picture) created by:

- **a)** One magnet.
- **b)** Two magnets with the two like poles close to one another.
- **c)** Two magnets with the two different poles close to one another.

2. Choose the right answers:

2.1. The area around a magnet that behaves like a magnet is called

- **a)** A magnetic field.
- **b)** A magnetic force.
- **c)** A magnetic surface

2.2. To detect a magnetic field, it can be used

- **a)** Small compasses
- **b)** Copper filings.
- **c)** Nickel filings.
- **d)** Iron filings.

2.3. The lines of a magnetic field go from

- **a)** North pole to south pole
- **b)** South pole to north pole
- **c)** Both answers are correct.
- **d)** None of these answers is correct.

2.4. The magnetic field of a magnet:

- **a)** It is strong anywhere around the magnet
- **b)** It is stronger on the poles.
- **c)** It is weaker as the distance from the magnet increases.
- **d)** It only exists on the poles.

3. What does it happen when iron particles are sprinkled over a magnet?

4. What does it happen when small compasses are situated around a magnet?

5. Where are the magnetic forces around a magnet stronger?

6. Where are the magnetic forces around a magnet weaker?

7. What do the magnetic lines of force around a magnet indicate?

8. Each iron filing is a magnet; it has a north and south pole. How the poles of each iron filing are situated in a magnetic field created by a magnet?

9. Is the Earth a magnet? In case of a positive answer, where are situated the north and the south magnetic poles?

10. Draw a picture of the Earth magnetic lines of force.

11.5. The compass

A **compass** is a magnetic device that indicates the direction of the magnetic poles of Earth.

It is believed that Chinese invented the magnetic compass during the Qin dynasty (221-206 B.C.). Chinese were aware of power of lodestone to attract iron and to magnetize objects made of iron by rubbing these objects with lodestone; they magnetized needles by stroking them with a lodestone (magnetite) and used these needles in navigation.

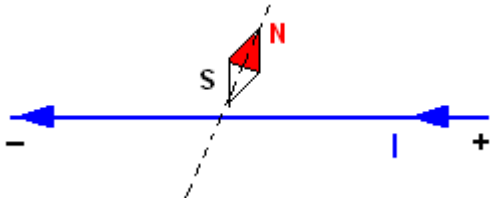
The **compass** is well known by their use as a navigational device due to their property to point the north-south direction of Earth (we already know that Earth is a magnet, it has a magnetic north and a south poles).

Questions

1. Explain what a compass is.
2. What happen when a compass is situate around a magnet?
3. Why are compasses used in navigation?
4. In ancient China, sailors carried a lodestone on the ship because the needle did not keep the magnetism. What they had to do to magnetize the needle again?
5. Which direction does a compass point to?

11.6. Electromagnet

In 1821, Hans Christian Oersted discovered that when an electrical current passed through a wire, close to a compass, the wire behaved as a magnet and the compass needle started moving. This experiment showed that magnetism also could be produced by moving electrical charges.



In the previous picture we can observe that when current goes through the wire, the south pole of compass moves forward and the north pole backward.

In the following web pages there are applets about Oersted experiment:

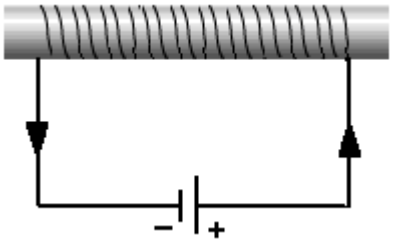
1. **http://www.edumedia-sciences.com/es/a184-experimento-de-oersted**

2. **http://www.walter-fendt.de/ph11s/mfwire_s.htm**

3. **http://www.ndt-ed.org/EducationResources/HighSchool/Magnetism/electricitymagnet.htm**: Applet that show the movement of a compass when a wire with electrical current is near.

The magnetic field created by only one wire is weak, therefore, to make an **electromagnet** wires are coiled several times (solenoid) around a soft iron core. The ends of solenoid are connected to a battery. When the current is turn on, the solenoid become a magnet, but if the current is turn off, magnetism disappear.

Electromagnets are temporary magnets because only work when the electric current flows through them.



In the following web page there is an applet about how an electromagnet works:

1. **http://www.ndt-ed.org/EducationResources/HighSchool/Magnetism/electromagnets.htm**

Questions

1. Choose the correct answers:

1.1. A magnetic field is produced by

a) Lodestone.

b) Electric currents.

c) All materials made of iron.

d) Metals.

