UNIT 2

The atom and the periodic table

WORK ON YOUR KEY COMPETENCES LS

The 'healthy' elements of the periodic table

Did you know that of the 118 elements in the periodic table, only a few exist in our bodies?

We suggest that you research which elements of the periodic table are essential to maintaining good health and the diseases that a deficiency or excess of those elements can cause.

Use the information to design a periodic table that highlights those elements.

OXFORD INVESTIGATION

Go to your GENiOX Desktop.

Think and discuss

1. What are the chemical elements in living things called?
2. Name other elements that are essential for our health.
3. What arguments would you use to convince someone that their diet should be complete and healthy?
4. Look up Sustainable Development Goal 2, Zero hunger. Describe how this goal relates to the content of the text.
5. Can radioactive isotopes help diagnose and treat non-communicable diseases?
6. Target 3.4 of the third Sustainable Development Goal, Good health and wellbeing, seeks to reduce mortality from non-communicable diseases by one third through prevention and treatment. How is that related to the text?
7. In class, discuss the use of radioactivity in medicine to save lives.

The 'healthy' elements of the periodic table

Phosphorus is present in our bodies, especially in our bones and teeth. It's an essential element for life. Henry Band discovered it by distilling urine. Phosphorus isn't found in a free state in nature.

It's part of the structure of DNA and ATP (the main energy-storing molecule in our cells), and it's also part of the phospholipids that make up cell membranes.

Phosphorus deficiency in our bodies is associated with fatigue, respiratory or nervous-system difficulties, muscle weakness and other disorders. Fortunately, phosphorus is found in many types of food: dairy, legumes, cereals, nuts, meat, and fish.

BBC World News,
October 2020 (Adapted)

With regard to Sustainable Development Goal 2, Zero hunger, you should know that the diseases that lead to death for most Europeans are the consequences of a poor diet. Therefore, to eat a complete and healthy diet you must ensure the presence of bioelements.

https://www.un.org/sustainabledevelopment/es/hunger/

In addition, there are certain elements that emit radiation (radioactive isotopes). Some of these are used in medicine for the diagnosis and treatment of cancer. In the first case, it's low intensity radiation and in the second case, it's more energetic radiation. An example is I-131, which is used in the treatment of thyroid cancer. This is related to Sustainable Development Goal 3, Good health and wellbeing.

Radioactive isotopes can be used to diagnose and treat cancer.

https://www.un.org/sustainabledevelopment/es/health/

1 What's matter made of? Atoms

The word 'atom'

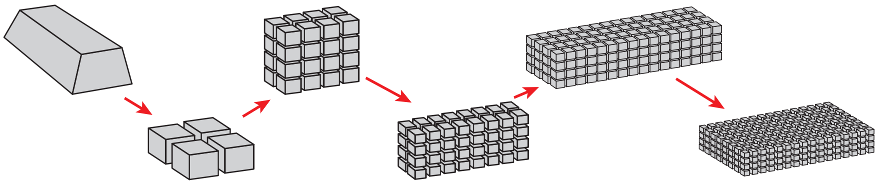
The Greek philosophers **Leucippus** and **Democritus** used this word for the first time. It means 'indivisible.'

[1] **indivisible:** not able to be separated into parts.

The size of atoms

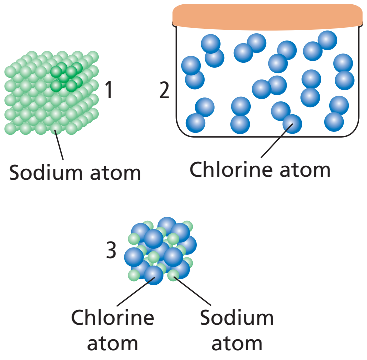
Atoms are so small that about one million of them would fit **stacked**[2] in the thickness of one page of this book. The smallest atom is hydrogen, whose size is of the order of 10^{-10} m.

Can a copper wire be divided indefinitely into ever smaller fragments?



At the beginning of the 19th century, **Dalton** concluded that:

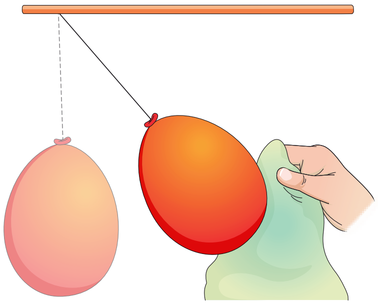
1. matter is made up of **indivisible**[1] **atoms**.
2. each **element** is made up of **identical atoms**.
3. **atoms of different elements** join together to form **chemical compounds** in a fixed ratio for each possible compound.



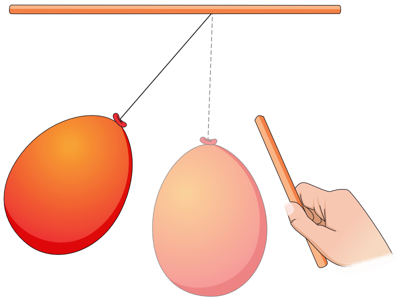
The drawing represents the atoms in a sodium crystal (1), the atoms that form chlorine gas molecules (2), and the atoms of chlorine and sodium in a sodium chloride crystal (3).

1.1. Is matter really indivisible? The electrical nature of matter

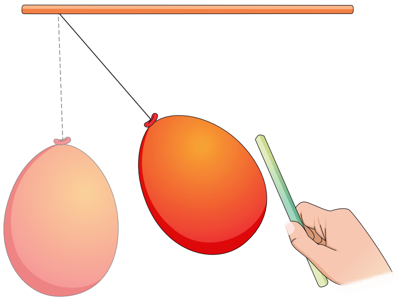
Look at the following experiments. *What conclusions can you draw from the results?*



Experiment 1. Hang an inflated balloon by a string and rub it with a piece of cloth. Hold the cloth close to the balloon.



Experiment 2. Now rub a plastic rod with a piece of cloth and hold the rod close to the balloon.



Experiment 3. Finally, rub a glass rod with a piece of silk and hold it close to the balloon.

These experiments about the electrification of matter reveal two electrical phenomena: **attraction** (the first and third experiments) and **repulsion** (the second experiment). These electrical phenomena show that there's one type of electrical charge that we call **positive** and another type that we call **negative**. Charges of the same type repel, and opposite charges attract.

The SI unit of charge is the **coulomb, C**.

The phenomenon of the electrification of matter also demonstrates the fact that **the atom is divisible**.

CLIL activities

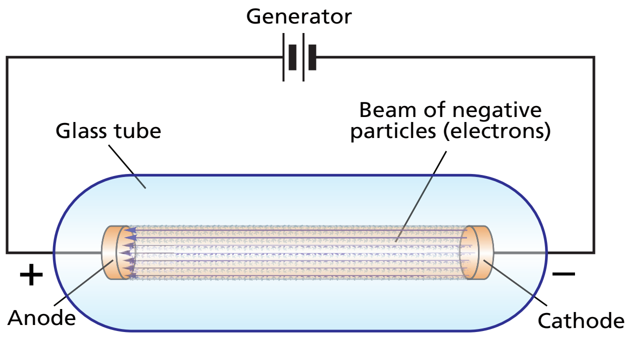
① Listen to this teacher talking about Dalton's theory. List two of his ideas which we now know are incorrect. Share your answers with a classmate.

2 What are negative and positive charges?

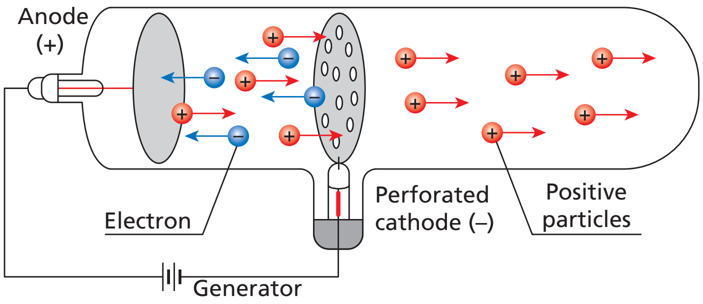
The electron and the proton

In the late 19th and early 20th centuries, several scientists carried out different experiments with glass tubes containing a low-pressure gas, which they subjected to high-voltage electrical discharges.

Discovery of the electron and proton



In a gas discharge tube like the one in the picture, electrons are directed from the negative electrode to the positive one, which means that the electrons are negatively charged.



This gas discharge tube contains hydrogen. The positive particles that travel from the positive electrode to the negative one are **protons**, and they have a positive charge.

