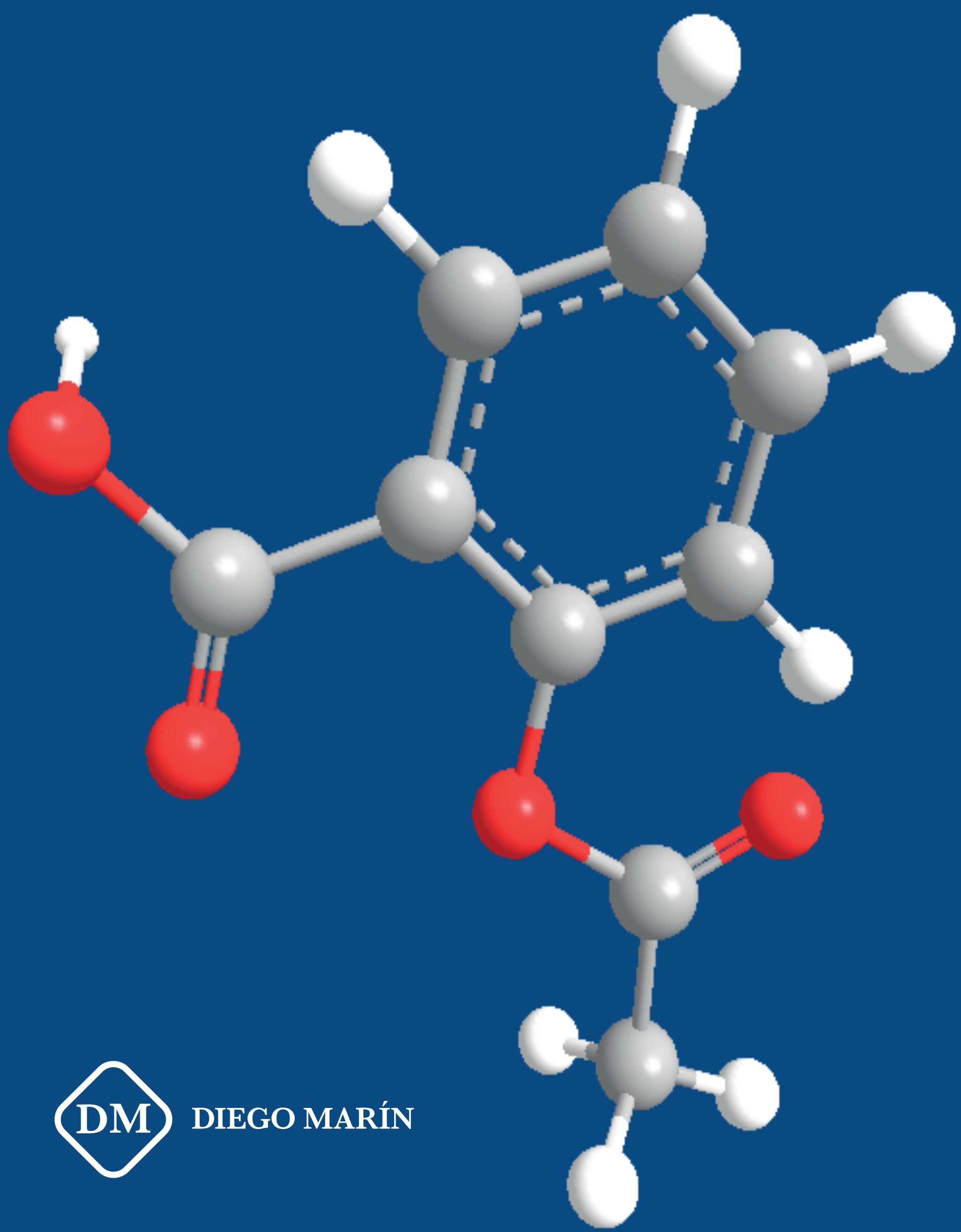
Physics and Chemistry



2 ESO

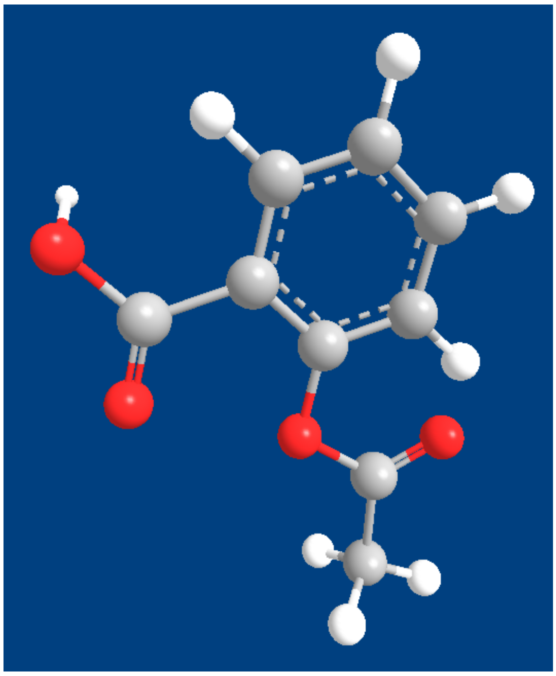
E. Aller González

DM DIEGO MARÍN

I dedicate this book to my family who have provided support and understanding through the years and to the students for whom this book was written.

Physics and Chemistry

2nd ESO



First Edition

Physics and Chemistry

2^{nd} ESO

For Bilingual Program

Enrique Aller González

Primera edición, 2021

ISBN: 978-84-18581-86-1

Edición a cargo de: Diego Marín Librero-Editor
Merced, 25. 30001 - Murcia
Tfnos. 968 24 28 29 / 968 23 75 78

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Preface

Physics and Chemistry 2nd ESO is a textbook designed for the English Bilingual Program of the Physics and Chemistry subject studied in the 2nd ESO course. It is written for a one-year course in introductory Physics and Chemistry. This textbook is based on the contents included in the curriculum of the current Organic Law on Education (LOMCE).

Its main objective is to introduce the student to the two sciences of Physics and Chemistry and to provide the student with a clear and logical presentation of their basic concepts and principles. The writing of the textbook is detailed, informative and very structured to make easy for the student to follow along. The language is clear and concise, straight to the point. It includes worked examples followed by practice activities so students can assess their mastery of the concepts. Lab activities and interactive simulations are also proposed in all the units where students learn through exploration and discovery. At the end of each unit there is an English Vocabulary activity with a selection of the most representative words to encourage the student to improve their knowledge of the English language.

Although in English language is used the dot as the decimal marker, the comma is commonly used in the Spanish language and it was accepted in the 22nd International Bureau of Weights and Measures in 2003. Numbers are divided in groups of three in order to facilitate reading; neither dots nor commas are ever inserted in the spaces between groups. In some cases, the symbols of some physical quantities are presented in the English manner and in the Spanish manner.

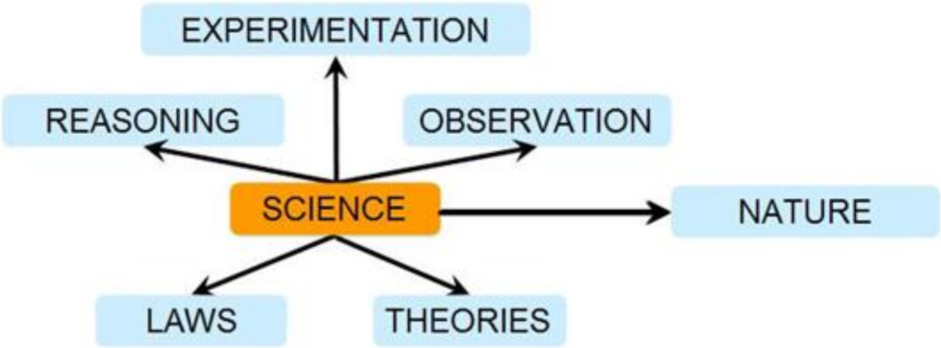
Unit 1: Science and the scientific method

1. What is science?

1.1. Science and natural sciences

In this unit you will learn how scientists work, make new discoveries and explain unknown phenomena of nature. All this knowledge is what we call Science.

