Chemistry

Chemistry is the study of the interactions between atoms and molecules.

Atoms and Molecules

An atom is a particle of matter that cannot be further divided without changing the chemical identity of the atom. The word *atom* derives from the Greek word meaning “uncuttable”.

Atoms are comprised of protons, neutrons, and electrons.

There are ~ 109 different kinds of atoms. The different kinds of atoms are called elements.

Examples of Atoms

H	Hydrogen	He	Helium
C	Carbon	Cu	Copper
O	Oxygen	Au	Gold
N	Nitrogen	Ag	Silver
Na	Sodium	Mg	Magnesium
Fe	Iron	Cl	Chlorine
U	Uranium	Ne	Neon

Atoms and Molecules

A molecule is a compound composed of two or more atoms. The atoms may be of the same element or of a combination of different elements.

Most of the matter we see in the universe is comprised of molecules.

Examples of Molecules

H_2O	Water
CO_2	Carbon Dioxide
NaCl	Sodium chloride (table salt)
$C_{12}H_{22}O_{11}$	Sucrose
N_2	Nitrogen
O_3	Ozone

Changes in Matter

Physical Change: When a substance undergoes a physical change, its molecular identity remains the same.

Chemical Change: When a substance undergoes a chemical change, the atoms in the substance are rearranged or exchanged with another substance to form new atoms or molecules.

Physical Properties of Matter

Mass

Mass is an intrinsic property of an object—it is a measure of how much material is in the object.

Mass and weight are not the same thing: weight is the gravitational force exerted on an object by another body (such as the Earth):

$$w = m \cdot g$$

(w = weight; g = acceleration due to gravity)

Physical Properties of Matter

Mass (con't.)

We often incorrectly refer to the mass of an object as its weight—we say we are weighing something when we are really determining its mass.

You can tell if you are measuring mass or weight by the device used—any device employing a spring determines weight; any device comparing forces, such as a balance, determines mass.

Physical Properties of Matter

Mass (con't.)

The units for mass are grams (or any multiple of grams such as kilogram, milligram, etc.)

A pound is actually a unit of weight, but in common usage, we can think of it as a mass unit: 1 kg = 2.205 lbs.

Mass does not change with pressure or temperature.

Physical Properties of Matter

Volume

Volume is a measure of the space occupied by an object.

Volume depends not only on the amount of material in the object, but also on the pressure acting on the object and the temperature of the object.

Units of volume are length cubed: 1 cm^3 = 1 mL, 1000 mL = 1 L, etc.

Physical Properties of Matter

Density

Density is related to what we usually refer to when we talk about something being heavy or light.

Definition:

density = mass/volume

units = g/mL (typically)

Physical Properties of Matter

Density

Table 1.1 lists density of some common substances.

Density is also a function of temperature and pressure because volume changes with temperature and pressure.

Which is more dense—a solid, a liquid or a gas?

Why does ice float on water?

Physical Properties of Matter

Time

Time is needed to determine such quantities as the energy of a system or the rate of a chemical reaction.

Units of time are second, (s), or multiples of seconds (millisecond [ms], microsecond [μs], nanosecond [ns], etc.).

Physical Properties of Matter

Temperature

Temperature is actually a measure of the internal energy of an object. The higher the temperature, the more internal energy an object possesses.

In science, temperature must be measured on an absolute scale with a defined value of zero below which temperature may not fall.

Physical Properties of Matter

<u>Temperature (con't.)</u>

Both Celsius and Fahrenheit temperature scales do not satisfy this requirement—each may have negative values of temperature.

Absolute zero is the lowest temperature attainable by an object—this corresponds to the minimum possible internal energy of an object. In practice, we may never reach absolute zero.

Physical Properties of Matter

<u>Temperature (con't.)</u>

The absolute temperature scale uses units of degrees Kelvin (abbreviated K).

$0.00\ K = -273.15\ ^oC$

The size of one degree Kelvin is the same as one degree Celsius.

When performing calculations involving temperature, if you use degrees Kelvin, you will always be safe.

Physical Properties of Matter

Temperature (con't.)