1.2. When the current flowing through an electromagnet is turned off,

a) Magnetism is weaker

b) Magnetism disappears.

c) Polarity of the electromagnet is reverted.

d) None of the previous answers.

1.3. Is it possible to increase the strength of a solenoid?

a) No, it is not.

b) Yes, increasing the current flowing through it.

c) Yes, coiling the solenoid around a soft iron bar.

d) None of the previous answers.

2. Tell if the following statements are true or false:

a) A compass situated close to an electrified wire, experiment a movement because of the gravity force between masses.

b) Electromagnets do not work when the current is turned on because the magnetic field disappears.

c) If we sprinkle iron filing close to an electrified wire, they will be attracted to the wire.

3. Explain how an electromagnet can be made and how it works.

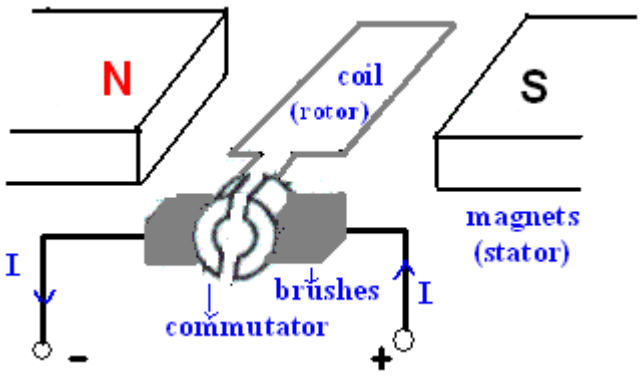
4. What is the relationship between electricity and magnetism?

11.7. The electric engine

An **electric engine** transforms the electrical energy into mechanical energy.

The main **parts** of an electric engine are:

- **Coil or rotor**: it is made of copper wire wound around an armature.
- **Permanent magnets**.
- **Brushes**: They always keep in contact with the commutator and are connected to an electricity generator.
- **Commutator**: it is divided in two halves. Each halve is connected to one end of the coil.



Explanation of how an electric motor operates:

- When the engine is connected to the battery and the current flows, this current goes to the coil through the brushes that make contact with the commutator.

- As the current flows through the coil, the coil becomes an electromagnet, and a north and south poles are created.
- The north pole of permanent magnet attracts the south pole of electromagnet; therefore, the coil starts moving.
- Once the coil gets the horizontal position, as the commutator is divided in two parts, the current in the coil change the direction, which means that the electromagnet poles are inverted, and will be repelled by the poles of the permanent magnets; consequently, the coil keeps spinning while the battery is on.

In the following web pages there are applets related to electric engines:

1. **http://www.ndt-ed.org/EducationResources/HighSchool/Magnetism/electricmotor.htm**: this applet is very useful to understand how an engine works with direct current and alternating current.

2. **http://www.metacafe.com/watch/971400/unexplained_phenomenon_simplest_electric_motor/:** very easy construction of an engine, an interesting video

3. **http://www.sciencejoywagon.com/physicszone/otherpub/wfendt/electricmotor.htm:** Walter Fendt applet. This Interactive lesson illustrates the roles that electricity, magnetism and force play in a DC electric motor. (a very good applet).

4. **http://teachingphysics.files.wordpress.com/2008/06/finished-motor.jpg:** Picture of an engine (very easy to make).

5. **http://videos.howstuffworks.com/hsw/20934-physics-electric-motor-speeds-and-lenzs-law-video.htm:** Video explaining the movement of a motor

Questions

1. Choose the right answers:

1.1. When the rotor of an electric engine is spinning

a) Current flows through the coil

b) Coil is an electromagnet.

c) Battery is on.

d) Battery is an electromagnet.

1.2. A motor can be connected to

a) Direct current

b) Alternating current

c) None of the above, because the motor itself generates electric current.

1.3. A motor change the electric energy into

a) Mechanical energy.

b) Chemical energy.

c) Heat.

d) Nuclear energy.

e) All of the above.

2. Tell if the following statements are true or false. In case of incorrect statements, write the correct ones.

a) A motor can work with alternating current. In this case is necessary that commutator is divided in two halves.

b) In a motor, the electromagnet moves in response to the attracting force of like poles and the repelling force of unlike poles.

c) Direct current is constantly changing the direction of flow, so a commutator divided in two halves is needed.

d) The rotation motion in a motor is due to the changing forces of attraction and repulsion forces between the electromagnet ant the permanent magnet.