Experiments such as these made it possible to identify the elementary particle responsible for the negative electric charge, the **electron**, and the particle responsible for the positive electric charge, the **proton**.

	Electron	Proton
Electric charge	$-1.602 \cdot 10^{-19}$ C	$1.602 \cdot 10^{-19}$ C
Mass	$9.109 \cdot 10^{-31}$ kg	$1.673 \cdot 10^{-27}$ kg
Discovery	**J. J. Thomson (1897)**	**E. Goldstein (1886)**

The charge of the electron is the smallest that exists and is called the **elementary charge**. Note that the absolute value of the electron's charge is the same as that of the proton. Therefore, the number of electrons must be equal to the number of protons in any electrically neutral body.

A body can only acquire an electric charge when it loses or gains electrons.

- If an electrically neutral body **loses electrons**, it becomes a body with a **net positive electric charge**.
- If an electrically neutral body **gains electrons**, it becomes a body with a **net negative electric charge**.

CLIL activities

2 How much larger is the charge of the proton than the charge of the electron? What about the mass?

3 The model of the atom proposed by Thomson has been compared to a watermelon. What do you think the red part of this fruit represents in this model? What do you think the seeds represent?

4 Describe the main discoveries of J.J. Thomson. Why do you think they were so important? Discuss your answer with a classmate.

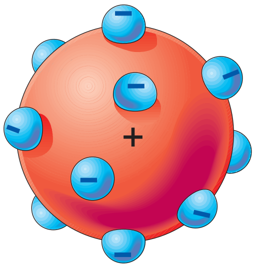
5 Listen and write the sentences in your notebook. Complete them correctly with the words *electron(s)* or *proton(s)*.

3 Where are the proton and the electron positioned in the atom? The first atomic models

The discoveries of the electron and the proton were seen as incompatible with the model of an indivisible atom, because these particles are located inside the atom.

3.1. Thomson's Atomic Model (1904)

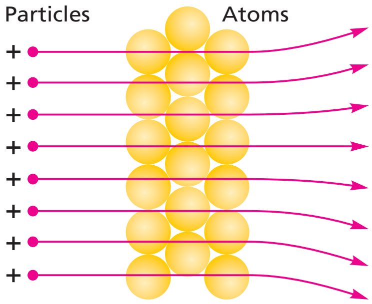
J.J. Thomson proposed the **plum pudding atomic model**: the electrons would be embedded in a **spongy**[1] and always positively charged sphere that contains almost all the mass.



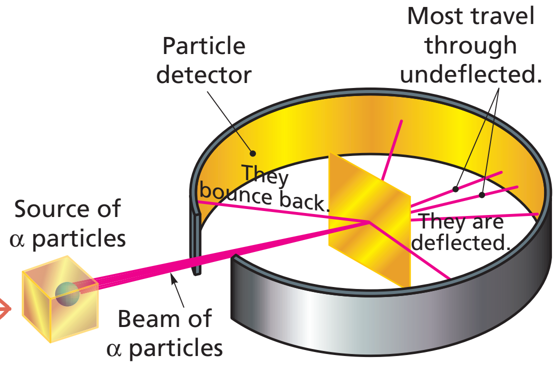
Thomson's model was accepted until a new discovery questioned its **validity**[2].

3.2. Rutherford's Atomic Model (1909)

In 1909, **Rutherford** and his colleagues **Geiger** and **Marsden** bombarded a piece of very thin gold foil with positively charged particles at high speed. They expected the particles to pass through the sheet with little deflection.



This illustration shows what happened instead.



1. Most of the particles passed through the very thin gold foil without changing direction.
2. Some particles deflected considerably.
3. Surprisingly, some particles bounced back.

Rutherford concluded from this experiment that:

1. the fact that the positive particles pass through the sheet without being **deflected**[3] indicates that the atom is mostly empty space.
2. the fact that some positive particles are deflected shows that they have passed near an area of the atom that is positively charged.
3. the fact that a few positive particles bounce back indicates a collision with a very dense and positively charged area of the atom.

CLIL activities

6 **Listen and write the sentences in your notebook. Find the mistakes and correct them.**

7 **Which particles are responsible for the mass of the atom? Explain to a classmate why Rutherford proposed the existence of the neutron before it was actually discovered.**

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[1] **spongy:** soft and able to hold liquid easily like a sponge.

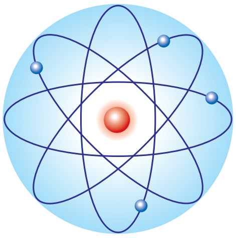
[2] **validity**: state of being officially accepted.

[3] **deflect:** change direction after hitting something.

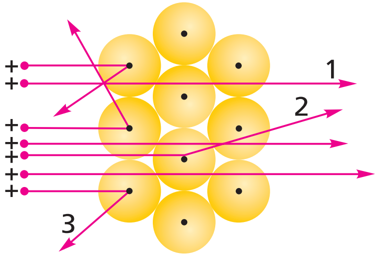
What did Rutherford's model propose?

To explain the result of the gold foil experiment, Rutherford proposed a **nuclear atomic model** consisting of two different zones:

- a **central zone** or **nucleus** which is positively charged and where practically all the mass of the atom is concentrated. The protons are in this zone.
- a **peripheral**[1] **zone**, or **electron shell**, in which negatively charged electrons rotate around the nucleus at some distance from it.



Observe the trajectories followed by the particles in Rutherford's experiment. *How does his model explain the gold foil experiment?*



1. The particles that pass far away from the nucleus pass through the atom without deflecting from their path.
2. Since the charge is concentrated in a central nucleus, the positive particles that pass near it deflect from their straight paths.
3. Positive particles that collide **head-on**[2] with the very dense and positive nucleus bounce back.

3.3. The discovery of neutrons (1932)

Rutherford's atomic model couldn't explain the mass of the atom because the sum of the masses of the protons and the electrons was smaller than that of the atom.

For example, the hydrogen atom has one electron and one proton, and the helium atom has two electrons and two protons, so the mass of helium should be twice that of hydrogen; however, it's four times greater.

Rutherford and other scientists proposed that another particle must exist in the nucleus, with mass but no electrical charge.

In 1932, **James Chadwick** discovered electrically neutral particles in the nucleus of atoms. He called them **neutrons** and their mass is similar to that of protons.

The planetary model

The atom is made up of:

- a **central nucleus** with a positive charge, in which practically all its mass is concentrated. That is, the mass of the protons and neutrons.
- an **electron shell** where electrons with a negative charge revolve at high speed around the nucleus. The nucleus and the electron shells are far apart in relation to their size.

As you can see, there's a certain similarity between the structure of the Solar System and the structure of the atom: the planets would be the electrons and the Sun would be the nucleus at the centre.

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[1] **peripheral:** around the edge of, far from the centre.

[2] **head-on**: in which the front part of one particle hits the front part of another particle.

The mass of the neutron

The **mass of the neutron**, m_n, is only slightly greater than the mass of **proton**, m_p:

$$m_n = 1.675 \cdot 10^{-27}\ \text{kg}$$

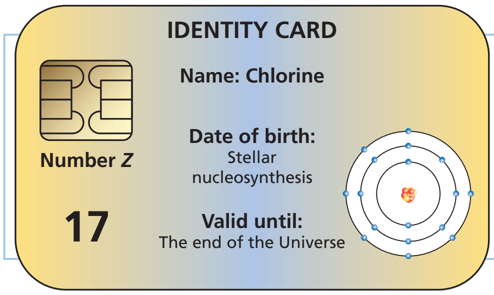
$$m_p = 1.673 \cdot 10^{-27}\ \text{kg}$$

CLIL activities

8 In your notebook, calculate the electric charge and the mass of an α-particle.

9 Draw the expected paths of α-particles through the gold foil in Thomson's and Rutherford's atomic models.

4 How are atoms identified? The atomic number and the mass number



Compare your identity card with that of chlorine (Cl).

What's the identifying mark of a person? And that of an atom?

The atoms of an element are identified by the **number of protons** they have in their nucleus, just as you identify yourself by your identity number, which is different from everyone else's.

All atoms of the same element have the same number of protons, which is called the **atomic number *Z***.

$$Z = \text{atomic number} = \text{number of protons}$$

The number of protons plus the number of neutrons in an atom is called the **mass number *A***.