Sometimes we use the change in temperature, ΔT, to calculate some properties of a chemical system, where:

$\Delta T = T_{final} - T_{initial}$

In this case, you may use either K or ^{o}C because the size of the units are the same.

The mks Unit Set

We use SI (Systeme Internationale, or metric) units in science. The standard set of units used by most chemists is the "mks" set: meter/kilogram/second.

Many other units are defined relative to these fundamental quantities.

Example: 1 J (joule) $\equiv$ 1 kg m^2 s^{-2}

There is also the "cgs" set of units that is sometimes used: centimeter/grams/second

Significant Figures

When writing a number, it is important to know how well the value of the number is known.

<u>Examples</u>

If I say I have 12 donuts, I usually mean I have exactly 12 donuts because donuts do not come in fractions of a unit.

Significant Figures

If I say I have 12 grams of salt, does that mean exactly 12 grams or something between 11.5 and 12.5 grams.

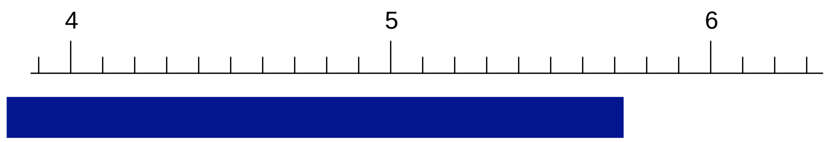
Because the mass of an object in grams may be expressed in fractions of grams, I must specify as precisely as possible what the mass is.

Significant figures indicate the precision with which a number has been determined.

Significant Figures

When expressing a value, the number of digits used indicates the number of digits that could be measured accurately.

The final digit in the value is an estimate of the least precise number.



Length = 5.73 units

Significant Figures

The manner in which a number is written indicates the number of significant figures it has.

<u>Examples</u>

4000

1 significant figure

as written, the zeros are simply place holders and do not indicate precision of the measurement.

the true value is between 3500 and 4500

Significant Figures

4000.

By placing a decimal point after the last zero, this indicates that the zeros were measured

4 significant figures

the true value is between 3999.5 and 4000.5

Significant Figures

4000.000

zeros following the decimal point with no other digits behind them also indicate precision of measurement, so they count as significant figures

7 significant figures

the true value is between 3999.9995 and 4000.0005

Significant Figures

.0004

for small numbers less than one, zeros following the decimal point before the first digit are simply place holders and do not indicate precision

1 significant figure

the true value is between .00035 and .00045

Significant Figures

.000400

zeros following digits in small numbers indicate precision and are significant.

3 significant figures

the true value is between .0003995 and .0004005

Mathematical Rules for Significant Figures

Addition/Subtraction

When adding or subtracting numbers, the number of significant figures in the result is determined from the position relative to the decimal point of the least significant figure of the numbers being added or subtracted:

Mathematical Rules for Significant Figures

Add 472.1, 3.192, and 5000.86

$$\begin{array}{r} 472.1 \\ 3.192 \\ +\ 5000.86 \\ \hline 5476.152 \end{array}$$

Because 472.1 has only 1 sig. fig. after the decimal point, the final answer can have only 1 sig. fig. after the decimal point—the correct answer is 5476.2

Mathematical Rules for Significant Figures

Subtract 126.5419 from 8000:

$$\begin{array}{r} 8000 \\ -\ \ 126.5419 \\ \hline 7873.4581 \end{array}$$

Because 8000 has only 1 sig. fig. four places to the left of the decimal point, the least significant figure in the final answer must also be four places to the left of the decimal point—correct answer is 8000

Mathematical Rules for Significant Figures

Multiplication/Division

The number of sig. figs. in the result is determined from the number of sig. figs. in the least significant value used in the calculation:

Mathematical Rules for Significant Figures

Multiply 88.037 by .00721

$$\begin{array}{r} 88.037 \\ \times \quad .00721 \\ \hline 0.63474677 \end{array}$$

88.037 has 5 sig. figs. and .00721 has 3 sig. figs. This limits the result to a total of three sig. figs.—the correct answer is 0.635

Scientific Notation

It can be very cumbersome to write very large or very small numbers using zeros as place holders:

m_{proton}= .00000000000000000000001673 g

c (speed of light) = 299800000 m s^{-1}

mole = 602200000000000000000000 molec

Scientific Notation

Instead, we use scientific notation to express the zeros in powers of ten:

m_{proton} = 1.673 x 10^{-24} g

c (speed of light) = 2.998 x 10^{8} m s^{-1}

mole = 6.022 x 10^{23} molecules

<u>Rules</u>

Add one power of ten when moving the decimal point one position to the left.