Science is the systematic knowledge of the world gained through **observation**, **reasoning** and **experimentation**, and the formulation of **laws** and **theories**.



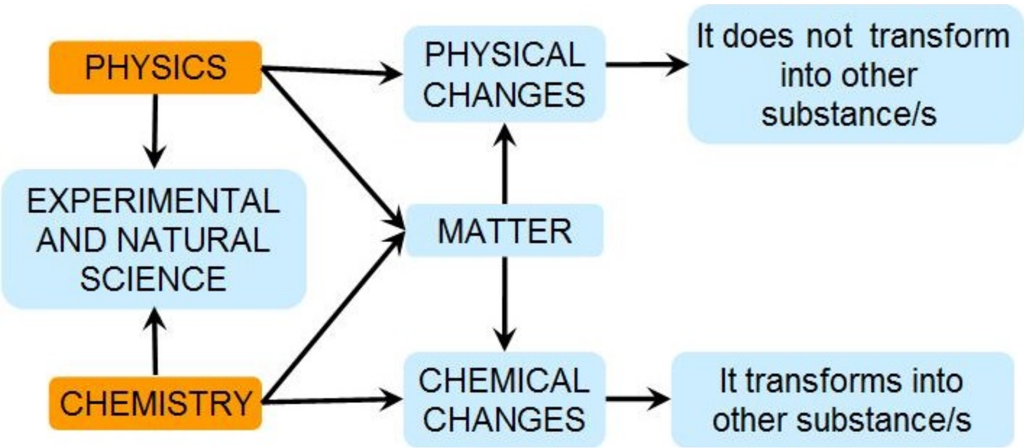
However, **Science** has **different branches** depending on what is being studied. We can divide Science into **two major groups**:

a) Natural Sciences, which study natural phenomena including biological life.

b) Social Sciences, which study human behaviour and societies.

Natural Sciences are **empirical sciences** that are based on observable natural phenomena and capable of being tested for their validity with experiments made by other researchers working under the same conditions.

Natural Sciences include **Physics**, **Chemistry**, **Biology** and **Geology**. In this subject we will learn what **Physics** and **Chemistry** study.



Physics is an **experimental** and **natural science** that studies the **composition** of **matter**, its **general properties** and its **physical changes**. A **physical change** of matter is a change that undergoes a substance, a body or an object without transformation into other substance/s, its chemical composition does not change.

Examples of physical changes are: changes in position, in volume, in form, in temperature or state, mixtures, electrical phenomena…

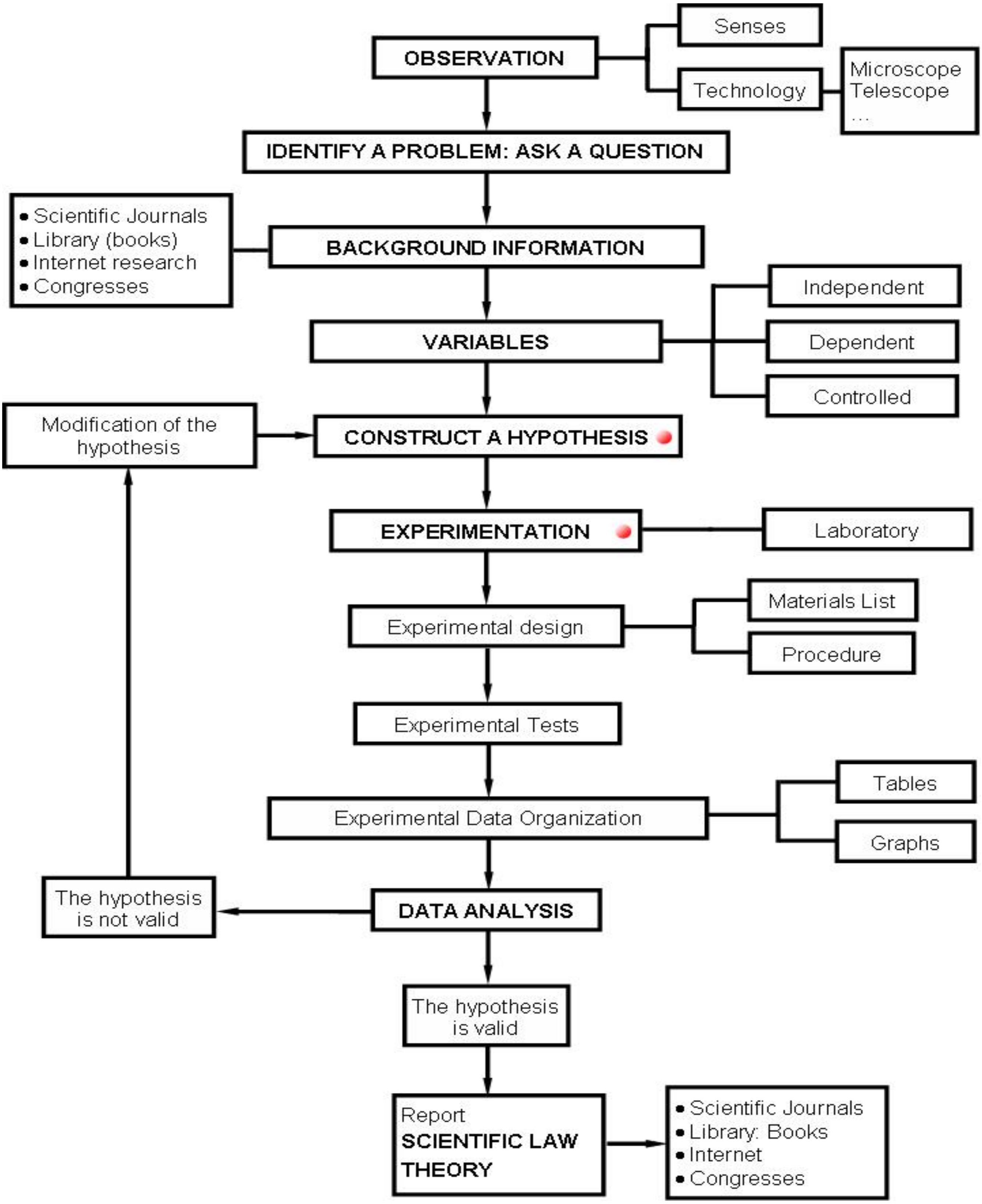
Chemistry is an **experimental** and **natural science** that studies the **composition**, the **structure** and the **properties** of **matter** and its **chemical changes**. A **chemical change** of matter is a change that undergoes a substance, a body or an object with transformation into other substance/s, its chemical composition changes.

Examples of chemical changes are: iron oxidation, fruit ripening, cooking, digestion, respiration...

1.2. The scientific method

Physics and **Chemistry** are two natural sciences, which study **matter** and its **properties**. The method that these two sciences use to understand matter and its changes is the **scientific method**. Therefore, scientists use the scientific method to know everything about Nature. However, the scientific method is not only used by scientists. Any worker, a doctor, a police officer or a technician, use this method to solve their unknown problems.

The **scientific method** is a sequence of steps that the scientist follows to solve a problem in scientific research.



The scientific method diagram.

a) The first step is the **observation**. Scientists observe nature through their senses. Scientific observation consists of receiving knowledge of the outside world through our senses. However, our senses have limits. We cannot see a distant object, or a very small object. We need to use technological instruments to obtain information from nature. We use telescopes to see distant objects. We can see small objects with the microscope. While human beings cannot detect radiations using their natural senses, many technologies exist that help detect and identify radiations, wherever they may be, such as the use of radio telescopes.

Scientists use technological instruments to observe Nature.

