Topic 1: Atomic structure and the periodic table

AQA GCSE Chemistry (8462), topic 4.1

Atomic structure and the periodic table: evidence and predictions

- tell elements, compounds and mixtures apart, write formulae and balance equations;
- choose a method to separate a **mixture**;
- explain how evidence changed the **model** of the atom;

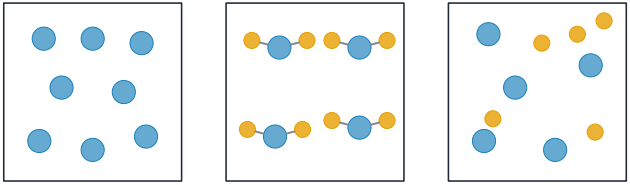
Atomic structure and the periodic table: evidence and predictions (2)

- count the protons, neutrons and electrons in atoms, ions and isotopes, and calculate **relative atomic mass**;
- link **electron** arrangement to position in the periodic table, and explain the trends in Groups 0, 1 and 7;
- (chemistry only) compare the **transition metals** with Group 1.

Elements, compounds and equations

- An **atom** 原子 is the smallest part of an **element** 元素 that can exist.
- All the atoms of one element have the same number of protons.
- An element can be made of single atoms, like helium, or of molecules, like oxygen, O_2: two atoms, but still only one element.
- A **compound** 化合物 contains two or more elements chemically combined in fixed proportions.

Figure: Elements, compounds and equations



element
only one
type of atom

compound
different
atoms bonded
in a fixed ratio

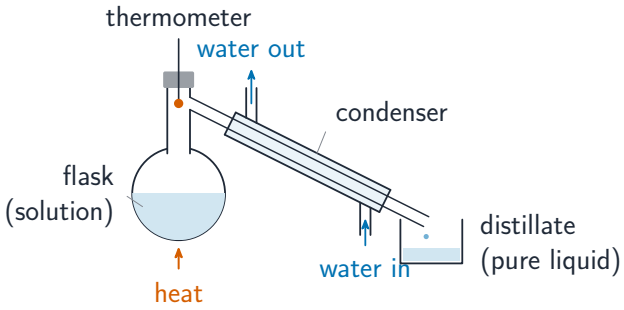
mixture
not bonded,
easy to separate

- An element has one type of atom; a **compound** has different atoms bonded in a fixed ratio; a **mixture** is not bonded
- Match each part of the diagram to the text.

Separating mixtures

- A **mixture** 混合物 contains substances that are not chemically joined, so each keeps its own properties.
- Separating a **mixture** makes no new substances.
- Choose the method from the property that differs between the parts.
- **Worked example 2: pure salt from rock salt.** Rock salt is salt mixed with sand.

Figure: Separating mixtures

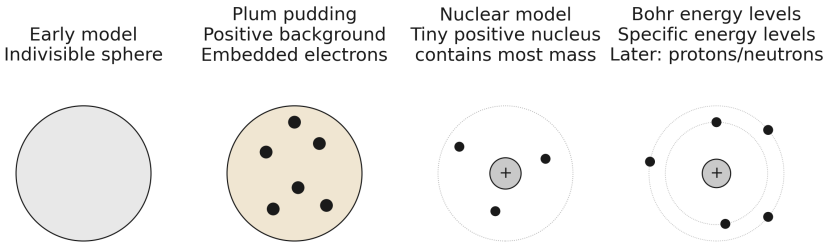


- **Simple distillation**: the solvent boils off, the condenser cools it back to a liquid, and the pure distillate is collected
- Match each part of the diagram to the text.

How evidence changed the model of the atom

- **Around 1800**, John Dalton described atoms as tiny spheres that could not be divided.
- **In 1897**, J. J. Thomson discovered the **electron**, a tiny negative particle inside atoms. So atoms must have parts. He proposed the **plum pudding model 布丁模型**: a ball of positive charge with negative electrons scattered through it.
- **In 1909**, Hans Geiger and Ernest Marsden, working for Ernest Rutherford in Manchester, fired positive alpha particles at a sheet of gold foil only a few hundred atoms thick.