Subtract one power of ten when moving the decimal point one position to the right.

Scientific Notation

9240 = 924. x 10^{1}

= 92.4 x 10^{2}

= 9.24 x 10^{3}

185530000 = 1.8553 x 10^{8}

.007724 = .07724 x 10^{-1}

= .7724 x 10^{-2}

= 7.724 x 10^{-3}

.000000000006626 = 6.626 x 10^{-12}

Prefixes

Prefixes on units of measurement are used to simplify expression of large or small numbers—they replace the use scientific notation in some cases:

giga (G) = 10^{9}

mega (M) = 10^{6}

kilo (k) = 10^{3}

centi (c) = 10^{-2}

milli (m) = 10^{-3}

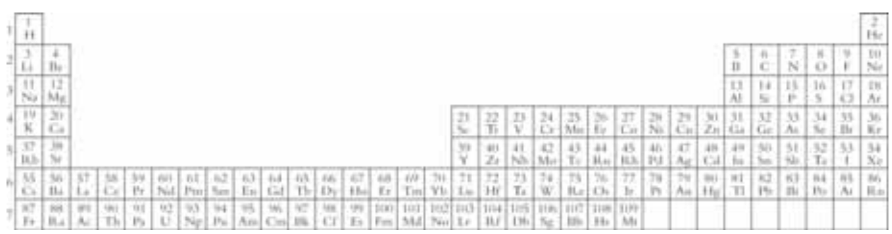
micro (μ) = 10^{-6}

nano (n) = 10^{-9}

pico (p) = 10^{-12}

femto (f) = 10^{-15}

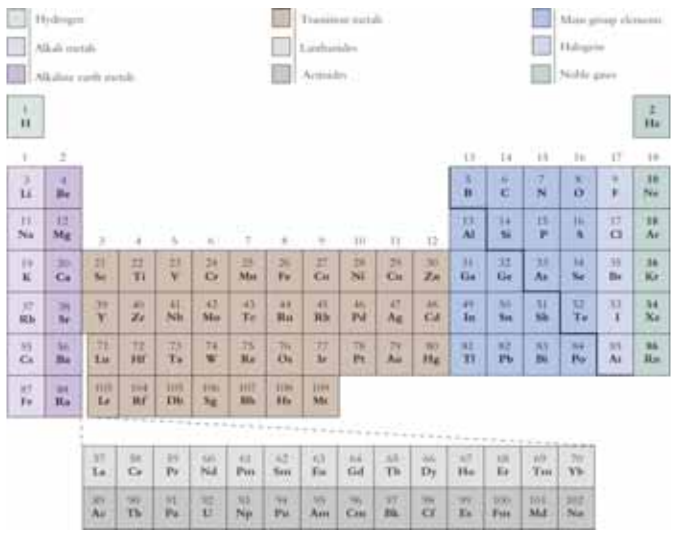
The Periodic Table



The Periodic Table arranges the elements according to their properties—structural (the manner in which the protons and electrons are arranged) and chemical (the properties resulting from the arrangement of the electrons, principally)

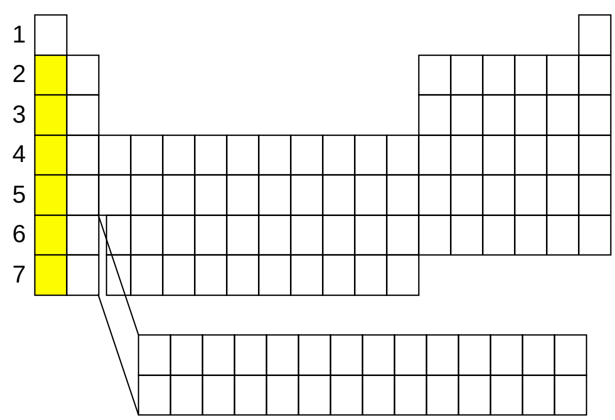
The Periodic Table has seven rows and 32 columns.

