Atoms and Isotopes
Atoms and Isotopes

Atomic structure

What are isotopes?

Relative atomic mass and isotopes

Summary activities
How big is an atom?

1 m (10^9 m)
A small child is about 1 m high.
That’s the same as 1,000,000,000 mm.
What particles are atoms made of?

Atoms are made up of three smaller particles:

- **protons**
- **neutrons**
- **electrons**

The protons and neutrons exist in a dense core at the centre of the atom. This is called the **nucleus**.

The electrons are spread out around the edge of the atom. They orbit the nucleus in layers called **electron shells**.
There are two properties of protons, neutrons and electrons that are especially important:

- mass
- electrical charge.

<table>
<thead>
<tr>
<th>particle</th>
<th>mass</th>
<th>charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>proton</td>
<td>1</td>
<td>+1</td>
</tr>
<tr>
<td>neutron</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>electron</td>
<td>almost 0</td>
<td>-1</td>
</tr>
</tbody>
</table>

The atoms of an element have no overall charge, why is this?
Each element has a fixed number of protons. All of the atoms of a particular element always contain the same number of protons. For example:

- hydrogen atoms always contain 1 proton
- carbon atoms always contain 6 protons.

If the number of protons changes, then the atom becomes a different element.

The number of protons in an atom is known as the atomic number or proton number.

It is the smaller of the two numbers in most periodic tables.
### The atomic number (proton number)

What are the atomic (proton) numbers of these elements?

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Number</th>
<th>Proton Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>Iron</td>
<td>56</td>
<td>26</td>
</tr>
<tr>
<td>Tin</td>
<td>119</td>
<td>50</td>
</tr>
<tr>
<td>Fluorine</td>
<td>19</td>
<td>9</td>
</tr>
</tbody>
</table>
What is the mass number? (1)

Electrons have a mass of almost zero, which means that the mass of each atom results almost entirely from the number of protons and neutrons in the nucleus.

The sum of the protons and neutrons in an atom’s nucleus is the mass number.

It is the larger of the two numbers in most periodic tables.

<table>
<thead>
<tr>
<th>Atoms</th>
<th>Protons</th>
<th>Neutrons</th>
<th>Mass Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Lithium</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Aluminium</td>
<td>13</td>
<td>14</td>
<td>27</td>
</tr>
</tbody>
</table>
What is the mass number? (2)

**mass number = number of protons + number of neutrons**

What is the mass number of these atoms?

<table>
<thead>
<tr>
<th>Atoms</th>
<th>Protons</th>
<th>Neutrons</th>
<th>Mass number</th>
</tr>
</thead>
<tbody>
<tr>
<td>helium</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>copper</td>
<td>29</td>
<td>35</td>
<td>64</td>
</tr>
<tr>
<td>cobalt</td>
<td>27</td>
<td>32</td>
<td>59</td>
</tr>
<tr>
<td>iodine</td>
<td>53</td>
<td>74</td>
<td>127</td>
</tr>
<tr>
<td>germanium</td>
<td>32</td>
<td>41</td>
<td>73</td>
</tr>
</tbody>
</table>
An **ion** is an atom, or a group of atoms, that has lost or gained electrons. This means that the number of electrons no longer equal the number of protons.

Sodium (Na) can form a Na\(^+\) ion. How many protons, electrons and neutrons does Na\(^+\) have?

Use the tile from the periodic table below to help you.

- **Na**
  - 11 protons
  - 12 neutrons
  - 10 electrons

Na\(^+\) has a charge of +1 because it has lost one electron, and has one more proton than electrons.
Atoms and Isotopes

- Atomic structure
- What are isotopes?
- Relative atomic mass and isotopes
- Summary activities
What is an isotope?

Elements are made up of one type of atom, but the atoms of an element can come in slightly different forms.

Although atoms of the same element always have the same number of protons, the number of neutrons they have can vary.

Atoms that differ in this way are called isotopes.

For example, two isotopes of carbon:
What are the isotopes of carbon?