Figure: How evidence changed the model of the atom



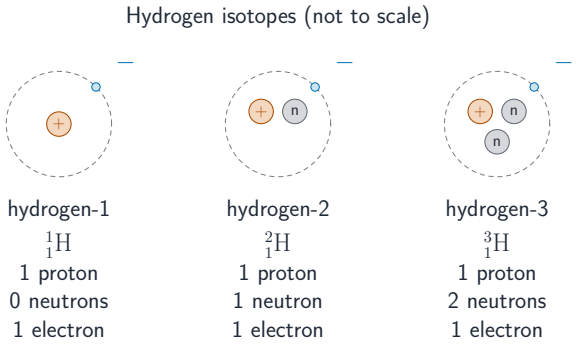
- The atom **model** timeline: indivisible sphere, plum pudding, nuclear, Bohr, then **proton** and **neutron**.
- Match each part of the diagram to the text.

Inside the atom: particles, size and isotopes

- The **atomic number 原子序数** is the number of protons.
- It decides which element an atom is.
- The **mass number 质量数** is the number of protons plus neutrons.
- In an atom the numbers of protons and electrons are equal, so the atom has no overall charge.

$$A_r = \frac{\sum(\text{mass number} \times \text{percentage abundance})}{100}$$

Figure: Inside the atom: particles, size and isotopes

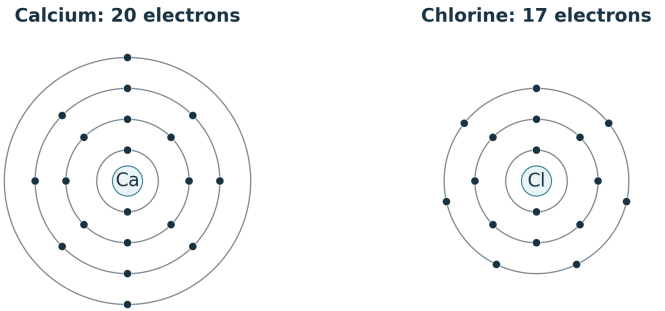


- Isotopes differ only in the number of neutrons
- Match each part of the diagram to the text.

Electrons and the periodic table

- Electrons fill the lowest **energy levels 能级**, or shells, first.
- For the first twenty elements, the first shell holds up to 2 electrons, the second up to 8, and the third up to 8 before the fourth shell begins.
- An **outer shell electron 最外层电子** is one in the highest occupied shell; these electrons decide how an element reacts.
- **Worked example 7.** Calcium has 20 electrons: 2 in the first shell, 8 in the second, 8 in the third and 2 in the fourth, written 2,8,8,2.

Figure: Electrons and the periodic table

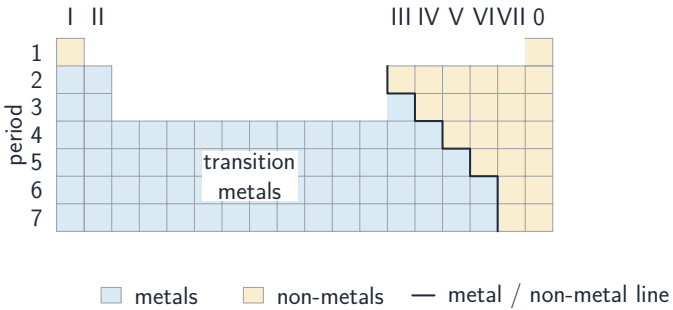


- Complete neutral calcium/chlorine shell diagrams;first-twenty **model**.
- Match each part of the diagram to the text.

Building the periodic table; metals and non-metals

- In the early 1800s, chemists arranged the elements in order of atomic weight, since protons were not yet known.
- These early tables put some elements next to others with very different properties.
- **Mendeleev** solved this in two ways: he left gaps for elements not yet discovered, and in a few places he changed the order to keep elements with similar properties in the same **group**.
- When gallium (1875) and germanium (1886) were found with the properties he had predicted, scientists accepted his table.