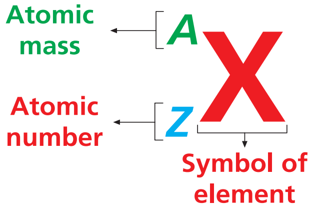
$$A = \text{number of protons} + \text{number of neutrons}$$

The number of neutrons, ***N***, is therefore:

$$N = A - Z$$

In an electrically **neutral atom**, the number of protons **is equal to** the number of electrons.

To represent an atom, we use the following **notation**[1]:



This notation tells us the number of protons and neutrons, and the number of electrons in the case of a neutral atom.

Worked example

1 Calculate the number of protons, neutrons and electrons in electrically neutral $^{23}_{11}$Na and $^{209}_{84}$Po atoms.

The atomic number of **sodium (Na)** is $Z = 11$, that is, it has 11 protons in its nucleus. Since it is electrically neutral, it also has 11 electrons.

Its mass number is $A = 23$, so the number of neutrons, N, will be:

$$N = A - Z = 23 - 11 = 12$$

The atomic number of **polonium (Po)** is $Z = 84$, that is, its nucleus has 84 protons. Being electrically neutral, it also has 84 electrons.

Its mass number is $A = 209$, so the number of neutrons, N, will be:

$$N = A - Z = 209 - 84 = 125$$

CLIL activities

10 Write these atoms using $^{A}_{Z}X$ notation.

a. oxygen (O): 8 protons; 8 neutrons

b. nitrogen (N): 7 protons; 7 neutrons

c. calcium (Ca): 20 protons; 20 neutrons

d. magnesium (Mg): 12 protons; 13 neutrons

11 Listen and write the sentences in your notebook. Complete them with *protons* or *neutrons*.

12 Look at these atoms and answer the questions.

A1: 13 protons; 14 neutrons; 13 electrons.

A2: 15 protons; 14 neutrons; 13 electrons.

A3: 13 protons; 15 neutrons; 12 electrons.

A4: 14 protons; 14 neutrons; 14 electrons.

a. Which ones are the same element? Why?

b. Which ones are electrically neutral? Why?

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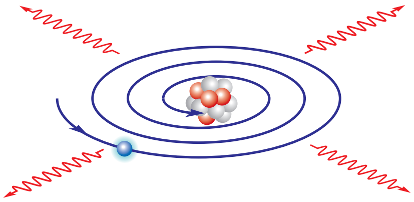
[1] **notation:** set of written symbols.

5 Bohr's atomic model (1913)

What's the problem with Rutherford's atomic model?

We know that moving electrical charges emit energy. In the Rutherford model, the electron rotates at high speed around the nucleus, so it should lose energy and gradually accelerate towards the nucleus in a spiral trajectory, until it collides with it. During this process, the atom would continuously emit energy. However, this doesn't happen. *Why?*



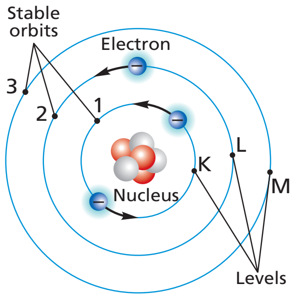
In 1913 **Niels Bohr** established a series of propositions that can be summarised as follows.

1. The electron only moves in stable circular orbits, without emitting any energy. Depending on their **orbit**, electrons have a certain **energy level**. The further from the nucleus, the higher their energy.
2. When an electron jumps from a higher energy level to a lower energy level, it emits energy as electromagnetic radiation. For an electron to go from a lower to higher energy level, it needs a supply of energy.

5.1. How are electron energy levels distributed?

The Bohr model had to be **refined**[1] later on to justify the spectra and chemical properties of the elements: each stable orbit or energy level can have different sublevels of energy.

In effect, electrons are distributed in energy levels and sublevels, each of which admits a maximum number of electrons.



Level 1 (K)	Maximum number of electrons: 2			
Level 2 (L)	Maximum number of electrons: 8			
	Sublevel 1 2 electrons	**Sublevel 2** 6 electrons		
Level 3 (M)	Maximum number of electrons: 18			
	Sublevel 1 2 electrons	**Sublevel 2** 6 electrons	**Sublevel 3** 10 electrons	
Level 4 (N)	Maximum number of electrons: 32			
	Sublevel 1 2 electrons	**Sublevel 2** 6 electrons	**Sublevel 3** 10 electrons	**Sublevel 4** 14 electrons

The electron configuration of an atom is the distribution of its electrons by energy levels and sublevels. For example:

- the helium atom ($Z = 2$) has 2 electrons, which occupy level 1, so this level no longer admits more electrons. Its electron configuration is **He: 2**.
- the boron atom ($Z = 5$) has 5 electrons, which fully occupy level 1 and partially occupy level 2. Its electron configuration is **B: 2 3**.

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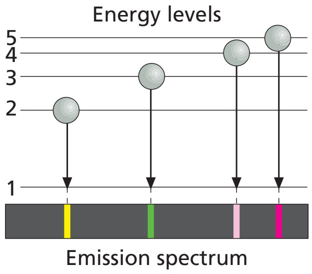
[1] **refine:** improve by making small changes or removing errors.

Emission spectra

When atoms receive energy, some electrons go from low energy levels, close to the nucleus, to other energy levels further away with higher energy. Once they return to their stable state, the electrons emit an amount of energy equal to the difference between the two levels. In those cases, the atoms emit known amounts of energy, which correspond to lines in the so-called **emission spectrum**.



CLIL activities

⑬ The potassium atom has 19 electrons. Choose the correct electron configuration:

a. 2 2 6 2 6 1

b. 2 2 5 2 5 3

c. 2 8 3 5 1

⑭ Investigate the reason for the orange colour of some street lights.

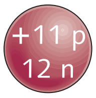
⑮ Listen to this clip from a science show on TV. Explain the main problem of Rutherford's model and how it was solved in Bohr's model.

5.2. How do we draw atoms?

We're going to draw atoms according to Bohr's atomic model, distributing the electrons in the different electron levels according to their electron configuration.

The atomic nucleus

1. Draw a circle to represent the atomic nucleus, made up of protons and neutrons.
2. Write the number of protons and neutrons inside the circle.

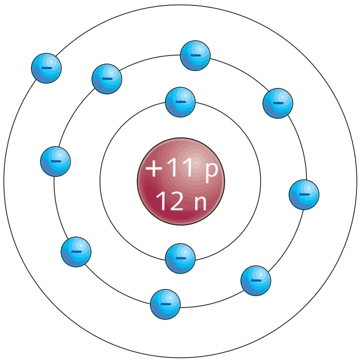


Nucleus of the sodium atom

The atomic number, Z, is the number of protons. The number of neutrons is the difference between the mass number and the atomic number: $N = A - Z$. For example, for $^{23}_{11}\text{Na}$ we know that the number of protons is $Z = 11$, so the number of neutrons will be $N = A - Z = 23 - 11 = 12$.

Electron levels

1. Draw electron levels around the core.
2. Place the electrons at the different levels.

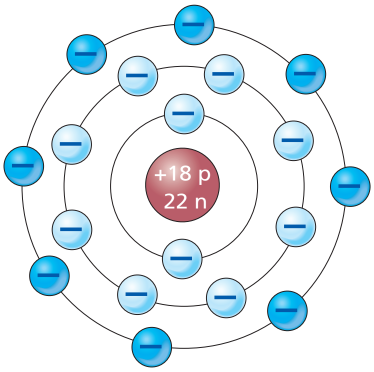


Representation of the sodium atom.

In an electrically neutral atom, the number of positive charges is equal to the number of negative charges, that is, the number of electrons. In the $^{23}_{11}\text{Na}$ example, the number of electrons is 11.

As we've already seen, the first electron level contains at most 2 electrons; the second level 8, the third 18, and so on. As a result, the electron configuration of the $^{23}_{11}\text{Na}$ is **2 8 1**.

Worked example



11 **Draw a $^{40}_{18}\text{Ar}$ atom.**

Number of protons = $Z = 18$

Number of neutrons = $A - Z = 40 - 18 = 22$

Number of electrons = $Z = 18$

Level 1: 2 electrons

Level 2: sublevel 1: 2 electrons; sublevel 2: 6 electrons

Level 3: sublevel 1: 2 electrons; sublevel 2: 6 electrons

Its electron configuration is **2 2 6 2 6** = **2 8 8**.