The Periodic Table



The Periodic Table

Alkali Metals



Lithium

Sodium

Potassium

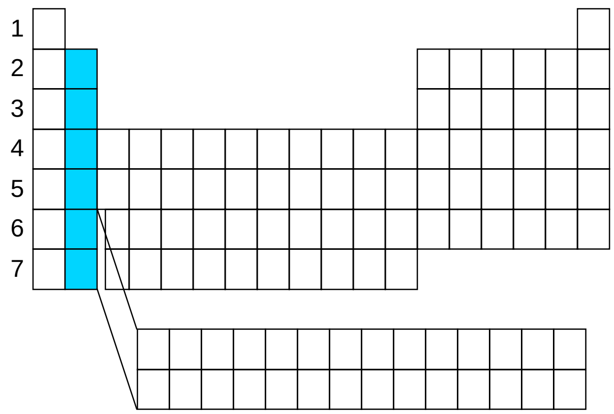
Rubidium

Cesium

Francium

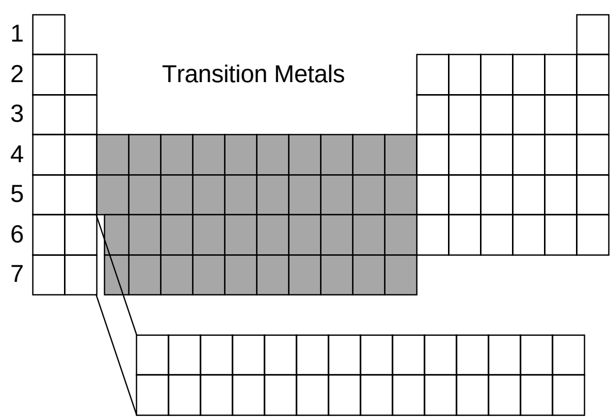
The Periodic Table

Alkaline Earth Metals



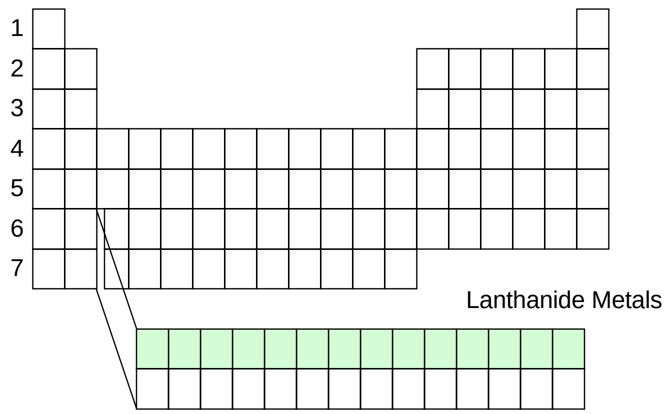
- Beryllium
- Magnesium
- Calcium
- Strontium
- Barium
- Radium

The Periodic Table



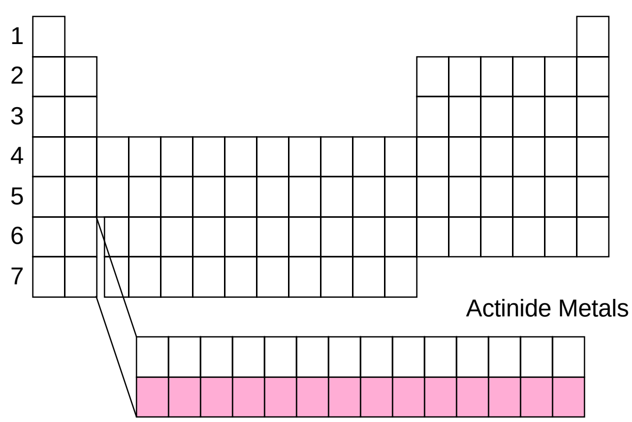
- Copper
- Gold
- Silver
- Platinum
- Chromium
- Zinc
- Tungsten
- etc.

