**Student worksheet**

**Starter activity**

Can you match up the particle, mass and charge?

<table>
<thead>
<tr>
<th>Particle</th>
<th>Charge</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>0</td>
<td>tiny</td>
</tr>
<tr>
<td>Neutron</td>
<td>-1</td>
<td>1 g per mole</td>
</tr>
<tr>
<td>Electron</td>
<td>+1</td>
<td>1 g per mole</td>
</tr>
</tbody>
</table>

**Isotopes**

Atoms of the same element but with different masses are known as isotopes.

Nearly all the mass in an atom of an element is concentrated in the centre part, called the nucleus. All nuclei are made up of tiny particles called protons and neutrons. All oxygen atoms (by definition) have 8 protons in the nucleus. Most have 8 neutrons. The electrons sit in shells around the outside, and the number of electrons (which for an uncharged atom of an element is always the same as the number of protons) determines how big the atom is.
2 in every 1,000 oxygen atoms (or 20 in 10,000) has 10 neutrons, giving 18 particles in the nucleus.

4 in every 10,000 oxygen atoms has 9 neutrons in the nucleus. Can you draw and name this isotope?

If only these three isotopes of oxygen exist, how many atoms in every 10,000 oxygen atoms are oxygen-16?

Calculate the average atomic mass of a randomly selected oxygen atom.

\[
\text{average} = \frac{\text{sum of terms}}{\text{number of terms}}
\]

\[
16 + 16 + 16 + ... + 17 + 17 + 17 + 18 + 18 + 18 + ... = \frac{20 \times 18}{10,000}
\]
Looking carefully

Can you match up the pairs of isotopes?

Ricky uses the fact that about 2 in every 1,000 water molecules contain oxygen-18 and are “heavier” than the other water molecules to find out about rainfall 140 million years ago.

Her mass spectrometer can determine how many heavy water molecules there are in rocks that formed during the Cretaceous period.

True or false? Isotopes of the same element take up the same amount of space, but are a different weight.

What is density?

Density is how heavy something is compared to how big it is. More dense things are the same size but heavier OR the same weight, but smaller. Can you write an equation to calculate density?
How many atoms are there in each of these molecules?

**Carbon dioxide, CO₂**
- Atoms: ____
- Weight: ____

**Nitrogen, N₂**
- Atoms: ____
- Weight: ____

**Oxygen, O₂**
- Atoms: ____
- Weight: ____

**Water, H₂O**
- Atoms: ____
- Weight: ____

On average...
- The oxygen atom weighs 16 g per mole.
- The hydrogen atom weighs 1 g per mole.
- The carbon atom weighs 12 g per mole.
- The nitrogen atom weighs 14 g per mole.

How much does each molecule weigh? Circle the heaviest.

**Our atmosphere**

The table below shows the composition of inhaled air and exhaled air.

Use the numbers 20.9%, 4.0%, and 0.94% and your knowledge of respiration to fill in the gaps.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Inhaled air</th>
<th>Exhaled air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>78.1%</td>
<td>78.1%</td>
</tr>
<tr>
<td>Oxygen</td>
<td></td>
<td>16%</td>
</tr>
<tr>
<td>Water vapour</td>
<td>0-3%</td>
<td>&gt; inhaled air</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>0.03%</td>
<td></td>
</tr>
<tr>
<td>Noble gases</td>
<td></td>
<td>0.94%</td>
</tr>
</tbody>
</table>

Is exhaled air heavier or lighter than inhaled air?

Test your answer. Blow up a balloon and let it go at shoulder height. What happens? Why?

**Observations:** ____________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

**Explanation:** ____________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

www.oxfordsparks.ox.ac.uk/scienceoutthere
Experiment

Air is a mixture of different gases. However, we can make pure carbon dioxide through a simple experiment.

For the experiments, you should work in pairs.

**Step 1:** You will need:

- 1 test tube
- 1 ruler
- 1 spoon
- Bicarbonate of soda
- Vinegar

**Instructions:** You are going to combine bicarbonate of soda and vinegar to make carbon dioxide.

\[ \text{Bicarbonate of soda} + \text{vinegar} = \text{carbon dioxide} + \text{salt} + \text{water} \]

But how much of each should you add? You want the mixture to bubble up to the top of your test tube, pushing out all the other air, but not to overflow.

Use the table to trial the experiment and deduce the right amounts.

Repeat the experiment as many times as you need. You do not need to fill in all the rows.

Remember to wash your test tube out between each trial.

www.oxfordsparks.ox.ac.uk/scienceoutthere
Step 2: You will need:

- 1 test tube
- 1 ruler
- 1 spoon
- 1 balloon
- Bicarbonate of soda
- Vinegar

Instructions: Measure out the right amount of vinegar in your test tube and the right amount of bicarbonate of soda in your balloon. Place the balloon round the top of your test tube.

You are going to lift up the balloon, dropping the bicarbonate of soda into the vinegar, but first, what do you think will happen when you do this?

Make a prediction:

Now try the experiment.

Observations:

You now have a balloon filled with carbon dioxide. Let it go at shoulder height. What happens? Why?

Extension

The half-life of an isotope describes how long it takes for half of it to decay away.

- $^{14}$C has a half-life of 5,730 ± 40 years and is used for dating historic artefacts.
- $^{238}$U has a half-life of 4.47 billion years and $^{235}$U has a half-life of 0.70 billion years. These isotopes are used to estimate the age of rocks.
- $^{18}$O is considered stable and is used for finding out how much rainfall fell where 140 million years ago.

Talk to your partner. Decide why each of these isotopes is chosen for its use.