3. What are the main parts in a motor?

4. In a motor, which part provides a steady magnetic field?

5. Which characteristic a commutator has to reverse the direction of current when using direct current?

6. What happen to the coil when an electric current flow through it?

7. Give five examples of devises in which motors are used.

8. In a motor,

a) Which poles attract each other?

b) Which poles repel each other?

9. What is the name of the responsible forces of the engine spinning?

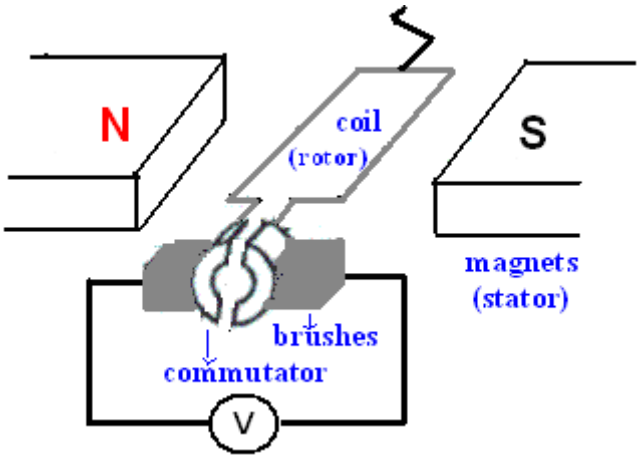
10. What happen in a direct current motor if the commutator is not divided in two halves?

11.8. The dynamo

The **Dynamo** transforms mechanical rotation into direct electric current through the use of a commutator.

A dynamo can be made and operates in a way similar to the previous motor, changing the battery by a voltmeter.

Moving the rotating coil, attached to the different halves of the single split-ring, inside the magnetic field, a direct current, DC, is generated. This current can be detected by a voltmeter.



When the coil is situated in the position of previous drawing, the voltmeter indicates zero volts because the magnetic lines of force do not pass through the coil. The maximum value of voltage is obtained after a rotation of 90º.

In the following web pages there are applets related to dynamos:

1. http://www.physclips.unsw.edu.au/jw/electricmotors.html#mandg (simulation of a direct current generator –dynamo-)

2. http://my.execpc.com/~rhoadley/magindex.htm (very interesting web about theory and experiments with magnets, electromagnets, generators, etc.)

3. http://micro.magnet.fsu.edu/electromag/java/generator/dc.html (simulation of a direct current generator. Frequency of the current can be changed translating a slider back and forth. Observe that the voltage amplitude increases with frequency)

4. http://www.walter-fendt.de/ph11e/generator_e.htm (In this simulation of a current generator you can see what happen when a commutator is used or not)

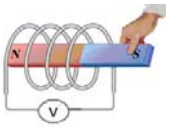
Questions

1. What happens to the voltmeter needle when the magnetic lines of force from the magnet interact with the electrical coil?

2. Tell if the following sentences are true or false. In case of a false sentence, change it to the correct one.

2.1. Electricity can be generated by moving a coil inside a magnetic field.

2.2. Electricity can be generated by moving a magnet inside a conductor coil.



2.3. In a dynamo potential energy change to magnetic energy.

2.4. Dynamos are very important in our lives because they produce electricity.

3. Look for some more applications of dynamos.

4. In the following text, underline in red the different ways of generating kinetic energy. Circle in blue the terms related to electromagnetism:

The discovery of electromagnetic induction is very important in our lives because it is the principle by which electric generators can make electricity. Through the use of magnets, a generator can convert mechanical energy to electrical energy and provide electricity that we need for so many things. Remember that energy is the ability to do work and that mechanical energy is the energy caused by moving objects. For example, when you move your legs to peddle a bicycle, you cause energy that moves the bicycle wheels and runs the bicycle. When a rushing wave of water hits a boat and turns it over, the moving water causes the energy that moves the boat to overturn it. When there is a way to turn this moving energy into electricity that can light a light bulb, we can get light in our home.