The Periodic Table



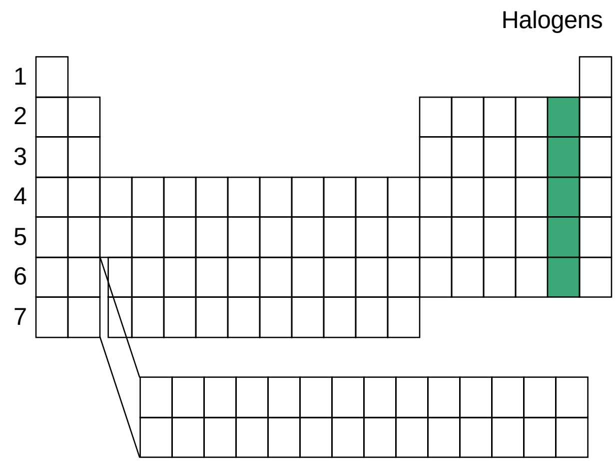
Lanthanum
Cerium
Praseodymium
Neodymium
Promethium
etc.

The Periodic Table



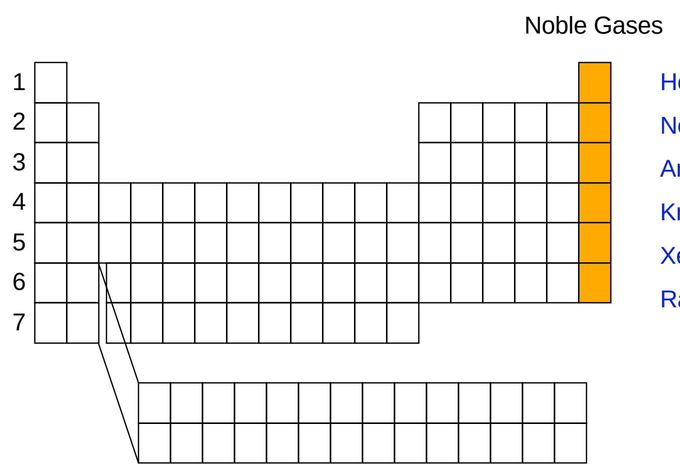
Actinium
Thorium
Uranium
Plutonium
etc.

The Periodic Table



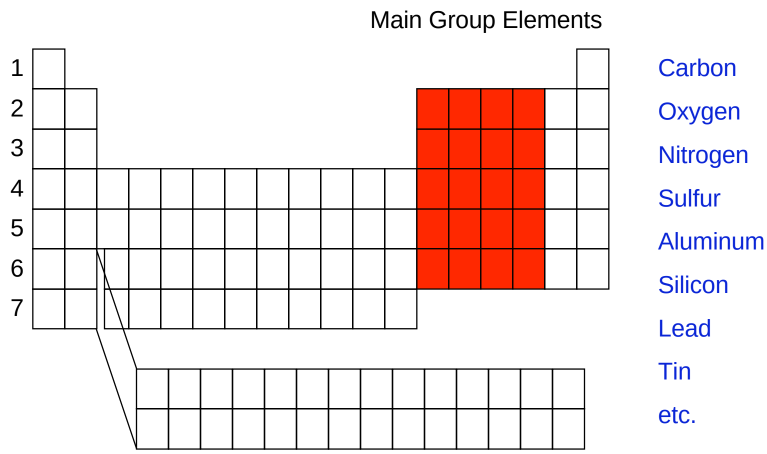
Fluorine
Chlorine
Bromine
Iodine
Astatine