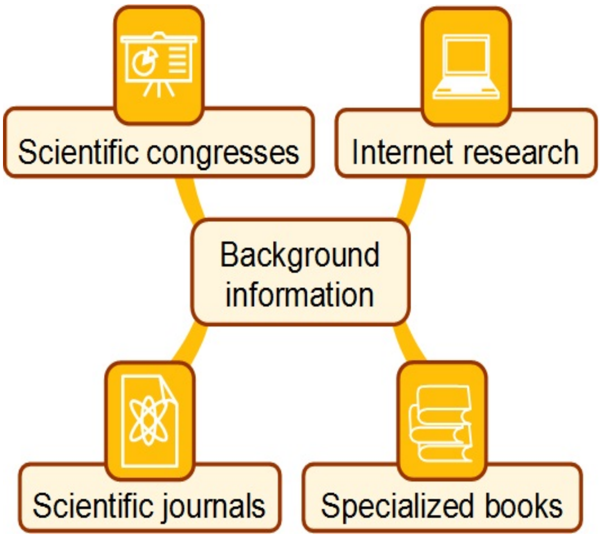
Observation is a step of the scientific method that consists of receiving information or knowledge of natural phenomena of the outside world through the senses and recording of data using scientific instruments.

b) The second step is to **identify the problem** and **to make the right question**. When a scientist watches nature with her instruments she sometimes finds unknown or unexplained phenomena. Scientists must make the right question to identify clearly the unsolved problem. If I want to study plant growth, it is a complex problem because there are multiple factors that can affect it: the amount of water, oxygen, carbon dioxide, light… A scientist cannot study all the variables that affect plant growth at the same time. Even plant growth is another variable. We must reduce the number of studied variables to two variables. So the right question is not, what affects plant growth? The right question would be: Does the amount of water affect plant growth? We only choose one factor that can affect plant growth. In the question there can only be **two variables**, the amount of water and the plant growth.

Identify the problem is the step of the scientific method in which the scientist identifies the unsolved problem.

c) The third step is to obtain the **background information**. To answer the question a scientist must obtain information about her/his problem, which can be found in **scientific journals**, **specialized books**, in **scientific congresses** or by an **Internet research**.

Background information is the knowledge that a scientist acquires through the research in scientific journals, Internet or books on the topic of the problem. Scientific inventions and discoveries must be published to be known by the rest of the scientific community.



Sources of the background information.

d) The **fourth step** is **to define the variables of the problem**. With this background information we have to identify the variables of the problem. For example, if we are studying plant growth our problem can be the following one: Does the amount of water affect plant growth? There are two variables written in the question: the amount of water (the volume of water) and plant growth, which can be measured with the length of the trunk or its diameter, or the number of new leaves or new branches. Of course, there are other variables that affect plant growth: the amount of sunlight, oxygen, carbon dioxide... However, we want to find the relationship between the amount of water and plant growth.

A **variable** is a quantitative property of an object that can take on different values (length, speed, density, volume…).

Now, we must define the variables of our problem:

The **independent variable** is the variable that a scientist deliberately changes during the experiment.

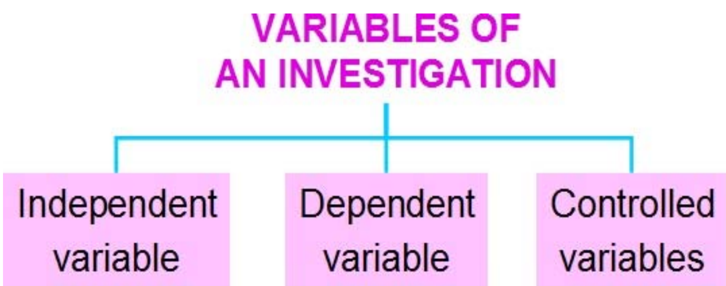
In our example is the amount of water.

The **dependent variable** is the variable that responds to the changes in the independent variable.

In our case, the dependent variable is plant growth.

The rest of the variables must be **controlled**, although these variables are changing in nature. However, we must control them to concentrate our study on the amount of water and the growth of the plant.

Controlled variables are variables that must be controlled; they do not change, during the experiment.



Variables of an investigation are classified into independent variable, dependent variable and controlled variables.

e) The **next step** is **to formulate a hypothesis**. With the background information we can make a prediction and answer the question. For example, the amount of water affects plant growth, without water plants die. However, this is a possible answer and it must be tested.

We call **hypothesis** an educated guess, a prediction that must be tested with an experiment. It is a tentative statement that proposes a possible explanation to some phenomenon or event.

f) **Experimentation**. Our hypothesis must be tested with an experiment. The experiment must be designed, indicating the procedure and a list of materials to make it. Then, the experiment or experiments are made and numerical data are recorded.

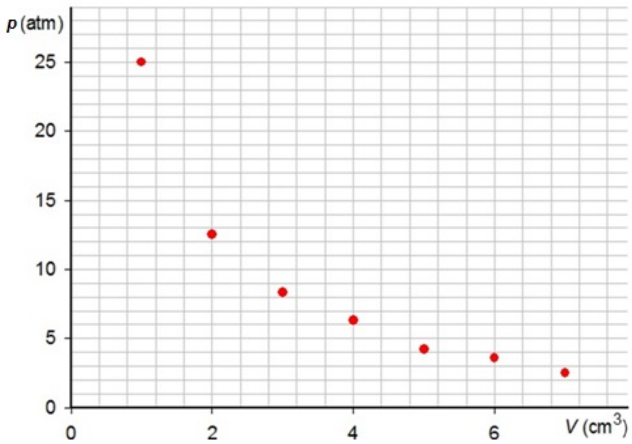
Experimentation is the step of the scientific method that involves carrying out experiments under controlled conditions to make observations and collect data to test a hypothesis. You must **design the experiment** before, indicating the **materials** and the **procedure** in steps and include as much detail as possible about measurements and techniques in each step.

Experimentation is made in labs under controlled conditions.

The numerical data of an experiment should be organized into **tables** and represented in **graphs**. Graphs represent data visually and it is much easier their analysis to test our hypothesis.

The Boyle's Law. Variation of pressure and volume of an enclosed gas at constant temperature

p **(atm)**	***V*** **(cm^3)**
2,5	7
3,6	6
4,2	5
6,3	4
8,3	3
12,5	2
25	1



Scientists can more easily interpret what they have observed in their experiments if they organize their results in data tables and graphs.

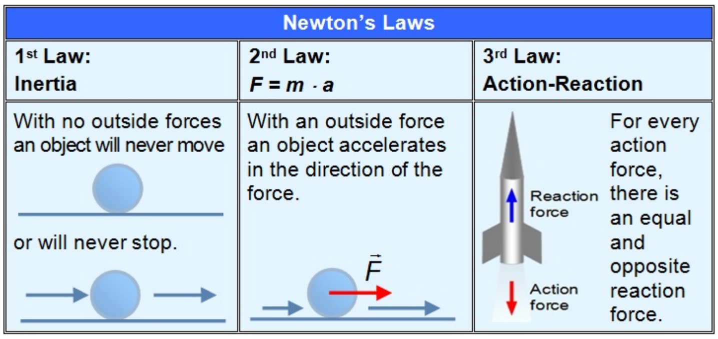
Experimental data organization: the experimental data must be organized in **tables** and **graphs** for analysis and interpretation.

g) In the following step, **data analysis**, we will test if our hypothesis is correct or is not valid. If the hypothesis is not valid, our work has not finished. A new hypothesis should be proposed or formulated according to the new knowledge. If the hypothesis is valid, then we should write a report with our conclusions.

Data analysis is the analysis of the data to look for patterns to know if there is a relationship between the independent variable and the dependent variable of the experiment.

h) **Laws** and **theories**. In science, once a hypothesis has been widely accepted, it is called a **scientific law**.

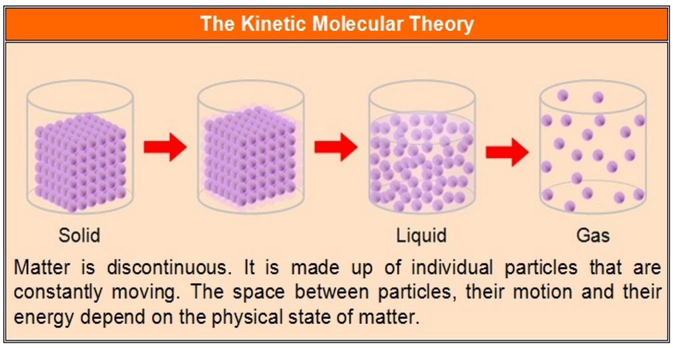
Scientific law is a concise verbal or mathematical statement which describes a relationship between the variables of a determined natural phenomenon (e.g. Newton's second law, $F = m \cdot a$).