CLIL activities

⑯ **Follow the instructions. Write the answers in your notebook.**

The magnesium atom has a mass number $A = 24$, and 12 neutrons

- **a.** Draw the neutral atom using standard notation and calculate the number of electrons.
- **b.** Draw a magnesium atom with 10 electrons and calculate the number of protons.
- **c.** Calculate the electron configuration in both cases.

⑰ **The chlorine atom has 17 electrons. Which of these electron configurations is correct? Write the number of electrons in each level.**

a. 2 2 6 2 6 **b.** 2 2 6 2 5 **c.** 2 8 8 1

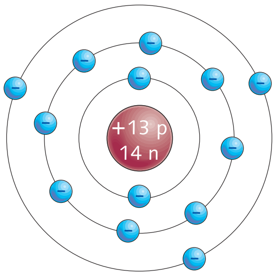
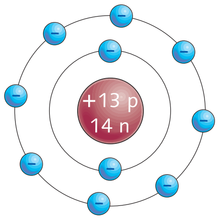
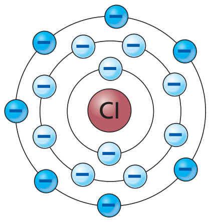
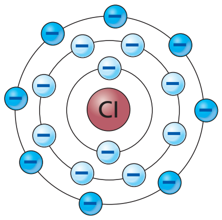
⑱ **A beryllium atom has 4 electrons. Discuss with a classmate which of these electron configurations is the correct one.**

a. 2 2 **b.** 2 1 1 **c.** 1 1 1 1

6 How are ions formed? What's their electron configuration?

In an **electrically neutral atom**, the **number of protons** in the nucleus **coincides** with the **number of electrons** in the shell.

- When a neutral atom **loses** electrons, it acquires a positive charge. We call this a **cation** or **positive ion**.
- When a neutral atom **gains** electrons, it acquires a negative charge. We call this an **anion** or **negative ion**.

Neutral atom	Positive ion (cation)	Neutral atom	Negative ion (anion)
			
$^{27}_{13}$Al: a neutral atom with 13 protons and 13 electrons. Electron configuration: **2 8 3**	$^{27}_{13}Al^{3+}$: if the neutral atom **loses** 3 electrons, it becomes a positive ion, with 10 electrons and 13 protons. Electron configuration: **2 8**	$^{35}_{17}$Cl: a neutral atom with 17 protons and 17 electrons. Electron configuration: **2 8 7**	$^{35}_{17}Cl^{-}$: when the neutral atom **gains** 1 electron, it becomes a negative ion, with 18 electrons and 17 protons. Electron configuration: **2 8 8**

Worked example

III The magnesium atom has a mass number of 24 and has 12 neutrons.

a. How many electrons does it have if the atom is neutral?

Since the atom is neutral, the number of electrons must be equal to $Z = A - N = 24 - 12 = 12$. It has 12 electrons.

b. How do you identify it? What's its electron configuration?

Identification: $^{24}_{12}$Mg Configuration: 2 8 2

c. If it had 10 electrons, how many protons would it have now and what would its ionic charge be? How would you identify it?

It would be a cation, since it would have lost 2 electrons. However, it would still have the same number of protons: 12.

Ionic charge $= 12 - 10 = +2$ Identification: $^{24}_{12}Mg^{2+}$

d. What would its electron configuration now be?

Configuration: 2 8

CLIL activities

19 Calculate the number of protons, electrons and neutrons of these atoms and ions.

a. $^{65}_{30}$Zn **b.** $^{85}_{37}Rb^{+}$ **c.** $^{80}_{35}Br^{-}$ **d.** $^{24}_{12}Mg^{2+}$

20 Listen and correct the sentences in your notebook. Explain your answers to a classmate.

21 Discuss with a classmate which one of these ions is more common and why.

a. $_{11}Na^{+}$ or $_{11}Na^{++}$

b. $_{17}Cl^{-}$ or $_{17}Cl^{++}$

c. $_{8}O^{2-}$ or $_{8}O^{+}$

d. $_{12}Mg^{2+}$ or $_{12}Mg^{2-}$

...is more common because...

7 Can the atoms of the same element have different mass numbers? Isotopes

Atoms of the same element that have the same number of protons but different numbers of neutrons are called **isotopes**.

The **isotopes** of an element have the same atomic number but different mass numbers.

Worked example

IV Indicate the number of protons, neutrons and electrons that the neutral isotopes of chlorine have: $^{35}_{17}\text{Cl}$ and $^{37}_{17}\text{Cl}$

$^{35}_{17}\text{Cl}$: 17 protons, 35 – 17 = 18 neutrons and 17 electrons.

$^{37}_{17}\text{Cl}$: 17 protons, 37 – 17 = 20 neutrons and 17 electrons.

What if it has a negative charge (chlorine anion)?

$^{35}_{17}\text{Cl}^-$: 17 protons, 35 – 17 = 18 neutrons and 18 electrons.

$^{37}_{17}\text{Cl}^-$: 17 protons, 37 – 17 = 20 neutrons and 18 electrons.

7.1. What are radioactive isotopes?

Look at this bone **scan**[1]. This **diagnostic**[2] method uses small amounts of radioactive isotopes which are injected into the patient. This radiation is detected by a special camera.

This method uses gamma rays to detect conditions, such as cancer tumours or infections, or breaks and bone fractures.

Radioactive isotopes, or **radioisotopes**, are isotopes of an element that have a higher or lower number of neutrons than protons in their nuclei. Their nuclei are unstable so they emit **radiation**. They have the same physical and chemical properties as an inactive isotope of the same element.

The presence of the atoms of a radioactive isotope is enough to generate radioactivity. The greater the number of atoms of a radioactive isotope, the greater the activity of the **sample**[3].

CLIL activities

22 Which are radioactive isotopes? Why?

a. ^{12}C or ^{14}C **b.** ^{18}F or ^{19}F **c.** ^{4}He or ^{6}He

23 Which of the following are isotopes of the same element? How do you know?

$^{27}_{13}\text{A}$ $^{26}_{13}\text{B}$ $^{29}_{14}\text{C}$ $^{30}_{14}\text{D}$

[1] **scan:** a medical test in which a machine produces a picture of the inside of a person's body.

[2] **diagnostic:** connected with identifying an illness.

[3] **sample:** small amount of a substance taken from a larger amount and tested in order to obtain information about the substance.

7.2. How many types of radiation are there?

The types of radiation are as follows:

- **Alpha (α) particles:** these consist of 2 protons and 2 neutrons. They have a positive charge and low penetrating power.
- **Beta (β) particles:** these are fast-moving electrons. They have a negative charge and medium penetrating power.
- **Gamma radiation (γ):** this has no electrical charge, but it does have high penetrating power, including the ability to penetrate living things.

What are radioactive isotopes used for?

Radioactive isotopes are used in very diverse fields.

- **Medicine:** they're used both in the diagnosis and in the treatment of cancer. In the first case, they're harmless radiation, and in the second, highly energetic radiation, which makes use of the ^{131}I isotope, for example.
- **Manufacturing:** they allow quality control of parts and welds. Using radioactive isotopes, we can get a photographic image of the internal structure of an object without affecting its integrity.
- **Agriculture:** some isotopes are useful for pest control and food preservation.
- **Archaeology and dating:** by measuring the amount of carbon-14 present in a sample, it's possible to find the age of organic remains.
- **Energy:** the controlled fission of uranium-235 cores generates a large amount of energy and doesn't contribute to global warming.

Waste management

The use of radioactive substances generates waste that can be radioactive. Depending on the activity (the rate at which the waste emits energy) and the time it takes to reduce it, waste is classified as:

- low-level and short-lived waste (less than 30 years). It's stored in warehouses above the ground.
- long-term, low-level waste (more than 30 years). It's deposited in underground warehouses.
- long-lasting, high-level waste (up to millions of years). It's deposited in deep geological stores.

CLIL activities

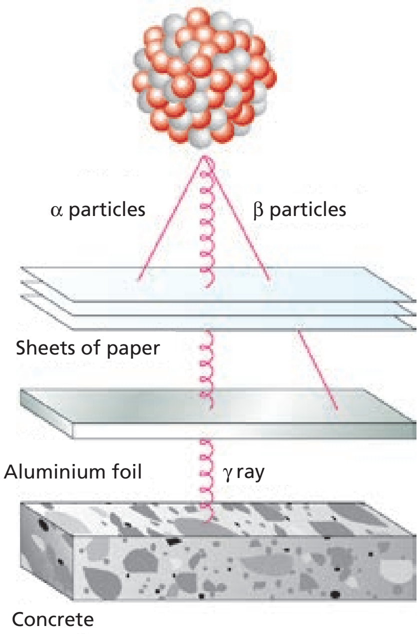
24 **Listen to the interview and explain to a classmate.**

a. What's radiocarbon dating?

b. What's the half-life of a radioactive isotope?