Most naturally-occurring carbon exists as carbon-12, about 1% is carbon-13 and a much smaller amount is carbon-14.

- Carbon-12: 6 protons, 6 neutrons, 6 electrons
- Carbon-13: 6 protons, 7 neutrons, 6 electrons
- Carbon-14: 6 protons, 8 neutrons, 6 electrons

How will this affect reactions involving carbon isotopes?
Properties of isotopes

The isotopes of an element are virtually identical in their chemical reactions.

This is because they all have the same number of protons and the same number of electrons.

The uncharged neutrons make little difference to chemical properties, but do affect physical properties such as melting point and density.

Natural samples of elements are often a mixture of isotopes.
What are the isotopes of hydrogen?

Hydrogen-1 makes up the vast majority of the naturally-occurring element, but two other isotopes exist.

- **Hydrogen**
  - 1 proton
  - 0 neutrons
  - 1 electron

- **Deuterium**
  - 1 proton
  - 1 neutron
  - 1 electron

- **Tritium**
  - 1 proton
  - 2 neutrons
  - 1 electron
What are the isotopes of chlorine?

About 75% of naturally-occurring chlorine is chlorine-35, and 25% is chlorine-37.

- **Chlorine-35**
  - 17 protons
  - 18 neutrons
  - 17 electrons

- **Chlorine-37**
  - 17 protons
  - 20 neutrons
  - 17 electrons
What are the isotopes of oxygen?

Almost all naturally-occurring oxygen is oxygen-16, but about 0.2% is oxygen-18.

How many protons, neutrons and electrons are in each isotope below?

**oxygen-16**
- 8 protons
- 8 neutrons
- 8 electrons

**oxygen-18**
- 8 protons
- 10 neutrons
- 8 electrons
**Isotopes – true of false?**

<table>
<thead>
<tr>
<th>Statement</th>
<th>True/False</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Isotopes of an element have the same number of protons but different numbers of neutrons.</td>
<td>True</td>
</tr>
<tr>
<td>2. Isotopes of an element have different atomic numbers but the same mass number.</td>
<td>False</td>
</tr>
<tr>
<td>3. Isotopes have the same chemical properties but different physical properties.</td>
<td>True</td>
</tr>
<tr>
<td>4. Natural samples of elements are always made up of just one isotope.</td>
<td>False</td>
</tr>
<tr>
<td>5. There are three isotopes of carbon – carbon-12, carbon-13 and carbon-14.</td>
<td>True</td>
</tr>
<tr>
<td>6. Most hydrogen occurs as hydrogen-1, with one proton and one electron, and no neutrons.</td>
<td>True</td>
</tr>
</tbody>
</table>
What is relative atomic mass?
Where are r.a.m. values found?

The values of **relative atomic mass (r.a.m.)** are usually given in a data book or found in the periodic table, so you don’t have to work them out or remember them all!

When looking up r.a.m in the periodic table, remember that it is always the larger of the two numbers given.
Why isn’t r.a.m. always a whole number?

Relative atomic mass (r.a.m.) is not always a whole number. For example, the r.a.m. of chlorine is 35.5. The standard r.a.m. value of each element is actually the average relative atomic mass, which takes all the isotopes of each element into account.

Chlorine has two isotopes: chlorine-35 (75%) and chlorine-37 (25%).

How do we calculate the average r.a.m of chlorine?

average r.a.m. of chlorine  = (35 × 75%) + (37 × 25%)
= (35 × 0.75) + (37 × 0.25)
= 26.25 + 9.25
= 35.5
To calculate the average r.a.m. of a mixture of isotopes, multiply the percentage of each isotope by its relative atomic mass and then add these together.

Naturally-occurring bromine is composed of two isotopes: bromine-79 (50.5%) and bromine-81 (49.5%).

What is the average r.a.m. of naturally-occurring bromine?

average r.a.m. = (79 \times 50.5\%) + (81 \times 49.5\%)

= (79 \times 0.505) + (81 \times 0.495)

= 39.895 + 40.095

= 79.99

This figure can be rounded up.
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Multiple-choice quiz