The Newton's Laws of motion are essential to understand motion in our universe.

Theories are general explanations based on a large amount of data. For example, *the Darwin's theory of evolution* applies to all living things and is based on a wide range of observations.

Theory is an explanation of a set of observations and scientific laws of an entire group of related phenomena of nature. It explains how they work, what causes them, and how they behave. It allows us to predict unknown situations related to the theory and to anticipate yet unknown phenomena (e.g. the *kinetic molecular theory of matter* or the *Einstein's General Theory of Relativity*).



The kinetic molecular theory is one of the most important and useful theories in science. It helps us to understand matter and its properties.

1.3. Science, technology and society

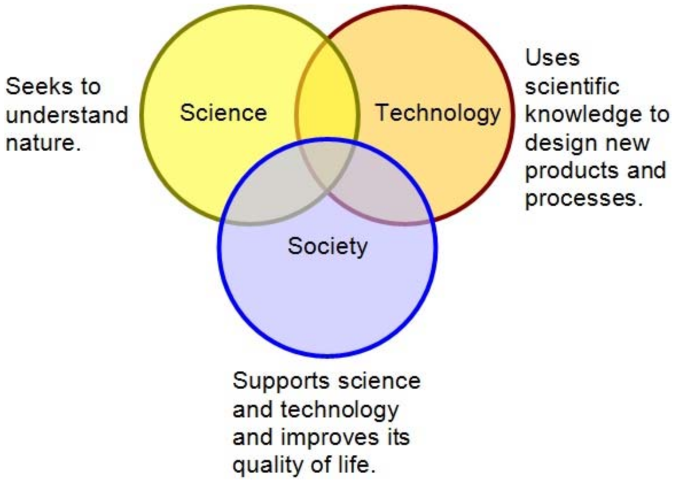
Science and **Technology** are not the same but are closely related in today's **Society**.

Technology dates back to antiquity, when artisans used tools and different processes to modify the materials of nature to satisfy their needs without the comprehension of the scientific knowledge of those processes.

Science began to evolve in the 17th century, but it was not only until the 19th century that humans began to apply science to technology. Since then, scientists, inventors and businessmen have worked together applying the new scientific discoveries to the development of new products and new technological processes for humanity: automobiles, computers, the Internet, new medical techniques, different electronic devices, drugs…

In addition, financial investment in science and technology is essential for the economic development and the social progress of a society. Therefore, governments of countries should make policies to support innovation in scientific and technological research and step up their financial investment. These investments must be accepted by their societies because the new scientific and technological developments affect society.

In conclusion, **science**, **technology** and **society** are not alone, they are interconnected.



Activities

1. Answer the following questions: a) What is Science? b) What do Natural Sciences study? c) What is Physics? d) What is a physical change? e) What is Chemistry? f) What is a chemical change?
2. Write the steps of the scientific method.
3. Answer the following questions: a) What is the independent variable of an experiment? b) What is the dependent variable of an experiment? c) What is a hypothesis? d) What is a scientific law?
4. Imagine that you have a lantern and it does not work. Formulate a hypothesis and design an experiment to test it.
5. A student is investigating how the temperature of water affects how much salt can be dissolved.

   a) Suggest a question that she could answer by doing and investigation.

   b) Classify the variables of this problem.

   c) Propose a hypothesis, a possible explanation for this investigation.

   d) Design an experiment to test your hypothesis with a procedure, a list of materials and the measuring instruments that you will use to make the experiment.
6. A group of students are investigating if the mass of an object affects the time of its free fall from a height to the Earth's surface.

   a) Suggest a question that they could answer by doing an investigation.

   b) Classify the variables of this problem.

   c) Propose a hypothesis, a possible explanation for this investigation.

   d) Design an experiment to test your hypothesis with a procedure, a list of materials and the measuring instruments that you will use to make the experiment.
7. Use the ICTs. Find information on the web about a relevant invention in history that shows the relationship between science, technology and society. Create a presentation with 8-10 slides.

2. Quantities and units

2.1. Physical quantities and their units

The goal of science is to provide an understanding of the physical world by developing theories based on experiments. The basic laws of physics and chemistry involve the measurement of properties of matter of all observed phenomena.

A **physical quantity** is a property of a phenomenon, body or substance that can be quantified or measured. Examples of quantities are mass, volume, temperature, speed…

A **quality** is a property of a phenomenon, body or substance that cannot be quantified. Examples of qualities are colour, shape, roughness, toughness…

A **unit** is a definite magnitude of a particular physical quantity, defined and adopted by convention, with which other particular physical quantities of the same kind are compared to express their value.

Measuring a physical quantity is to compare it with a chosen value of that physical quantity, a unit, to express its value with a number followed by the chosen unit.

For example, when we measure a quantity, we always compare it with some reference standard. When we say that a rope is 30 metres long, we mean that it is 30 times as long as a metre stick, which we define to be 1 metre long.

The **result of a measurement** includes a **number** and the chosen **unit** for the measurement. The value of a physical quantity is generally expressed as the product of a number and a unit.

All physical quantities can be classified into two types: **base quantities** and **derived quantities**.

Base quantities are physical quantities that are common to every object or phenomenon and are **independent**; they do not depend on others. There are seven base quantities used in **The International System of Units (SI)**. Each base quantity has its own **SI base unit**. The symbols used for the base quantities and their base units are:

Base quantities and their SI base units			
Quantity	**Symbol**	**Unit**	**Symbol**
Length	l, x, r, …	metre	m
Mass	m	kilogram	kg
Time	t	second	s
Intensity of electric current	I, i	ampere	A
Temperature	T	kelvin	K
Amount of substance	n	mole	mol
Luminous intensity	I_v	candela	cd

Base units can be too large or too small for some measurements, so the base units may be modified by attaching **prefixes**, which are decimal multiples and submultiples, and we obtain **secondary units**. These prefixes are given the name of **SI prefixes**. The prefix names and symbols are listed below:

SI prefixes		
Factor	**Prefix Name**	**Symbol**
1 000 000	mega	M
1 000	kilo	k
100	hecto	h
10	deca	da
0,1	deci	d
0,01	centi	c
0,001	mili	m
0,000 001	micro	μ

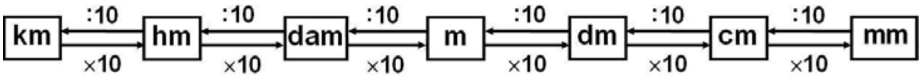
Secondary units are decimal multiples or submultiples of the base units based on the SI prefixes.

Examples

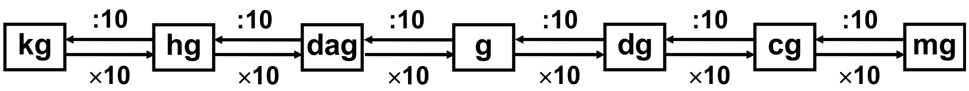
- Decimetre: 1 dm = 0,1 m.
- Centimetre: 1 cm = 0,01 m.
- Hectometre: 1 hm = 100 m.

The most common units for the base quantities **length**, **mass** and **time** are listed below:

- **Length units:**



- **Mass units:**



- **Time units:**

Name	Symbol	Value (SI Unit)
second	s	
minute	min	1 min = 60 s

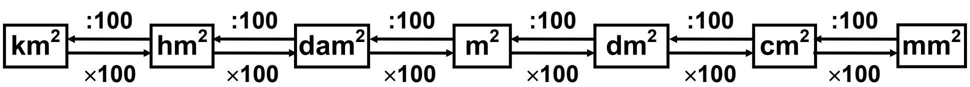
Name	Symbol	Value (SI Unit)
hour	h	1 h = 60 min = 3 600 s
day	d	1 d = 24 h = 86 400 s

All other physical quantities different from base quantities are known as **derived quantities,** physical quantities that derive from the base quantities by equations. Examples of derived quantities are: area, volume, capacity, density, speed, force, pressure...

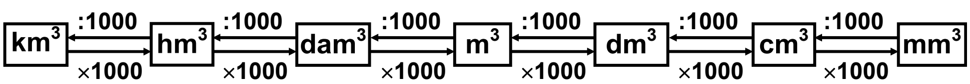
Derived quantities are physical quantities that derive from the base quantities (volume, area, density, speed, force, pressure...).