25 LS **Search for information about which isotopes are used in the diagnosis and treatment of thyroid cancer.**

26 LS **What properties of radioactive waste must we consider when storing it? Indicate how to take them into account.**



The penetrating power of the different types of radiation

Marie Curie (1867–1934)

Curie was the winner of two Nobel prizes: one in Physics for her work on radiation and the other in Chemistry for the discovery of the elements radium and polonium. Curie also led the first studies into the treatment of neoplasms or tumours with radioactive isotopes.

She was able to measure the amount of radiation emitted by the uranium atom in each study sample.

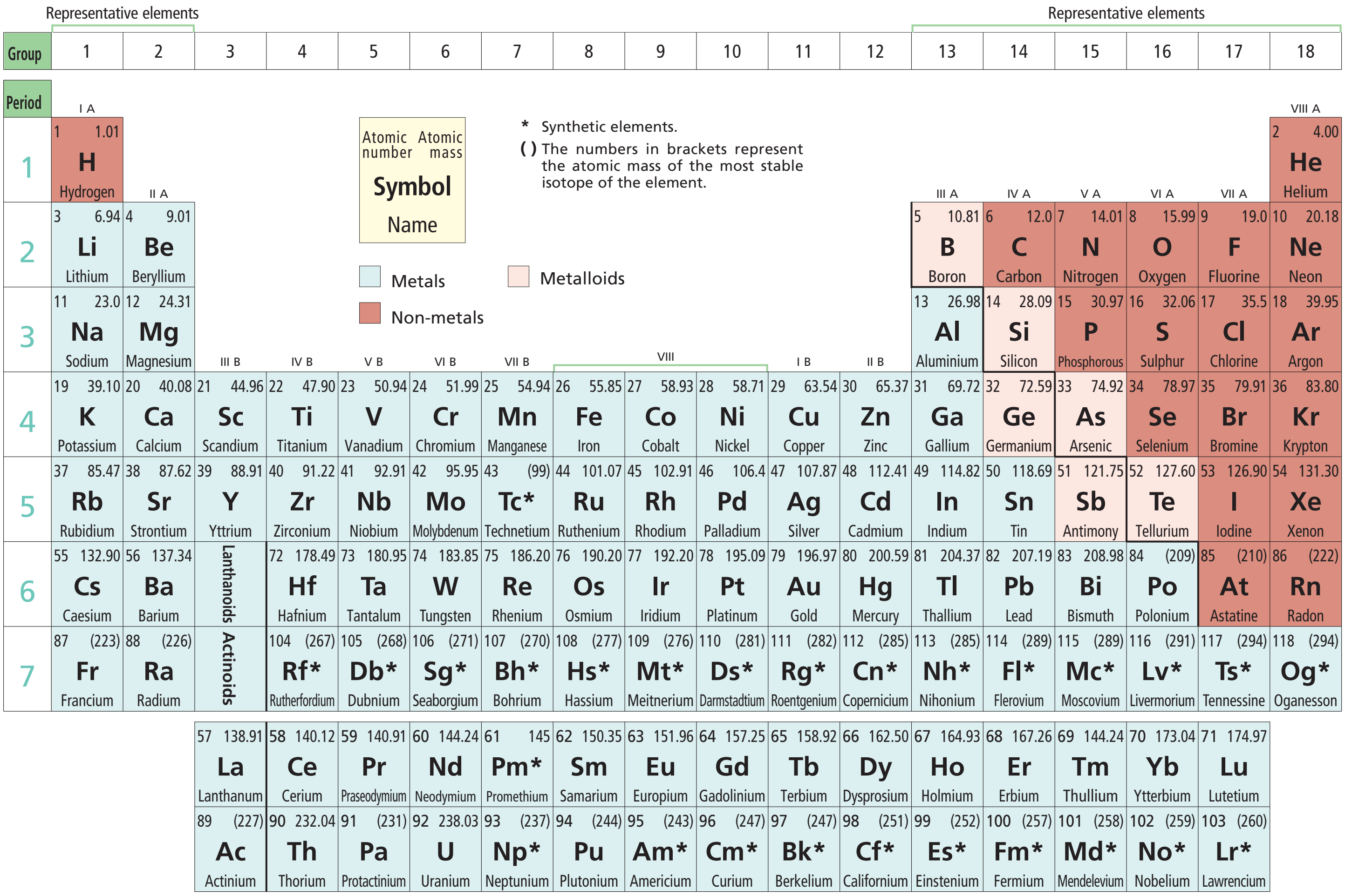
Together with her husband, she managed to isolate **polonium** and **radium** from the mineral **pitchblende** (which contains approximately 30 elements).

8 How are the elements arranged in the periodic table?

So far, 118 chemical elements have been discovered. We can arrange them in order according to their atomic number in the **periodic table,** or **periodic table of elements**.

A **chemical element** is made up of atoms of the same type, which have the same atomic number, *Z*.

PERIODIC TABLE OF ELEMENTS



Representative elements (groups 1–2) · Representative elements (groups 13–18)

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period	I A	II A	III B	IV B	V B	VI B	VII B	VIII			I B	II B	III A	IV A	V A	VI A	VII A	VIII A
1	1 1.01 **H** Hydrogen																	2 4.00 **He** Helium
2	3 6.94 **Li** Lithium	4 9.01 **Be** Beryllium											5 10.81 **B** Boron	6 12.0 **C** Carbon	7 14.01 **N** Nitrogen	8 15.99 **O** Oxygen	9 19.0 **F** Fluorine	10 20.18 **Ne** Neon
3	11 23.0 **Na** Sodium	12 24.31 **Mg** Magnesium											13 26.98 **Al** Aluminium	14 28.09 **Si** Silicon	15 30.97 **P** Phosphorous	16 32.06 **S** Sulphur	17 35.5 **Cl** Chlorine	18 39.95 **Ar** Argon
4	19 39.10 **K** Potassium	20 40.08 **Ca** Calcium	21 44.96 **Sc** Scandium	22 47.90 **Ti** Titanium	23 50.94 **V** Vanadium	24 51.99 **Cr** Chromium	25 54.94 **Mn** Manganese	26 55.85 **Fe** Iron	27 58.93 **Co** Cobalt	28 58.71 **Ni** Nickel	29 63.54 **Cu** Copper	30 65.37 **Zn** Zinc	31 69.72 **Ga** Gallium	32 72.59 **Ge** Germanium	33 74.92 **As** Arsenic	34 78.97 **Se** Selenium	35 79.91 **Br** Bromine	36 83.80 **Kr** Krypton
5	37 85.47 **Rb** Rubidium	38 87.62 **Sr** Strontium	39 88.91 **Y** Yttrium	40 91.22 **Zr** Zirconium	41 92.91 **Nb** Niobium	42 95.95 **Mo** Molybdenum	43 (99) **Tc*** Technetium	44 101.07 **Ru** Ruthenium	45 102.91 **Rh** Rhodium	46 106.4 **Pd** Palladium	47 107.87 **Ag** Silver	48 112.41 **Cd** Cadmium	49 114.82 **In** Indium	50 118.69 **Sn** Tin	51 121.75 **Sb** Antimony	52 127.60 **Te** Tellurium	53 126.90 **I** Iodine	54 131.30 **Xe** Xenon
6	55 132.90 **Cs** Caesium	56 137.34 **Ba** Barium	Lanthanoids	72 178.49 **Hf** Hafnium	73 180.95 **Ta** Tantalum	74 183.85 **W** Tungsten	75 186.20 **Re** Rhenium	76 190.20 **Os** Osmium	77 192.20 **Ir** Iridium	78 195.09 **Pt** Platinum	79 196.97 **Au** Gold	80 200.59 **Hg** Mercury	81 204.37 **Tl** Thallium	82 207.19 **Pb** Lead	83 208.98 **Bi** Bismuth	84 (209) **Po** Polonium	85 (210) **At** Astatine	86 (222) **Rn** Radon
7	87 (223) **Fr** Francium	88 (226) **Ra** Radium	Actinoids	104 (267) **Rf*** Rutherfordium	105 (268) **Db*** Dubnium	106 (271) **Sg*** Seaborgium	107 (270) **Bh*** Bohrium	108 (277) **Hs*** Hassium	109 (276) **Mt*** Meitnerium	110 (281) **Ds*** Darmstadtium	111 (282) **Rg*** Roentgenium	112 (285) **Cn*** Copernicium	113 (285) **Nh*** Nihonium	114 (289) **Fl*** Flerovium	115 (289) **Mc*** Moscovium	116 (291) **Lv*** Livermorium	117 (294) **Ts*** Tennessine	118 (294) **Og*** Oganesson
			57 138.91 **La** Lanthanum	58 140.12 **Ce** Cerium	59 140.91 **Pr** Praseodymium	60 144.24 **Nd** Neodymium	61 145 **Pm*** Promethium	62 150.35 **Sm** Samarium	63 151.96 **Eu** Europium	64 157.25 **Gd** Gadolinium	65 158.92 **Tb** Terbium	66 162.50 **Dy** Dysprosium	67 164.93 **Ho** Holmium	68 167.26 **Er** Erbium	69 144.24 **Tm** Thullium	70 173.04 **Yb** Ytterbium	71 174.97 **Lu** Lutetium	
			89 (227) **Ac** Actinium	90 232.04 **Th** Thorium	91 (231) **Pa** Protactinium	92 238.03 **U** Uranium	93 (237) **Np*** Neptunium	94 (244) **Pu** Plutonium	95 (243) **Am*** Americium	96 (247) **Cm*** Curium	97 (247) **Bk*** Berkelium	98 (251) **Cf*** Californium	99 (252) **Es*** Einstenium	100 (257) **Fm*** Fermium	101 (258) **Md*** Mendelevium	102 (259) **No*** Nobelium	103 (260) **Lr*** Lawrencium	

