# 1 Atoms and elements

EXPERIMENT

# Atoms and elements

## Goal

The goal of this laboratory experiment is to familiarize with the appearance of metals, non-metals, and metalloids. The goal is also to discuss the nature of the atom in terms of its constituents and to understand the nature of isotopes.

## Materials

- ☐ Display of different elements (Al, C, Cu, Fe, Mg, Ni, N, O, P, Si, S, Sn, Zn)

## Background

### The periodic table

The periodic table is a chart containing all known elements arranged in increasing number of electrons per atom in a way that elements with similar chemical and physical properties are located together. The periodic table contains all existing elements–some of them are synthetic others are natural–that form the matter arranged in columns and rows. Every element has a different name accompanied by a symbol that represents their name. The tabular arrangement of elements in the form of rows and columns allow further classification of the elements according to their properties. This section will cover the different features of the periodic table.

Elements cannot be broken down into simpler substances. For example aluminum is an element only made of aluminum atoms and if you analyze the composition of a piece of this metals you would only find aluminium atoms. Chemical symbols are one- or two-letter abbreviations that represent the names of the elements. Only the first letter is capitalized and if a second letter exist in the element's name, the second letter should be lowercase. For example, the chemical symbol for aluminum is Al, written as capital A and lowercase l.

The physical and chemical properties of some elements of the table are similar, and these similarities led to the organization of the periodic table. Elements in the same group share properties and for example, oxygen and sulfur have similar properties: both are reactive elements. Differently, the properties across periods change going from metals to nonmetals. For example, the properties of Li and Ne are very different and lithium is a reactive metal whereas neon is a nonreactive gas.

Overall, the elements of the periodic table can be classify as metals, nonmetals, and metalloids. Metals are those elements on the left of the table and nonmetals are the elements on the right of the table. The elements between metals and nonmetals are called metalloids and include only B, Si, Ge, As, Sb, Te, Po, and At. Metals are shiny solids and usually melt at higher temperatures. Some examples of metals are Gold (Au) or Iron (Fe). Nonmetals are often poor conductors of heat and electricity with low melting points. They also tend to be matt (non-shinny), malleable, or ductile. Some examples of nonmetals are Carbon (C) or Nitrogen (N). Metalloids are elements that share some properties with metals and others with the nonmetals. For example, they are better conductors of heat and electricity than the nonmetals, but not as good conductors as the metals. Metalloids are semiconductors because they can act as both conductors and insulators under certain conditions. An example of metalloids is Silicon (Si) that should not be confused from silicone, a chemical employed in prosthetics.

### Early experiments of the atom

Scientists wondered about the nature of the atom and its structure for years. In a series of experiments carried in the late nineteenth century, scientists such as J.J. Thomson, Henri Becquerel, or Ernest Rutherford gained insight into the nature and structure of the atom. These remarcable scientists and these creative experiments helped shape the view of the atom that we have nowadays.

The English researcher J.J. Thomson investigated electric discharges in partially evacuated tubes–tubes in which the air has been partially removed; these tubes, made of a positive and negative electrode, are the base of old-fashion, bulky televisions. Thomson found that rays emanated from the negative electrode when applying high-voltage to these tubes. These rays were names cathodic rays as the negative electrode of the tube is called the cathode. Thomson also found that cathodic rays were repelled from the negative pole of an electric field. Hence, these rays were postulated to be a stream of negatively charged particles, now known as electrons. By studying the deflection of these rays by an electric field, Thomson was able to calculate the charge-to-mass ratio of an electron:

$$\boxed{\frac{e}{m_e} = -1.76 \times 10^8 C/g} \tag{1}$$

where:

$e$ is the charge of an electron

$m_e$ is the mass of an electron

Overall, the biggest of Thomson's discoveries was that all atoms are made of negatively charged particles. As atoms are charge-neutral, they are also made of positively charged particles. These observations led to a new atomic model, the *plum pudding model*, that envisioned atoms as a diffuse cloud of positive charges with negative electrons embedded in it. The name plum pudding comes from an English dessert that contains a raising spread on it. A different scienticts, Robert Millikan, revealed the magnitude of the electric charge of the electron. Millikan used an apparatus that dispersed charged oil droplets falling under the influence of an electric field. Given the applied voltage and the droplet mass, Millikan was able to calculate the droplet charge. He found that the oil drop charge was always a whole-number time the electron charge,

$$\boxed{e = 1.60 \times 10^{-19}\mathrm{C}} \tag{2}$$

where a Coulomb is a unit of charge. With the value of the charge-to-mass ratio of an electron and the electron charge, Millikan was also able to calculate the mass of an electron,

$$\boxed{m_e = 9.11 \times 10^{-31}\mathrm{kg.}} \tag{3}$$

Ernest Rutherford carried further experiments to validate the plum pudding model of the atom. He exposed a thin sheet of metal foil to $\alpha$ particles known to be massive and possitively charged particles. According to the plum pudding model, the bulky $\alpha$ particles should have crashed through the thin foil and traverse through without being deflected. However, the results did not corroborate his expectations. Indeed, some particles traversed the film, whereas other were slightly deflected and some were strongly deflected at large angles. These observations did not corroborate the plum pudding model. However, they contributed to the creation of the modern atomic mode in which a large number of positive charges were concentrated at a point–called the nucleus– instead of being spread whereas the electrons move around the nucleus at large distances from it. In the last part of the nineteenth century, scientists came to the discovery that some materials were able to produce high-energy radiation. Among the scientist working in this field, Henri Becquerel discovered that pitchblende, a mineral containing uranium, was able an image on a photographic plate in the absence of light. In the early twentieth century, three different types of radiation were discovered: alpha radiation, beta radiation, and gamma radiation. Further studies revealed that gamma radiation was made of gamma particles, high-energy radiation, whereas beta radiation was made of high-energy electrons. Alpha particles were found to be positively charged, with a charge twice the charge of an electron and a mass 7300 times that of the electron. These particles were indeed Helium nucleus, resulting from removing electrons from atoms of Helium.

# Procedure

## Appearance of some chemical elements

☐ *Step 1:* – Write the chemical symbol and describe the color of the elements listed below.

☐ *Step 2:* – Describe the luster of the elements listed below (shiny/dull).

☐ *Step 3:* – Based on your observations, describe the elements as metals, nonmetals or metalloids.

**Good Lab Practice**

✍ Be gentle when handling the display of chemical elemens.

## The atom and its composition

☐ *Step 1:* – Fill the table below indicating the number of electrons, protons and neutrons of the following neutral isotopes.

## Neutral isotopes

☐ *Step 1:* – Fill the table below indicating the number of electrons, protons and neutrons of the following neutral isotopes.

## Charged isotopes

☐ *Step 1:* – Fill the table below indicating the number of electrons, protons and neutrons of the following charged isotopes.

## Average atomic masses

☐ *Step 1:* – For the element below calculate the average atomic mass by multiplying the mass of the different isotopes by its abundance and adding the contributions.

## Atomic spectrum

☐ *Step 1:* – Your instructor will show you the light spectra for a set of elements and compounds.

☐ *Step 2:* – Describe the light color for each.