Figure: Building the periodic table; metals and non-metals



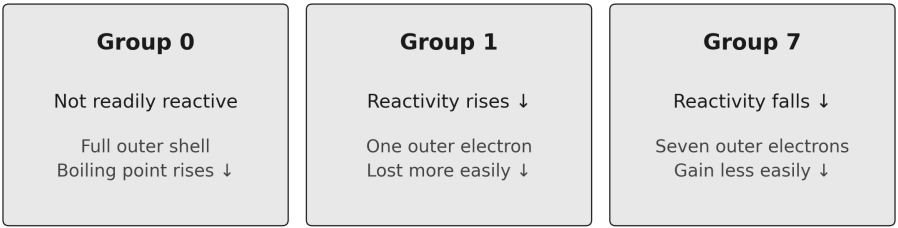
- Groups are the columns and periods are the rows; metals lie to the left of the staircase, non-metals to the right
- Match each part of the diagram to the text.

Groups 0, 1 and 7

- **Group 0.** Each **noble gas** 稀有气体, such as helium, neon or argon, is very unreactive because its outer shell is full.
- The noble gases exist as single atoms.
- Their boiling points increase down the **group** as the **relative atomic mass** increases.
- **Group 1.** Each **alkali metal** 碱金属 has one outer **electron** and forms a $+1$ ion.

$4\mathrm{Li} + \mathrm{O_2} \rightarrow 2\mathrm{Li_2O}$ $2\mathrm{Na} + \mathrm{Cl_2} \rightarrow 2\mathrm{NaCl}$ $2\mathrm{K} + 2\mathrm{H_2O} \rightarrow 2\mathrm{KOH} + \mathrm{H_2}$

Figure: Groups 0, 1 and 7



Down a group, the outer occupied shell is farther from the nucleus.

- **Group** 0, 1 and 7 trend summary: reactivity, outer electrons and boiling points.
- Match each part of the diagram to the text.

Transition metals (chemistry only)

- they can form ions with different charges, such as Fe^{2+} and Fe^{3+};
- their compounds are often coloured: copper(II) sulfate solution is blue, iron(II) compounds are often pale green and iron(III) compounds orange-brown;
- they and their compounds are often useful as a **catalyst** 催化剂: iron in the Haber process for making ammonia, and nickel for turning vegetable oils into margarine.

Sources for this lesson

- AQA, *GCSE Chemistry (8462) specification*, section 4.1.
- D. **Mendeleev**, "Die periodische Gesetzmässigkeit der chemischen Elemente", *Annalen der Chemie und Pharmacie*, supplement 8 (1871), with the predictions for eka-aluminium.
- P.-É. Lecoq de Boisbaudran, reports on gallium in *Comptes rendus* (1875–1876).

Sources for this lesson (2)

- H. Geiger and E. Marsden, "On a diffuse reflection of the α-particles", *Proceedings of the Royal Society A* (1909), and E. Rutherford, *Philosophical Magazine* (May 1911).
- J. Chadwick, "Possible existence of a **neutron**", *Nature* (27 February 1932).

Common errors

- Changing a formula to balance an equation; change only the numbers in front.
- Saying the **atomic number** is the number of protons plus neutrons; that is the **mass number**.
- Saying an ion forms when an atom gains or loses protons; only electrons change.

Common errors (2)

- Saying isotopes are different elements; they have the same number of protons.
- Taking a simple average of **isotope** masses instead of a weighted mean.
- Saying the alpha particles that bounced back show the atom is solid; most went straight through.
- Saying **Group** 1 reactivity increases because the outer **electron** is "more attracted"; it is less attracted, so it is lost more easily.

Key terms

- **Element**: a substance made of only one kind of atom, all with the same number of protons.
- **Compound**: two or more elements chemically combined in fixed proportions.
- **Mixture**: two or more substances that are not chemically combined.

Key terms (2)

- **Atomic number**: the number of protons in the nucleus of an atom.
- **Mass number**: the total number of protons and neutrons in an atom.
- **Isotope**: an atom of an element with a different number of neutrons.

Key terms (3)

- **Relative atomic mass**: the weighted mean mass of the atoms of an element.
- **Group**: a column of the periodic table; elements in it have the same number of outer electrons.

Check yourself

- 1.
- Is air an element, a **compound** or a **mixture**?
- Explain. 2.
- Which method would you use to separate the dyes in a black felt-tip pen? 3.