Atomic number Atomic mass
Symbol
Name

- 🟦 Metals
- 🟥 Non-metals
- ▢ Metalloids

* Synthetic elements.
( ) The numbers in brackets represent the atomic mass of the most stable isotope of the element.

The elements are organised according to their atomic number, that is, according to their electron configuration. They're arranged from left to right and top to bottom in increasing order of their atomic number, in columns called **groups** and in **rows**[1] called **periods:**

- **There are 18 groups.** The elements of the same group have the same number of electrons in the last layer or level (valence electrons) and therefore, have similar chemical properties.

  The elements in groups 1, 2, 13, 14, 15, 16, 17 and 18 are called **representative elements**.

- **There are 7 periods.** The elements from the same period have the same number of electron levels.

  Elements with atomic numbers 58 to 71 (lanthanides) and 90 to 103 (actinides) are in two rows outside the table, which are extensions of periods 6 and 7.

Dimitri Mendeleev

In 1869, Mendeleev arranged the 63 elements known at that time in increasing order of atomic masses and found that the elements of the same group had similar chemical properties.

---

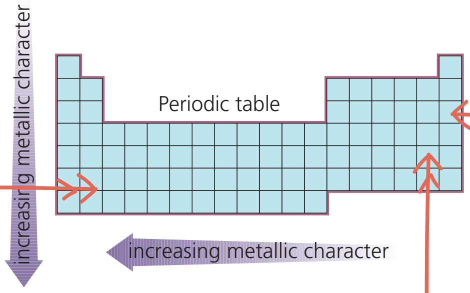
[1] **row:** line in a table.

8.1. Metals and non-metals

The illustration shows how the metallic and non-metallic character of elements varies across the groups and periods in the periodic table.

Metals: Fe, Cu, Zn, Sn, Hg, Au, Ca, Na...

Metals are opaque, lustrous, good conductors of heat and electricity, malleable (meaning they can be moulded into sheets) and ductile (meaning they can be drawn into threads) and have high melting and boiling points. Except for mercury, they're solid at room temperature.



Noble gases: He, Ne, Ar, Kr, Xe, Rn

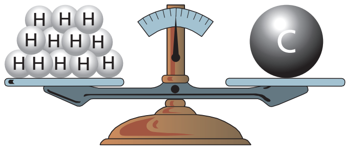
Noble gases are non-metals and are characterised by their tendency not to combine with other elements. This is because their last electron level is full.

Non-metals: O, Cl, Br, S, C, N, F, He, Ne...

These non-metals aren't shiny, are poor conductors of heat and electricity, can be solid, liquid or gaseous at room temperature and have low melting and boiling points.

8.2. What's the atomic mass of an element?

The **relative atomic mass** of an element is the mass of an atom of that element and is measured in comparison to the mass of the carbon-12 atom. An **atomic mass unit** is 1/12 the mass of the C-12 atom. For example, when we say that the relative atomic mass of the hydrogen atom is 1, we mean that its mass is 1/12 of the mass of the C-12 atom.



The relative atomic mass of hydrogen is one twelfth of the mass of C-12.

If an element is made up of different isotopes, *what will the atomic mass of that element be?*

The **relative atomic mass** of an element is defined as the weighted mass of the atomic masses of its isotopes according to their abundance in nature:

$$\text{relative atomic mass} = \frac{\%\ \text{isotope 1}}{100} \cdot m_1 + \frac{\%\ \text{isotope 2}}{100} \cdot m_2 + \frac{\%\ \text{isotope 3}}{100} \cdot m_3 \ldots$$

In the previous equation, m_1, m_2, m_3... are the atomic masses of the isotopes of the element in question.

Worked example

V In nature, there are two stable isotopes of copper: ^{63}Cu, with an abundance of 69.2%, and ^{65}Cu, with an abundance of 30.8%. What is their relative atomic mass?

We calculate the weighted average mass of the isotopes:

$$\text{relative atomic mass} = \frac{69.2}{100} \cdot 63 + \frac{30.8}{100} \cdot 65 = 63.62$$

So, the relative atomic mass of copper is 63.62.

CLIL activities

27 Two isotopes of a given element ^{39}A and ^{41}A have natural abundances of 93.3% and 6.7%, and atomic masses m_{39} = 38.98 u and m_{41} = 40.98 u, respectively. Calculate the relative mass of the chemical element.

28 Use the periodic table to name the groups and periods of these elements: Fe, P, Hg, Zr, H, He, Co, Rb.

29 Listen and make notes about the key points of the periodic table. Then compare your notes with a classmate.

The position of an element ... In a period, ... In a group, ...

Revision activities

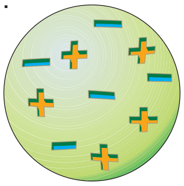
Atoms

㉚ **Use Dalton's theory to explain whether the following statements are *true* or *false*, and why.**

- a. The atoms of a single element are identical to one another.
- b. Atoms are divisible and don't change.
- c. Chemical compounds are always formed by the combination of atoms of two different elements.

㉛ **Identify which of these objects has a positive charge, which has negative charge, and which is electrically neutral.**

1.



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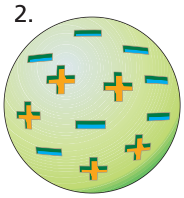

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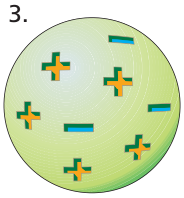


㉜ **Are the statements about the objects in the previous activity *true* or *false*? Explain your answers.**

- a. For object 1 to become object 3, it must lose positive charges.
- b. For object 1 to become object 3, it must gain negative charges.
- c. For object 3 to become object 2, it must gain negative charges.
- d. For object 2 to become object 3, it must gain positive charges.

Electrons and protons

㉝ **Copy and complete the sentences in your notebook with the words *electron(s)* or *proton(s)*.**

- a. The elementary particle with a negative charge is the … .
- b. The elementary particle with a positive charge is the … .
- c. The mass of the … is greater than that of the … .
- d. In a gas discharge tube, … are directed from the negative to the positive electrode.
- e. In a gas discharge tube, the … are directed from the positive to the negative electrode.
- f. The absolute value of the charge of the … is the same as that of the … .

㉞ **What's the relationship between the number of electrons and the number of protons in electrically neutral matter?**

㉟ **Given that the charge of the electron is $-1.602 \cdot 10^{-19}$ C, how many electrons would you need to have a charge of −1 C?**

㊱ **Answer the questions.**

- a. How many excess electrons does an object have if its charge is −2 C?
- b. How many electrons would it be missing if its charge were +2 C?