**STUDENT INFO**

Name: ____________________ Date: __________

### Pre-lab Questions

# Atoms and elements

1. The mass number of an atom is equal to the number of: (a) electrons (b) neutrons (c) neutrons plus protons (d) protons

2. Consider a neutral atom with 30 protons and 34 neutrons. The mass number of the element is: (a) 30 (b) 32 (c) 34 (d) 64 (e) 94

3. Consider a neutral atom with 30 protons and 34 neutrons. The atomic number of the element is: (a) 30 (b) 32 (c) 34 (d) 64 (e) 94

4. In an atom, the nucleus contains: (a) an equal number of protons and electrons. (b) all the protons and neutrons (c) all the protons and electrons (d) only neutrons (e) only protons

**STUDENT INFO**

Name: ____________________ Date: __________

**Results**
**EXPERIMENT**

# Atoms and elements

## Appearance of some chemical elements

| Element | Symbol | Atomic number | Luster<br>Shinny/dull | Metallic Character<br>Metal/Nonmetal/Metalloid |
|---|---|---|---|---|
| Aluminium | ___________ | ___________ | ___________ | ___________ |
| Carbon | ___________ | ___________ | ___________ | ___________ |
| Copper | ___________ | ___________ | ___________ | ___________ |
| Iron | ___________ | ___________ | ___________ | ___________ |
| Magnesium | ___________ | ___________ | ___________ | ___________ |
| Nickel | ___________ | ___________ | ___________ | ___________ |
| Nitrogen | ___________ | ___________ | ___________ | ___________ |
| Oxygen (not given) | ___________ | ___________ | ___________ | ___________ |
| Phosphorus | ___________ | ___________ | ___________ | ___________ |
| Silicon | ___________ | ___________ | ___________ | ___________ |
| Silver (not given) | ___________ | ___________ | ___________ | ___________ |
| Gold (not given) | ___________ | ___________ | ___________ | ___________ |
| Sulfur | ___________ | ___________ | ___________ | ___________ |
| Tin | ___________ | ___________ | ___________ | ___________ |
| Zinc | ___________ | ___________ | ___________ | ___________ |
| Calcium | ___________ | ___________ | ___________ | ___________ |

**The atom and its composition**

| Name | Symbol | Atomic number, Z | Mass number, A | Protons | Neutrons | Electrons |
|---|---|---|---|---|---|---|
| | Fe | | | | 30 | |
| | | | 134 | | | 55 |
| | | | | | 32 | 28 |
| Fluorine | | | 18 | | | |
| | C | | 12 | | | |

**Neutral isotopes**

| Isotope | Protons | Neutrons | Electrons |
|---|---|---|---|
| $^{27}_{12}Mg$ | | | |
| $^{64}_{29}Cu$ | | | |
| $^{79}_{34}Se$ | | | |
| $^{103}_{46}Pd$ | | | |

**Charged isotopes**

| Isotope | Protons | Neutrons | Electrons |
|---|---|---|---|
| ${}^{27}_{12}Mg^{2+}$ | | | |
| ${}^{64}_{29}Cu^{+}$ | | | |
| ${}^{18}_{8}O^{2-}$ | | | |
| ${}^{15}_{7}N^{3-}$ | | | |

**Average atomic masses**

| Isotope | Isotopic mass (m) | Abundance (%) | Fractional Abundance ($f$) | $m \times f$ |
|---|---|---|---|---|
| ${}^{32}_{16}S$ | 31.97207 | 95.0 | | |
| ${}^{33}_{16}S$ | 32.97146 | 0.76 | | |
| ${}^{34}_{16}S$ | 33.96786 | 4.22 | | |
| Average mass (amu) | | | | |

## Charged isotopes

Nitrogen

Oxygen

Helium

Neon

Argon

**STUDENT INFO**

Name: ____________________ Date: __________

**Post-lab Questions**

# Atoms and elements

1. The atomic mass of Ga is 69.72 amu. There are only two naturally occurring isotopes of gallium: 69Ga, with a mass of 69.0 amu, and 71Ga, with a mass of 71.0 amu. Calculate the natural abundance of the 69Ga isotope.

2. Magnesium contains three different isotopes: magnesium-24 with an abundance of 79% and a mass of 23.9850423 amu, magnesium-25 with an abundance of 10% and a mass of 24.9858374 amu, and magnesium-26 with a mass of 25.9825937 amu. Calculate the abundance of magnesium-26 and the average atomic mass of a sample of magnesium.