The most common units for the derived quantities **area**, **volume** and **capacity** are listed below:

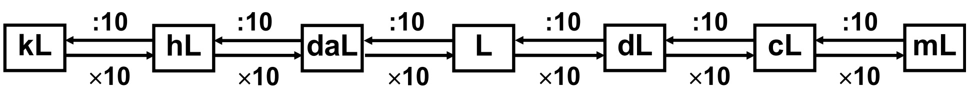
- **Area units.** Area is a physical quantity that measures the extent of a two-dimensional surface.



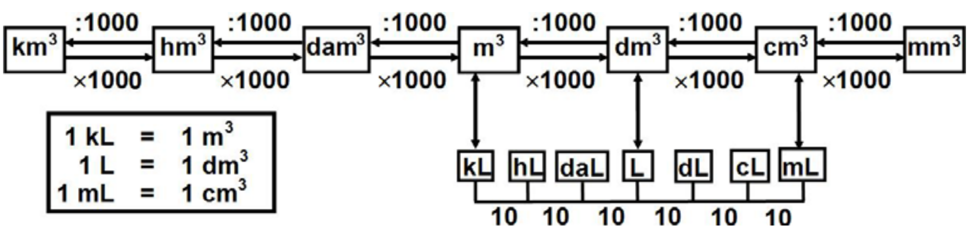
- **Volume units.** Volume measures the amount of three-dimensional space an object occupies.



- **Capacity units.** Capacity measures the amount of substance, liquid or gas, which a container can hold.



- **Conversion between volume units and capacity units:**



Activities

8. What is a physical quantity? Give five examples.

9. What is a unit?

10. What is a quality? Give five examples.

11. What is a base quantity? Give three examples.

12. What is a derived quantity? Give three examples.

2.2. Unit conversions

Units are multiplied and divided just like ordinary algebraic symbols. We can express the same physical quantity in two different units and form an equality. For example, when we say that 1 m = 100 cm we do not mean that the number 1 is equal to the number 100, but rather that 1 m represents the same physical length interval as 100 cm. To find the number on centimetres of 25 m, we write:

$$25\ \text{m} = (25\ \cancel{\text{m}}) \cdot \left(\frac{100\ \text{cm}}{1\ \cancel{\text{m}}}\right) = 2\,500\ \text{cm}$$

A **conversion factor** is a ratio of units that represents a physical quantity expressed in some unit or units divided by its equal expressed in some different unit or units, such as 1 m/100 cm (or 1 m = 100 cm). The units of the physical quantity and the conversion factor must be combined properly to give the desired final units.

The unit conversion method

1. Write the physical quantity you want to change its unit.	2 000 mL
2. Write the equality between the old unit and the new unit. Remember the table of prefixes.	1L = 1 000 mL
3. Write the conversion factor as a fraction or ratio with the two units properly combined to give the desired final unit. The old units must be dividing each other.	$(2\,000\ \text{mL}) \cdot \left(\frac{1\text{L}}{1000\ \text{mL}}\right)$
4. Multiply the physical quantity by the conversion factor, cancel the old units and express the final result.	$(2\,000\ \cancel{\text{mL}}) \cdot \left(\frac{1\ \text{L}}{1\,000\ \cancel{\text{mL}}}\right) = 2\ \text{L}$

The unit conversion method can also be used to convert units of derived quantities, which are composed of two different units. In this case, you must use a conversion factor for each unit.

Examples

1. Convert 0,05 hL to mm^3.

$$0{,}05\ \cancel{\text{hL}} \cdot \left(\frac{100\,000\ \cancel{\text{mL}}}{1\ \cancel{\text{hL}}}\right) \cdot \left(\frac{1\ \cancel{\text{cm}^3}}{1\ \cancel{\text{mL}}}\right) \cdot \left(\frac{1000\ \text{mm}^3}{1\ \cancel{\text{cm}^3}}\right) = 5\,000\,000\ \text{mm}^3$$

2. The maximum speed limit on motorways in Spain is 120 km/h. Express this speed in m/s.

$$120\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \cdot \left(\frac{1000\ \text{m}}{1\ \cancel{\text{km}}}\right) \cdot \left(\frac{1\ \cancel{\text{h}}}{3\,600\ \text{s}}\right) = 33{,}33\ \frac{\text{m}}{\text{s}}$$

Activities

13. Convert the following units and indicate their corresponding quantity.

a) 7,2 mm to dam	**b)** 5,2 m^2 to mm^2	**c)** 3,5 m to cm	**d)** 20,456 hL to dL
e) 0,000 2 kg to mg	**f)** 0,004 5 mm^2 to hm^2	**g)** 0,2 m^3 to cm^3	**h)** 3 m^3 to dm^3
i) 4 300 cm^3 to L	**j)** 3 dm^3 to dL	**k)** 0,000 3 cm^3 to daL	**l)** 3 820 s to h
m) 2,3 mL to m^3	**n)** 0,2 cm^3 to mL	**o)** 1 day to s	**p)** 2,34 L to dm^3
q) 0,001 2 hL to dm^3	**r)** 40,56 g to hg	**s)** 1,000 3 mm^3 to L	**t)** 220 kL to m^3

14. Express in metres the result of the following operation: 0,30 km + 3,6 hm + 23,45 m + 284 cm.

15. How many mL are there in 1/3 L?

16. How many g are there in 1/4 kg?

17. Convert the following units and indicate their corresponding quantity.

a) 55 m to cm	**b)** 4,67 m^2 to mm^2	**c)** 2 mL to cm^3	**d)** 1 t to kg
e) 20 m^3 to dm^3	**f)** 2 mm^2 to dm^2	**g)** 200 mL to m^3	**h)** 120,03 dam^3 to mm^3
i) 2 mm to m	**j)** 3 000 mg to kg	**k)** 180 s to min	**l)** 200 L to mm^3
m) 7 m to mm	**n)** 3 hours to s	**o)** 2 000 g to kg	**p)** 200 kg to g
q) 2 days to s	**r)** 1 h to s	**s)** 200 g to mg	**t)** 200 hL to km^3

3. Measurement and error

3.1. Measuring instruments

A **measuring instrument** is a device for measuring a physical quantity.

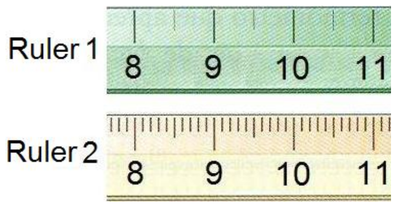
We use different measuring instruments depending on the physical quantity and the amount we are going to measure (a balance for measuring masses, a ruler for measuring lengths, a watch for measuring time …).

A measuring instrument has a set of characteristics:

1. **The measuring range** is the range of values that the instrument can measure.

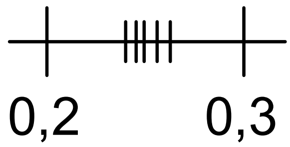
2. The **sensitivity** or **resolution** of a measurement instrument is the smallest amount of a physical quantity that the instrument can detect.

   For example, ruler 1 has a sensitivity of 0,5 cm, and ruler 2 has a sensitivity of 1 mm (0,1 cm).



3. The **precision** or **reproducibility** of a measurement instrument is the degree to which repeated measurements of the same physical quantity under unchanged conditions show the same results.

   The instrument on the right is precise because all measurements are grouped tightly together in a very small range, between 0,2 and 0,3.



4. The **accuracy** of a measuring instrument is the degree of closeness of the measurements of a determined quantity to that quantity's true value.

3.2. Measurement

Measurement of any physical quantity involves two parameters: the **value** of the measurement and the **chosen unit** of measurement. For example, if we have to measure the height of a wall the result of this measurement can be 2,50 metres, where 2,50 is the value of the measurement and metres is the chosen unit of measurement.

Measurements can be classified into two types: direct measurements and indirect measurements.

a) A **direct measurement** is the determination of the value of a physical quantity with a measurement instrument.

   For example, the measurement of the mass of a substance with a balance.

b) An **indirect measurement** is the determination of the value of a physical quantity by calculation.