㊲ **How does an electrically neutral body acquire a positive charge? What about a negative charge?**

The first atomic models

㊳ **According to Thomson's model, is the atom divisible or indivisible? Explain your answer.**

㊴ **Write whether these statements related to the Rutherford, Geiger and Marsden experiment are *true* or *false*. Correct the false ones.**

- a. Most of the positive particles pass through the foil without being deflected, which indicates that the atom is mainly empty space.
- b. Most of the positive particles collide directly with a very dense and positive nucleus.
- c. Some positive particles pass near a very dense and positive nucleus and are deflected.
- d. According to Thomson's model, all the particles should have passed through the sheet in a straight line with hardly any deflection.

㊵ **Why did Rutherford hypothesise that there must be an undiscovered particle in the nucleus, which was later called the neutron? Which particles are responsible for most of the mass of the atom?**

㊶ **Match each particle, *electron*, *proton* and *neutron*, with one or more of these statements.**

- a. It has a positive electric charge.
- b. It has no electrical charge.
- c. It's found only inside the nucleus.
- d. It orbits around the nucleus.
- e. It has a slightly higher mass than a proton.
- f. It has a negative electrical charge.
- g. Its mass is less than that of a proton.

42 The particles with which Geiger and Marsden bombarded the fine gold foil were alpha particles. An alpha particle is a helium atom that has two protons and two neutrons in its nucleus, but has lost its two electrons.

- **a.** What's an alpha particle's charge?
- **b.** What's the mass in kilograms of an alpha particle?
- **c.** Draw a complete helium atom and an alpha particle from one helium atom.

The atomic number and mass number

43 Represent these atoms in $^{A}_{Z}X$ notation.

- **a.** Oxygen: symbol O; $Z = 8$; $A = 16$.
- **b.** Nitrogen: symbol N; $Z = 7$; $A = 14$.
- **c.** Calcium: symbol Ca; $Z = 20$; $A = 40$.
- **d.** Magnesium: symbol Mg; 12 protons; and 13 neutrons.
- **e.** Bromine: symbol Br; 35 protons; and 45 neutrons.

Bohr's atomic model

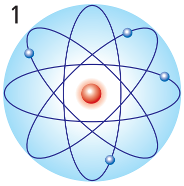
44 Are these sentences *true* or *false*? Correct the false ones.

- **a.** Energy level 2 can contain a maximum of 18 electrons.
- **b.** Energy level 1 can contain a maximum of 2 electrons.
- **c.** Rutherford's atomic model isn't valid because any rotating electrical charge must emit radiation, and this doesn't happen.
- **d.** Bohr's first proposition states that the electron moves around the nucleus in circular orbits, without any emission of energy.
- **e.** According to Bohr, all the electrons in an atom are at the same energy level.

45 Answer the questions about the atomic models of Bohr, Thomson and Rutherford.

- **a.** List these atomic models in chronological order.
- **b.** Briefly describe the characteristics of each of the models.
- **c.** Match each model with one of these drawings.

1



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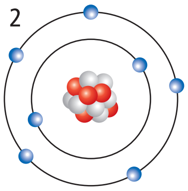

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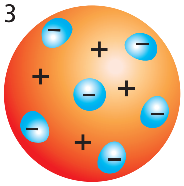
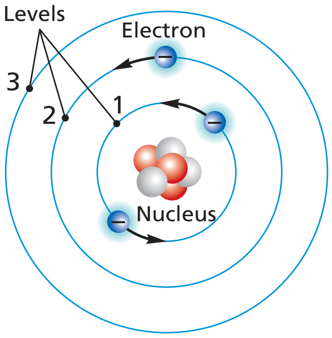
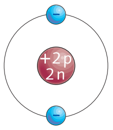


46 Look at the diagram. What happens if the electron from level 3 goes to level 2?

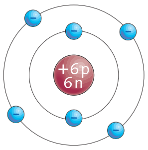


47 What's the distribution of electrons in levels and sublevels of these two atoms?

a.



b.



48 Match these atoms to the correct electron configuration: helium (2 electrons), fluorine (9 electrons), lithium (3 electrons), sodium (11 electrons), and argon (18 electrons).

a. 2 8 8 **b.** 2 **c.** 2 7 **d.** 2 1 **e.** 2 8 1

49 In your notebook, draw a $^{11}_{5}B$ atom and specify its electron configuration.

50 Draw the nucleus and energy levels of a phosphorous atom: $Z = 15$; $A = 31$.

Ion formation

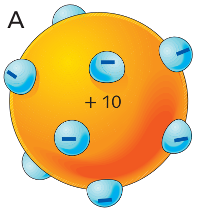
51 What happens if an electrically neutral atom loses or gains electrons?

52 Are these sentences *true* or *false*? Correct the false ones.

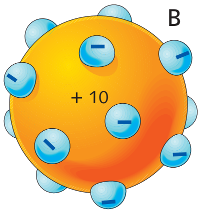
- **a.** A fluorine atom becomes an anion when it loses a proton.
- **b.** A fluorine atom becomes an anion when it gains an electron.
- **c.** A sodium atom becomes a cation if it gains a proton.

53 Thomson's model was able to explain the ion formation mechanism. What will be the net charge of an atom that has lost two electrons (A)? What will it be for an atom that has gained two electrons (B)?

A

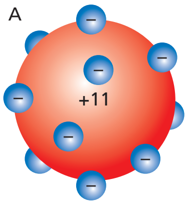


B

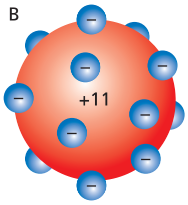


54 Look at the diagrams and answer the questions.

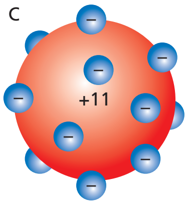
A



B



C



a. According to Thomson's model, which of these atoms is a neutral atom?

b. Which one is a positive ion?

c. Which one is a negative ion?

55 Draw an electrically neutral Thomson atom with seven negative charges embedded in a sphere with corresponding positive charges. Next, draw the same atom in the form of the following ions:

a. an ion with a negative charge.

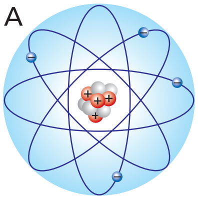
b. an ion with two negative charges.

c. an ion with a positive charge.

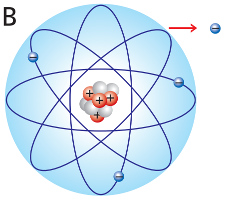
d. an ion with two positive charges.

56 Look at the drawings. What's the net charge in each case? Which one represents a neutral atom? Which represents an anion and a cation?

A



B



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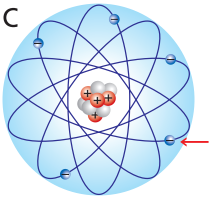


57 Work out the number of protons, neutrons, and electrons in:

a. an electrically neutral ${}^{65}_{30}\text{Zn}$ atom.

b. a ${}^{85}_{37}\text{Rb}^{+}$ ion.

c. a ${}^{80}_{35}\text{Br}^{-}$ ion.

d. an electrically neutral ${}^{81}_{35}\text{Br}$ atom.

e. an electrically neutral ${}^{205}_{82}\text{Pb}$ atom.

Isotopes

58 The isotopes of hydrogen are the only ones that have their own name. Thus, the ${}^{1}_{1}\text{H}$ isotope is called protium, or simply hydrogen, and has the symbol H. The ${}^{2}_{1}\text{H}$ isotope is called deuterium and has the symbol D, and the other ${}^{3}_{1}\text{H}$ isotope is known as tritium and has the symbol T.

a. Do you think there can be an isotope of hydrogen with two protons? What about with two neutrons? Explain your answers.

b. Draw the three isotopes of hydrogen.

59 LS Potassium naturally has three isotopes: ${}^{39}\text{K}$, ${}^{40}\text{K}$ and ${}^{41}\text{K}$. Of these, ${}^{40}\text{K}$ is radioactive. In foods such as bananas, plums and apples, we find naturally occurring potassium. Look for information about the biological functions of potassium and find out what the consequences are if our diet is deficient in this mineral.

60 We have this data about atoms A, B, C and D. Use the table to answer the questions.

A	B	C	D
13 protons 14 neutrons	13 protons 13 neutrons	14 protons 15 neutrons	14 protons 15 neutrons

a. Which ones belong to different isotopes of the same element?

b. Which ones belong to the same isotope of the same element?

c. Are atoms B and C from the same element? Explain why/why not.

61 The carbon-14 test was used to confirm that this table doesn't belong to the time of King Arthur and, therefore, isn't the Round Table.