5. Which materials are necessaries to make a dynamo?

6. Match a word on the left column with their definition on the right column.

Electromagnet	Instrument for determining direction, with a magnetized needle which points to magnetic north.
Electron	Devise that transforms mechanical rotation into direct electric current through the use of a commutator
Battery	Rock with magnetic properties and attracts iron, cobalt, nickel, …
Dynamo	Property of attraction displayed by magnets to some materials.
Commutator	Subatomic negatively charged particle.
Lodestone	Magnet in which an iron or steel core is magnetized by the electric current going through the coil of insulated wire wound around it.
Magnetic poles	A cylindrical arrangement of insulated metal bars connected to the coils of a direct-current electric motor or generator, providing a unidirectional current from the generator or a reversal of current into the coils of the motor.
Magnetism	Device that generates electricity by means of chemical reactions.
Compass	Either of two regions of a magnet, designated north and south, where the magnetic field is strongest.

7. Give some examples of common items that rely on magnetism to work.

Experiments:

Experiment 1: Properties of magnets

OBJECTIVES

Test the magnetic force.

Visualize magnetic lines.

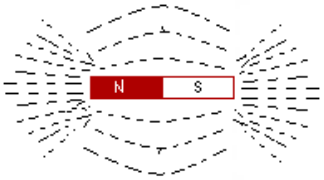
Magnetize objects.

MATERIALS

Magnets	Iron filings
Sheet of paper	Metal objects (paper clips, nails, coins, etc.)

PROCEDURE

1. Place the magnet on a table and place the sheet of paper over it.
2. Sprinkle some steel iron filing on the paper and record your observations.



3. Approach the magnet to different metal objects (argent or gold rings, copper coins, nickel coins, paper clips, nails, etc.) Record your observations.
4. Rub the previous metal objects with the magnet.
5. Repeat the procedures 1 and 2 with every object. Record your observations.

QUESTIONS

1. Look for the definition of magnetic field. Draw the magnetic field created by a magnet.
2. Tell which materials you have tested are magnetic or not and explain the differences between them.
3. Explain why a metal became a magnet.

Experiment 2: The magnetic pendulum

OBJECTIVES

Test how magnetic properties change with temperature.

MATERIALS

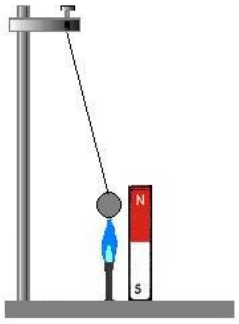
A Magnet — Nickel coin (1, 2 or 5 cent of euro)

Support — Metallic wire

Source of heat (a candle, alcohol or Bunsen burner)

PROCEDURE

1. Wrap or attach a nickel coin to a large metallic wire, leaving enough wire to suspend the coin as a pendulum.
2. Place a magnet close enough to the pendulum (without touching the coin), so that the coin moves and sticks to the magnet.
3. Place the source of heat under the coin, the flame just touch the coin. Record your observations for about 15 minutes.



QUESTIONS

1. Look for the definition of Curie temperature.
2. What is the Curie temperature of nickel?
3. Reorder the following sentences related to this experiment:

Once it is a little cool, it regains its ability to stick to the magnet. The flame heat up the coin until it loses its magnetic properties. The coin cool down a little bit once it is away from the flame. The magnet attracts the coin again into the flame, and the whole process repeats. Gravity pulls the pendulum away from the magnet.

4. What happen if you use coins of 10, 20 or 50 cent of euro instead of the previous ones? Why?

Note: a rare earth magnet will work a little better because it loses its magnetic properties at a lower temperature.

Experiment 3: Building a DC motor

OBJECTIVES

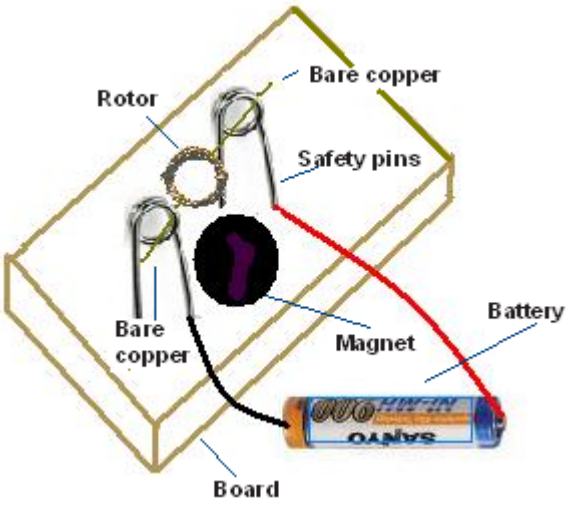
Know some applications of electromagnetism.