   For example, the determination of the density of a solid substance requires the measurement of its mass and its volume, followed by a calculation.

3.3. Errors

All measurements are approximate values, not true values.

An **error** is a comparison between the measured value and the true value of a measurement.

Errors can be classified into two types:

a) **Systematic or determined errors**, errors that produce a result that differs from the true value by a fixed amount. They can be identified and corrected. These errors result from **biases** introduced by:

   1. **Instrumental bias**. For example, errors in the calibration of the measuring instruments.
   2. **Human bias**. For example, the person who is measuring might read an instrument incorrectly or might let knowledge of the expected value of a result influence the measurement.
   3. **Method bias**. For example, the person might make an incorrect scale reading because of parallax error.
   4. **Operative bias**. For example, the person knows the measurement method but might make it wrong.

b) **Random errors** are caused by unknown and unpredictable changes in the measurement. These changes may occur in the measuring instruments or in the environmental conditions.

   They cannot be corrected but the can be minimized by:

1. Making **several measurements**.
2. Calculating the **arithmetic mean**.

Example

- **The mass of an object was measured several times: 2,350 g, 2,352 g, 2,348 g, 2,350 g. What is the accepted value for its mass?**

$$\text{Arithmetic mean} = \frac{2{,}350 + 2{,}352 + 2{,}348 + 2{,}350}{4} = 2{,}350 \text{ g}$$

3.4. Significant figures and rounding

Significant figures are the digits in any measurement that are known with certainty plus one digit that is estimated, and hence, is uncertain. The right-most digit is always the estimated digit.

For example, the number 5,423 cm has four significant figures. There are some **rules** for counting the significant figures in a number:

1. **Non-zero integers** always count as significant figures (452 ⇒ **3**; 2,227 ⇒ **4**).
2. **Zeros** appearing between two significant digits are significant (101,25 ⇒ **5**).
3. **Leading zeros** (zeros that precede all the non-zero digits) are not significant (0,706 ⇒ **3**; 0,000 708 0 ⇒ **4**).
4. **Trailing zeros** (zeros at the right end of the number) in a number containing a decimal marker are significant (13,430 0 ⇒ **6**; 5,030 ⇒ **4**; 0,001 343 00 ⇒ **6**; 35,0 ⇒ **3;** 35,00 ⇒ **4**).
5. In **scientific notation**, all the figures that appear before 10 are significant (1,430 · 10^5 ⇒ **4**).
6. If you perform an **arithmetic operation** (addition, subtraction, multiplication or division), the number of significant figures of the result must not exceed the lowest number of significant figures of the numbers (3,5432 + 2,531 = 6,0742 ≅ **6,074**; 2,33 · 2,4 = 5,592 ≅ **5,6**).

Examples

Measurement	No. of significant figures	Measurement	No. of significant figures
0,000 509 0 dg	4	80,0 s	3
0,0036 g	2	3,05 hm	3
7,64 cm	3	0,220 kg	3
248 m	3	42,05 km	4
64,01 kg	4	2 500 mm	4

Rounding is the process of replacing a number by another of approximately the same value but having fewer digits.

If the digit following the last digit to be retained is:

1. 5 or greater than 5 the last digit should be increased by 1.
2. Less than 5 the last digit should be stay the same.
3. It is advisable to round a number only until two decimal places.

Example

- **Round the number π to the hundredth place and to the thousandth place:**

  π = 3,141 592 6...

  To the hundredth place: π = 3,14

  To the thousandth place: π = 3,142

Activities

18. We measured with a chronometer the time of the free fall of an object from the roof of a building. We obtained the following measurements: 1,43 s; 1,45 s; 1,47 s; 1,42 s; 1,46 s; 1,43 s; 1,47 s. What is the accepted value for the time of the free fall?

19. What is the difference between saying that the mass of an object is 5 g, 5,0 g or 5,00 g?

20. Round the following decimal numbers to the hundredth place:

a) 4,234 **b)** 16,267 **c)** 0,145 0 **d)** 8,685 0

21. Lab activity. Measurements and unit conversions

1. Length, area and volume units

Lab materials

Measuring tape.

Experimental procedure

a) Measure the three lengths of your lab bench, its width, ***a***, its length, ***b***, and its thickness, ***c***.

a =	***b*** =	***c*** =

b) Change the units of the last measurements to km, m and mm. Use conversion factors.

a = km	***a*** = m	***a*** = mm
b = km	***b*** = m	***b*** = mm
c = km	***c*** = m	***c*** = mm

c) Work out the surface area of your lab bench, ***A***. Remember the shape of the surface and the equation you need for the calculation.

A =

d) Change the unit of the calculated surface area to km^2, m^2 and mm^2. Use conversion factors.

A = km^2	***A*** = m^2	***A*** = mm^2

e) Work out the volume of the board of your lab bench, ***V***. Remember the shape of its volume and the equation you need for the calculation.

V =

f) Change the unit of the calculated volume to m^3, dm^3, mm^3, L, kL and mL. Use conversion factors.

V = m^3	***V*** = dm^3	***V*** = mm^3
V = L	***V*** = kL	***V*** = mL

2. Mass units

2.1. Measurement of the mass of a solid object

Lab materials

An electronic balance and three different objects.

Experimental procedure

a) Press the ON/OFF key to turn on the balance and wait until zero is displayed in the screen. If the screen does not show zero, press the ZERO key so that it shows zero in the screen.

b) Measure the masses of three solid objects of different sizes and take note of the measurements with their corresponding units. Indicate the names of the objects.

m_A =	m_B =	m_C =

c) Change the unit of the mass of object A to kg, dag and mg. Use conversion factors.

m_A = kg	m_A = dag	m_A = mg

2.2. Measurement of the mass of a finely divided solid

Lab materials

An electronic balance, a watch glass and a spatula spoon.

Experimental procedure

a) Press the ON/OFF key to turn on the balance and wait until zero is displayed in the screen. If the screen does not show zero, press the ZERO key so that it shows zero in the screen.

b) Place a dry, clean watch glass on the balance and press the ZERO key so that it shows zero in the screen.

c) Measure the mass of 5 g of sand. Take the sand container with one hand and the spatula with the other hand over the watch glass. Add slowly and carefully the solid on the watch glass. Sand must not fall on the weighing surface.

d) Record the measurement with the right number of significant figures.

m_{sand} =

2.3. Measurement of the mass of a liquid

Lab materials

An electronic balance, a wash bottle, two 100 mL beakers and a dropper.

Experimental procedure

a) Press the ON/OFF key to turn on the balance and wait until zero is displayed in the screen. If the screen does not show zero, press the ZERO key so that it shows zero in the screen.

b) Place a dry, clean 100 mL beaker on the balance and press the ZERO key so that it shows zero in the screen.

c) Add some water in the other 100 mL beaker with the wash bottle and measure the mass of 5 g of water. To do this, take small amounts of water with the dropper and add the water slowly, without splashes, at the bottom of the beaker. Water must not fall on the weighing surface.

d) Record the measurement with the right number of significant figures.

m_{water} =

3. Measurement of the volume of a liquid

Lab materials

100 mL graduated cylinder, a wash bottle, a 100 mL beaker and a dropper.

Experimental procedure

a) Measure the volume of 100 mL of water. First, add water with the wash bottle in the graduated cylinder up to a mark close to the volume, for example, 95 mL.

b) Add some water in a 100 mL beaker, take small amounts of water with the dropper and add the water slowly, without splashes, in the graduated cylinder up to the mark of 100 mL.

c) Read the volume from the bottom of the meniscus straight on at eye level to avoid parallax errors.

d) Record the result of your measurement with the right number of significant figures in mL, L, kL, cm^3, dm^3 y m^3.

V = mL	**V** = L	**V** = kL
V = cm^3	**V** = dm^3	**V** = m^3

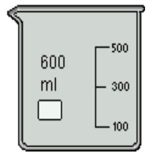
4. Laboratory equipment and safety rules

4.1. Laboratory equipment

The laboratory is the place where scientists make their designed experiments to test their hypothesis. In the lab, you have the basic lab equipment needed to make your experiments of Physics and Chemistry. The lab equipment can be classified into different groups based on their functions:

1. **Function**: **glassware used to contain liquids and solutions and to make solutions**. They can be heated.