Look for other cases where the carbon-14 test has been used to detect fake archaeological relics. Describe one of them.

62 What's the meaning of this symbol?

63 LS Many rocks contain potassium compounds. This element has a radioisotope, potassium-40. Out of every 10 000 potassium atoms, only twelve are potassium-40.

Its activity lasts a very long time – twelve thousand million years – until it ends up transforming into argon. Find out how scientists take advantage of this to find the age of a rock.

The periodic table

64 As new chemical elements were discovered, we needed some criteria to classify them according to their physical and chemical properties. One of the simplest forms of classifying them is as metals or non-metals.

a. Name five metallic and five non-metallic elements.

b. Do you know any other way to classify chemical elements? Explain.

65 Name the groups and periods in which these elements are found: nitrogen, aluminium, krypton, silver, rubidium, titanium, caesium and lead.

66 Group 18 elements such as neon are known as noble gases because they're extremely unreactive. Use the electron configuration of neon to explain why it's unlikely to form compounds.

67 Consider these chemical elements: O, Ni, Ne, Ag and N. Write:

a. their names.

b. whether or not they're metals.

c. whether or not they're representative elements.

d. the ones that belong to group 18.

e. the ones that are in the second period.

68 Write the symbols of these elements.

a. magnesium
b. carbon
c. aluminium
d. argon
e. lithium
f. silicon
g. copper
h. zinc
i. helium

69 Write the names of these elements.

a. O
b. N
c. Ni
d. H
e. Ne
f. Mn
g. Ag
h. Au
i. Hg
j. I

70 Which element is in the same period as potassium and in the same group as nitrogen?

71 We don't measure the mass of atoms on a scale or in kilograms. Instead, we compare it to the mass of a ^{12}C atom and express the result in atomic mass units.

a. Why isn't it helpful to express the mass of atoms in kilograms?

b. Find out about the instrument used to measure the mass of atoms by comparing it to that of the ^{12}C atom.

72 Find the atomic masses of rubidium, magnesium, and nickel in the periodic table of the elements. Why do you think they aren't whole numbers?

73 There are two isotopes of natural neon: one with a relative atomic mass of 20 and 90% abundance, and another with a relative atomic mass of 22 and 10% abundance. Find the relative atomic mass of the element neon.

Answer: 20.2

74 A certain chemical element is found in nature in the form of two isotopes, ^{39}X and ^{41}X, and the abundance of the former is 93.3 %. What's the relative mass of this chemical element?

Answer: 39.13

Study skills

I Write a summary of the unit by answering these questions.

- *What two electrical phenomena does matter experience?*
- *What subatomic particles are responsible for positive and negative charges?*
- *How are positive and negative charges located in the Thomson model?*
- *What's Rutherford's atomic model?*
- *What are subatomic particles?*
- *What are their basic characteristics and where are they found according to Bohr's model?*
- *How are atoms identified?*
- *When is an atom electrically neutral? When does it acquire a positive charge? And a negative charge?*
- *What are isotopes? What are radioactive isotopes?*
- *What's a chemical element?*
- *What are the criteria for ordering the elements in the periodic table? What are the representative elements? Where are metals and non-metals found in the periodic table?*

II Draw a concept map of the unit. Include these concepts: *atom, Thomson's model, Rutherford's model, Bohr's model, level and sublevels of energy, ion formation, applications of radioactive isotopes, periodic system.*

III Create your own scientific glossary. Define these terms and include others that you think are important: *electron, proton, neutron, planetary model of the atom, atomic model, mass number, K, L M and N levels, radioactive isotopes, groups and periods, metal, non-metals, noble gases, representative elements, atomic mass, relative atomic mass.*

Passnotes Digital revision activities Concept map

Science practical

Atomic spectra

In the mid-20th century, the scientists Kirchhoff and Bunsen discovered that all chemical elements produced a characteristic colour when you heat them so that they glow. In this practical, we're going to observe the characteristic light that certain elements emit.

The flames in the picture on the right show, from left to right, barium, strontium, lithium, sodium, copper and potassium.

OBJECTIVES

- Work with materials and instruments from the Physics and Chemistry lab.
- Follow safety rules in the laboratory.
- Value the importance of systematic experimental work.
- Observe, through an experiment, the light that certain chemical elements emit.

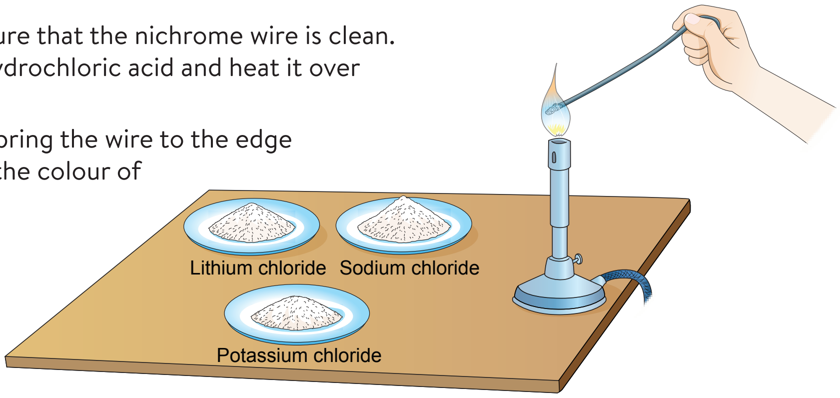
MATERIALS

- three watch classes and a test tube.
- a piece of nichrome wire
- a Bunsen burner
- hydrochloric acid, HCl
- lithium chloride, LiCl; sodium chloride, NaCl; and potassium chloride, KCl

METHOD

1. Number the three watch glasses. Put lithium chloride crystals in the first one; potassium chloride in the second one; and sodium chloride in the third one.
2. Between each stage of the experiment, make sure that the nichrome wire is clean. Insert it into the test tube with concentrated hydrochloric acid and heat it over the flame until there's no colour.
3. Take a small sample of the lithium chloride and bring the wire to the edge of the flame of the Bunsen burner. Note down the colour of the flame.

   Warning: Be careful with the flame from the Bunsen burner and avoid accidents such as burning your skin.
4. Clean the wire again and repeat the previous steps with the other two chlorides.



Analyse the results

① Based on your results, complete a table like the following in your report.

Chloride used	Flame colour observed
...	...
...	...
...	...

② Compare your results with those obtained by your classmates. Have you all come to the conclusion that each element emits a different colour?

③ Repeat the procedure with an unknown sample and find out what chloride it is.

④ Why's it necessary to clean the wire after each test?

Experiment video   Lab report

Work on your key competences

The 'healthy' elements of the periodic table

Identification sheet

Of the 118 chemical elements currently identified in the periodic table, fewer than 30 are found in living things and 21 of them are present our bodies. Deficiencies of these elements, due in most cases to a poor diet, cause various symptoms and diseases. Therefore, it's necessary to have a balanced and healthy diet that provides us with the necessary amount of each of these bioelements.

On the other hand, certain radioactive isotopes of some chemical elements are used in medicine for the diagnosis and therapy of cancer.

The **objective** of this task is to identify which elements exist in our bodies and which are isotopes used in cancer diagnosis and therapy.

Research

1. **Find out which chemical elements, such as phosphorus or potassium, are found in our bodies and are essential for health.**
2. **Find out which foods contain these elements.**
3. **Look up the health problems caused by deficiencies of these elements.**
4. **Research which radioactive isotopes are used to diagnose tumours. Which radioactive isotopes are used to treat them?**

Development

5. **Build a periodic table containing only the elements you have researched. Present it so that the following aspects are clearly visible:**
   - the bioelements. Make sure that you include their atomic symbols, atomic numbers and their origin and function.
   - the radioactive isotopes used to treat cancers. Make sure that you include their atomic numbers and mass numbers.

Writing up

6. **Plan a personal, balanced diet containing these elements. You should include:**
   - a list of those elements necessary to maintain your health and the proper functioning of your body.
   - the foods in which these elements are present and the weekly amount of each food that you should consume in a balanced diet.
7. **In a small group, make cards with the properties and uses of each of the elements you found out about. Display the cards on a physical or digital wall.**

Share your findings

8. **In your group, discuss:**
   a. the arguments you can use to convince someone that they should follow a balanced and healthy diet.
   b. the use of radioactivity in medicine to treat save lives.
   c. recommendations on how to achieve the related Sustainable Development Goals.

Task guide