MATERIALS

A ceramic disc magnet	Battery
Isolated copper wire	2 paper clips o safety pins
Tape	Board

PROCEDURE

1. Wind the copper isolated wire around a round battery or something with a round shape, about 20 coils, leaving 3 or 4 cm of bare wire at both ends. Now you have made the rotor.
2. Stick the safety pins (or the paper clips, given then an adequate shape to hold the ends of the rotor) to the board.
3. Place the ceramic magnet in the middle of the board, between the safety pins.
4. Place the rotor in the safety pin supports.
5. With a copper wire, connect one of the safety pins to one pole of the battery.
6. To start the DC motor, connect the other safety pin to the other end of battery.



QUESTIONS

1. What makes the motor run?
2. How can you make the motor spin faster or slower?
3. Fill in the blanks: Motors are devices that convert _____ energy into _____ energy.

4. Choose the right answers: a motor might *increase* the speed at which it spins?
   a. Increasing the number of magnets.
   b. Decreasing the number of batteries.
   c. Increasing the number of loops of rotor.
   d. Using iron instead of copper to make the rotor.

5. Give five examples of devises that need a motor to work.

Web pages related to motors:

1. http://www.sciencebuddies.org/mentoring/project_ideas/Elec_p009.shtml

2. www.flinnsci.com

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Experiment 4: Building an electromagnet

OBJECTIVES

Know the relationship between electricity and magnetism.

MATERIALS

A long nail	4,5 V and 9 V batteries
Isolated copper wire	Iron filings or paper clips

PROCEDURE

1. Wind the copper isolated wire around a long nail.
2. Connect one end of the copper wire to one pole of the 4,5 V battery.
3. To make the electromagnet work, connect the other end of copper wire to the other pole of battery.

4. Put some iron filings close to the nail. Record your observations.

QUESTIONS

1. What makes the electromagnet work?
2. Change the battery for another 9 V battery. Is more or less quantity of iron filing attracted? Why?
3. Remove the nail. Is more or less quantity of iron filing attracted? Why?
4. Choose the right answer: an electromagnet might *increase* their strength
   - **a.** Decreasing the voltage of battery.
   - **b.** Increasing the number of loops of wire.
   - **c.** Using iron instead of copper wire.

5. What electromagnets are used for? Give two examples.

STUDENT SELF-EVALUATION CHECKLIST (WHAT STUDENTS HAVE LEARNT)

1.- When you know the meaning of the following words, tick the box:

- Magnet ☐
- Magnetization ☐
- Magnetic poles ☐
- Ferromagnetic substances ☐
- Paramagnetic substances ☐
- Diamagnetic substances ☐
- Compass ☐
- Electromagnet ☐
- Electric engine ☐
- Dynamo ☐

2.- Tick the one you think is your answer:

	I know very well	**I need some revision**	**I need some more help**
I know that magnetism is the property of attraction displayed by magnets on other materials.			
I know that the main materials that exhibit magnetic properties are nickel, iron, cobalt, some rare earth elements and their alloys.			
I know that magnetic poles are either of two regions of a magnet where the magnetic field is strongest.			
I know that unlike poles are attracted from one another and like poles are repelled.			
I understand the concept of magnetization and how a ferromagnetic substance can be magnetized.			
I understand the concept of magnetic field.			
I know how a compass is made and what is used for.			
I know the composition and properties of magnetite.			
I known the difference between ferromagnetic, paramagnetic and diamagnetic substances.			
I know that a ferrofluid is a colloidal mixture that contains nanoscale particles of magnetic solid.			
I know what the Curie temperature is.			
I know that a magnetic domain is like a small region of material in which the magnetic fields of atoms are aligned.			

I know that an electromagnet is a magnet consisting essentially of a coil of insulated wire wrapped around a soft iron core that is magnetized only when current flows through the wire.			
I understand how an electromagnet works.			
I know that electromagnets are temporary magnets because only work when the electric current flows through them.			
I understand how an electric engine works.			
I know that an electric engine transforms the electrical energy into mechanical energy.			
I understand how a dynamo works.			
I know that a dynamo transforms mechanical rotation into direct electric current through the use of a commutator.			

3.- What ideas or parts of this unit do you think are:

- More interesting.
- More difficult.
- Boring
- Not enough explained.
- Best learned.
- Not enough worked.

4.- Tell the tasks you have done the best.

5.- Tell the tasks you have done incorrectly.

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