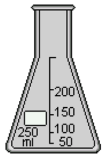
   a) **Name**: **beaker.**

   It is used for mixing liquids or liquids and solids and gentle heating. The graduations are approximate and not intended for accurate volume measurements of liquids.

   They are available in different sizes.

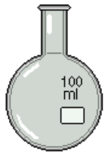
   b) **Name**: **Erlenmeyer flask.**

   It is used for mixing and gentle heating solutions that may release gases or that are likely to splatter if stirred or heated.

   Erlenmeyer flasks are available in a variety of sizes.

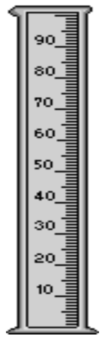
   c) **Name**: **round bottom flask.**

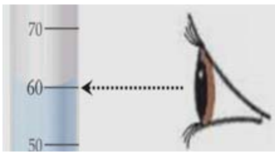
   It is shaped like a tube emerging from the top of a sphere. It is used for heating solutions and for making chemical reactions. The round bottom provides uniform heating of the mixture.

2. **Function**: **glassware used to measure volumes of liquids**.

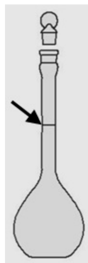
   a) **Name**: **graduated cylinder.**

   It is used to measure volumes of liquids. It has etched marks to indicate volumes and a pouring lip. Read the volume from the bottom of the **meniscus**. The meniscus is the curved surface of a liquid in a narrow cylindrical container. Try to avoid **parallax errors**. Parallax errors arise when a meniscus is viewed from an angle rather than straight on at eye level. Read always the graduation below the meniscus.

   b) **Name**: **volumetric flask.**

   It is used to make up a solution of a fixed volume very accurately. Volumetric flasks are calibrated at only a specific volume indicated by the mark on their neck. They are of various sizes.

   To prepare a solution, first dissolve the solid material completely in a beaker, in less solvent than required to fill the volumetric flask to the mark. This concentrated solution is poured into the flask and it is filled to the mark with more solvent. Beware of parallax error when you measure a volume with this volumetric flask.

   c) **Name**: **graduated pipette.**

   It is a laboratory instrument used to measure and deliver exact and small volumes of liquids. It is usually a narrow glass tube that has different graduations to measure different volumes having 0 point at the top. They can be of various sizes like, 1 mL, 2 mL, 5 mL, 10 mL or 20 mL. The graduated pipette is shown in the left picture.

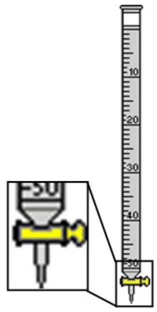
   d) **Name: volumetric pipette.**

   It is a long narrow tube with a bulb in the middle. It measures a fixed volume of a liquid very accurately with a single calibration mark at the top. The volumetric pipette is shown in the right picture.

   Both pipettes need a pipette dispenser, bulb filler, or a pipette pump to handle the liquids inside a pipette.

   Beware of parallax error when you measure a volume with a pipette.

e) Name: **buret or burette.**



It is a long glass tube open at both ends, that is used to measure out precise volumes of liquids. It is filled from the top and it is graduated to measure different volumes. It has the 0 mL mark at the top.

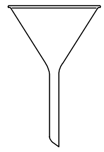
Liquid is dispensed from a buret at the desirable rate through a glass stopcock at the lower end of the glass tube.

Beware of parallax error when you measure a volume with a buret.

It is used for titrations, a common laboratory method of quantitative chemical analysis.

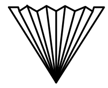
3. Function: **glassware used for filtration**.

a) Name: **funnel.**



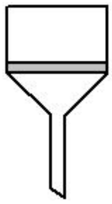
It is a glass tool used to aid in the transfer of a liquid from one container to another with a small opening. It is also used to do filtrations, a common laboratory method to separate an insoluble solid from a liquid.

b) Name: **filter paper.**



It is a special paper to do filtrations to separate insoluble solids from liquids. It has tiny pores, which allow the small liquid molecules to pass easily, while not allowing the solid to pass through.

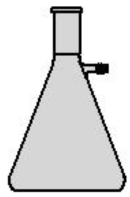
c) Name: **Büchner funnel.**



It was designed by the German chemist Ernst Büchner in the 19^{th} century. It is used in filtration by vacuum suction. The filtration proceeds much more quickly.

It is made of porcelain or glass. On top of the funnel-shaped part there is a cylinder with a perforated plate separating it from the funnel. The flat bottom of the funnel must be covered with an unfolded piece of circular filter paper.

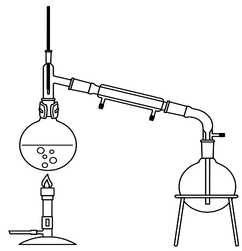
d) Name: **Kitasato flask.**



It is known as Kitasato flask, in honour of Kitasato Shibasaburō. It is a thick-walled Erlenmeyer flask with a short glass tube in which a hose can be adapted. The other end of the hose can be connected to a vacuum pump. It is primarily used together with a Büchner funnel fitted through a drilled rubber bung or an elastomer adapter at the neck on top of the flask for filtration of samples.

4. Function: **glassware used for distillation**.

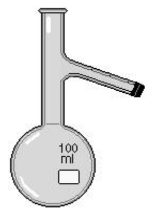
Distillation equipment.



The following glassware is used for distillation. Distillation is a common laboratory technique used for the separation of components from liquid mixtures. The liquid component is vaporized from the solution by using selective boiling. Then it is condensed and finally collected.

The distillation equipment consists of three major parts: the distillation flask, the condenser and the collection vessel.

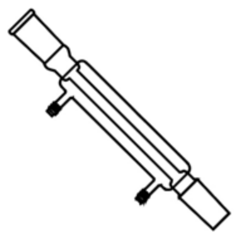
a) Name: **A distillation flask.**



A distillation flask or distilling flask is a round-bottomed flask used to contain mixtures, which are subject to distillation.

It has a long narrow neck with a side-arm tube that is connected to the condenser. It can be heated.

b) Name: **condenser**.



It is a piece of lab glassware used in distillations to condensate hot vapours.

It consists of a large glass tube containing a smaller glass tube running its entire length, within which the hot fluids pass. The outer glass tube usually has two hose connections, and a coolant (usually water) is passed through it.

There is a wide variety of condensers, each one with specific qualities. The Liebig condenser is the simplest condenser design.

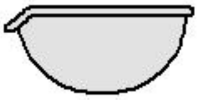
5. **Function**: **glassware used to contain solid substances**.

   a) **Name**: **watch glass.**

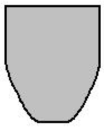
   It is a circular concave piece of glass used to hold a small amount of solid while being weighed or to evaporate a liquid.

   b) **Name**: **evaporating dish.**

   This porcelain dish is used for gentle heating of stable and humid solid substances or to heat and evaporate liquids.

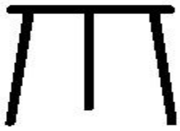
   c) **Name**: **crucible.**

   It is a ceramic container used for heating at very high temperatures certain solids, particularly metals, to make chemical reactions. Solid substances may be melted inside a crucible.

6. **Function**: **equipment used to support lab equipment**.

   a) **Name**: **tripod stand.**

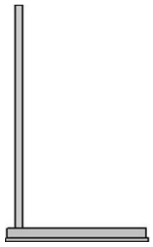
   It is a metallic three-legged stand used to support glassware, such as beakers, and flasks. Due to its height, a Bunsen burner can be placed underneath to heat them up.

   b) **Name**: **clamp.**

   It is used to secure glassware to the ring stand or support stand.

   c) **Name**: **support stand.**

   It consists of a long steel rod and a heavy steel base.

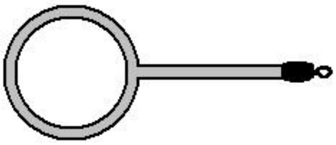
   It is used to hold glassware and other equipment in place, using clamps and/or support rings.

   d) **Name**: **clamp holder.**

   It is a piece of laboratory equipment that is used to secure a clamp to a support stand.