The Periodic Table



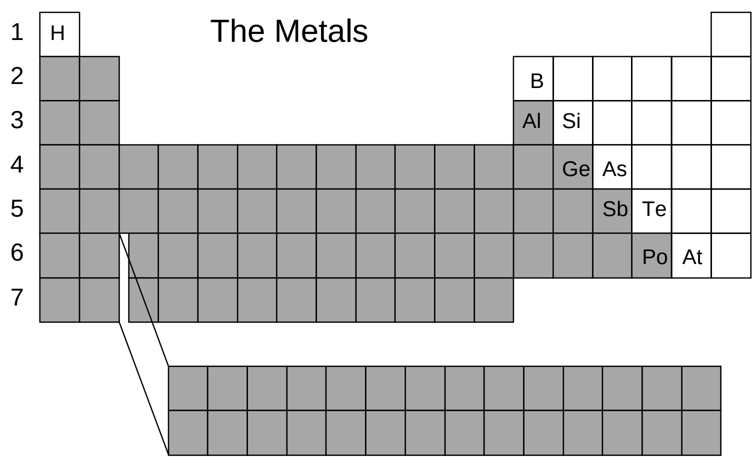
Helium
Neon
Argon
Krypton
Xenon
Radon

The Periodic Table

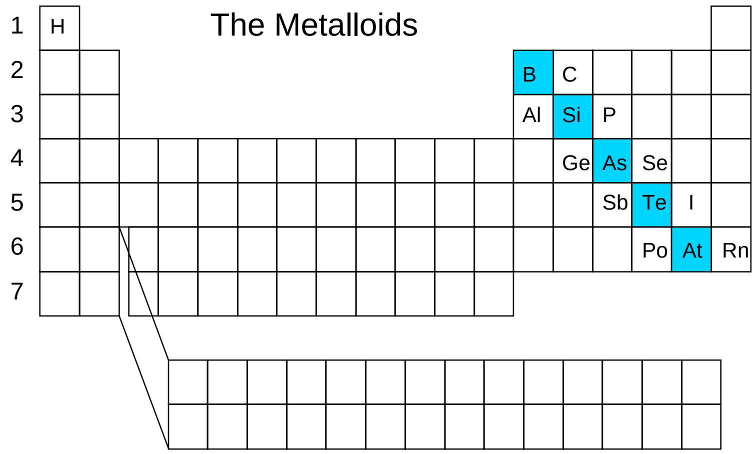


Main Group also includes Alkali, Alkaline Earth metals, Halogens, and Noble gases.

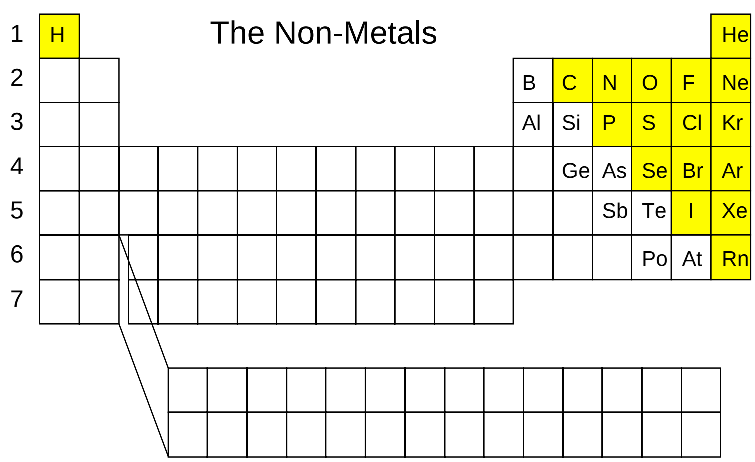
The Periodic Table



The Periodic Table

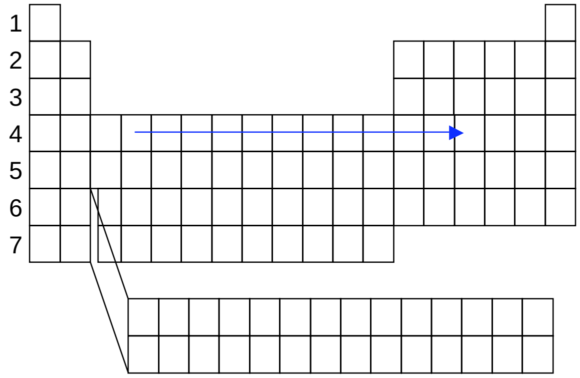


The Periodic Table



The Periodic Table

As you move from left to right in a given row of the Periodic Table, the elements get heavier (not necessarily larger). The chemical properties also undergo significant change when moving between columns of the Periodic Table.



The Periodic Table

As you move down a column in the periodic Table, the elements increase in mass and size, but the chemical properties do not change dramatically between rows.