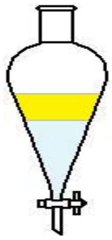
   e) **Name**: **iron ring.**

   It is attached to a support stand and is used to support laboratory equipment above the work surface such as a funnel or a separatory funnel. Wire gauze is placed on top of the iron ring to support beakers and flasks when heating them.

7. **Lab equipment with different functions.**

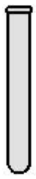
   a) **Name**: **separatory funnel.**

   This piece of glassware is also known as separation funnel. It takes the shape of a cone with a stopper at the top and a stopcock (a tap) at the bottom. It is used to separate two liquids that are immiscible, such as water and oil.

   Iron rings or clamps are used to hold separatory funnels.

   b) **Name**: **test tube.**

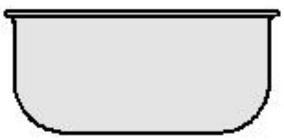
   Test tubes are used to make tests with small amounts of substances.

   c) **Name**: **test tube rack.**

   It is for holding and organizing test tubes.

   d) **Name: crystallising dish.**

   It is a wide and shallow dish to allow maximum evaporation to occur which is used to separate a solid from a liquid solution when the solvent slowly evaporates. The solid precipitates as crystals (a solid with a highly ordered inner structure) at the bottom and the walls of the crystallizer.

e) Name: wash bottle.

A wash bottle is a flexible plastic bottle with a spout that delivers distilled water or other solvents to a specific area by means of pressure on the bottle.

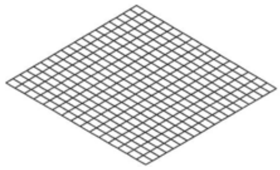
It is used to clean laboratory glassware or other equipment and to deliver small amount of solvent to make experiments in the lab.

f) Name: Bunsen burner.

It was designed by the German chemist Robert Bunsen in the 19^{th} century. It is used for heating non-volatile liquids and solids in the lab. It works with gas.

It consists of a metal tube on a base with a gas inlet at the lower end of the tube. It has an air hole at the bottom of the tube with a collar to control the amount of air that mixes with the gas. That allows complete or incomplete combustion so you can adjust the flame's temperature.

g) Name: **wire gauze**.



A wire gauze is a sheet made of metallic wire mesh with ceramic centre that is used to support the glassware on a tripod stand during heating with a burner. It helps to spread the flame (and heat) out evenly over the container.

h) Name: **mortar and pestle**.

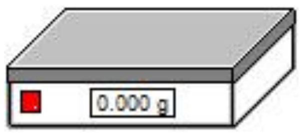
The mortar and pestle are used to crush solids into powders to better dissolve them.

They can be made of glass or porcelain.

i) Name: **dropper and rubber bulb**.

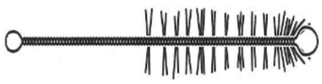
A dropper and a rubber bulb is a small glass tube with a vacuum bulb at one end that is used to transfer small amounts of liquid from one container to another.

j) Name: **electronic balance**.



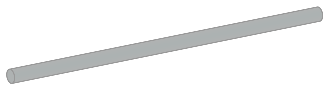
Electronic balances are used to measure the mass of small amounts of substance. They usually have the "ON" button to turn them on and the "Tare" or "Zero" button to automatically deduct the weight of the container used to measure the mass of a substance.

k) Name: **test tube brush**.



A test tube brush is a brush used for cleaning test tubes and other laboratory glassware.

l) Name: **glass stir rod**.



A glass stir rod is used to manually stir solutions and to transfer a single drop of a solution to make any test of a substance.

m) Name: **thermometer**.

A thermometer is a measuring instrument used to determine the temperature by reading its scale at eye level.

n) Name: **wooden test tube holder**.

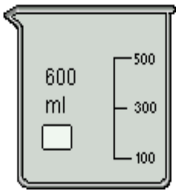
A wooden test tube holder is used for holding a test tube, which is too hot to handle.

o) Name: **Spatula spoon**.

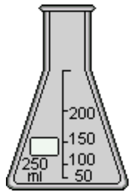
A spatula spoon is a stainless steel tool used to dispense solid chemicals from their containers.

English-Spanish lab equipment

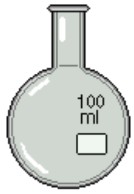
- **Function: glassware used to contain liquids and solutions and to make solutions**. They can be heated (contener líquidos y disoluciones, preparar disoluciones; se pueden calentar).



Beaker
Vaso de precipitados

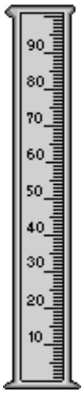


Erlenmeyer flask
Matraz Erlenmeyer

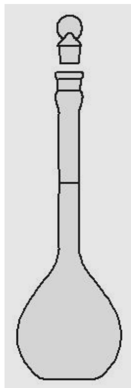


Round bottom flask
Matraz de fondo esférico

- **Function: glassware used to measure volumes of liquids** (medir volúmenes de líquidos).



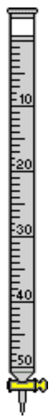
Graduated cylinder
Probeta



Volumetric flask
Matraz aforado

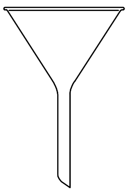
Graduated pipette
Pipeta graduada

Volumetric pipette
Pipeta aforada

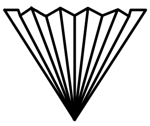


Buret or burette
Bureta

- **Function: glassware used to aid in the transfer of a liquid and for filtration** (vertido de líquidos, filtración).

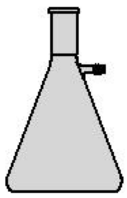


Funnel
Embudo



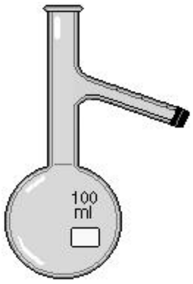
Filter paper
Filtro de papel

Büchner funnel
Embudo Büchner

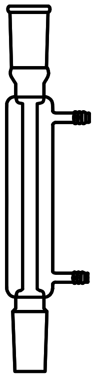


Kitasato flask
Matraz Kitasato

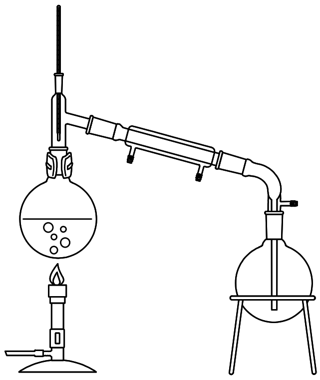
- **Function: glassware used for distillation** (destilación: separación de líquidos de disoluciones).



Distillation flask
Matraz de destilación



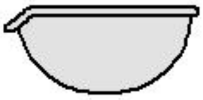
Condenser
Refrigerante



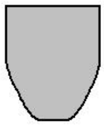
Distillation equipment
Equipo de destilación

- **Function: glassware used to contain solid substances** (soporte de muestras sólidas, secado, reacciones químicas en estado sólido).

Watch glass
Vidrio de reloj



Evaporating dish
Cápsula de porcelana

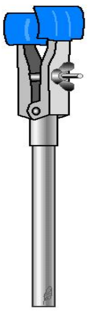


Crucible
Crisol

- **Function: equipment used to support lab equipment** (soporte de material de laboratorio).

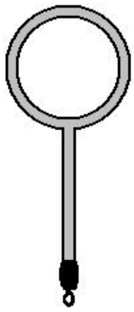
Tripod stand
Trípode

Clamp holder
Doble nuez



Clamp
Pinzas

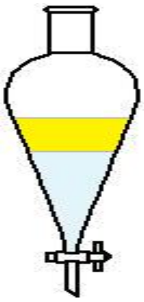
Test tube holder
Pinzas de madera



Iron ring
Aro

Support stand
Soporte

- **Function: lab equipment with different functions** (otro material con funciones diversas).



Separatory funnel
Embudo de decantación

Separation of immiscible liquids

Wash bottle
Frasco lavador

Delivery of water

Test tube
Tubo de ensayo

Small tests

Test tube rack
Gradilla

Holding and organizing test tubes