Heavy Water

Suitable for UK KS3 or ages 11-14

Student worksheet

Starter activity

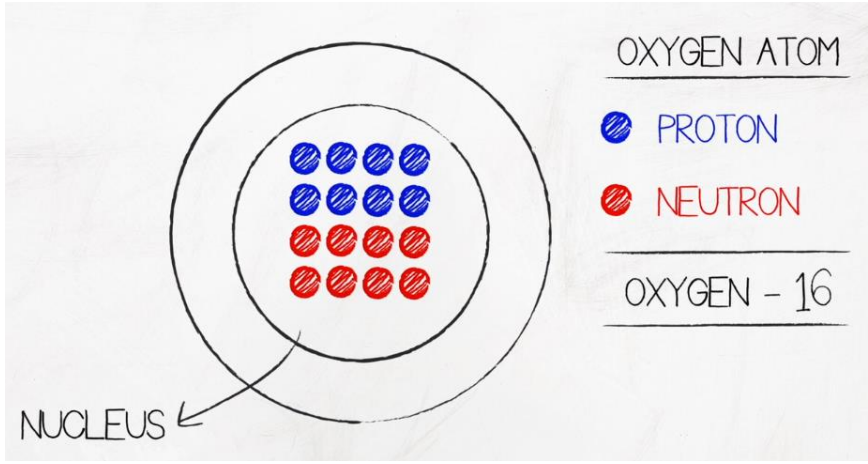
Can you match up the particle, mass and charge?

Particle	Charge	Mass
Proton	0	tiny
Neutron	-1	1 g per mole
Electron	+1	1 g per mole

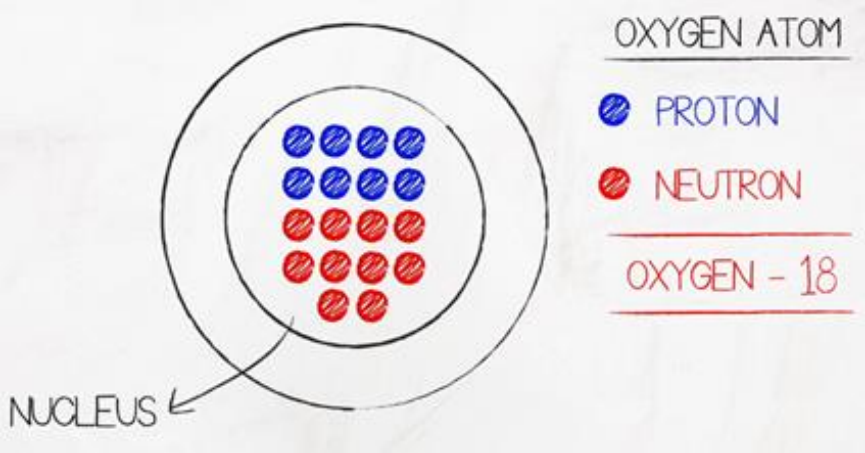
Isotopes

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?

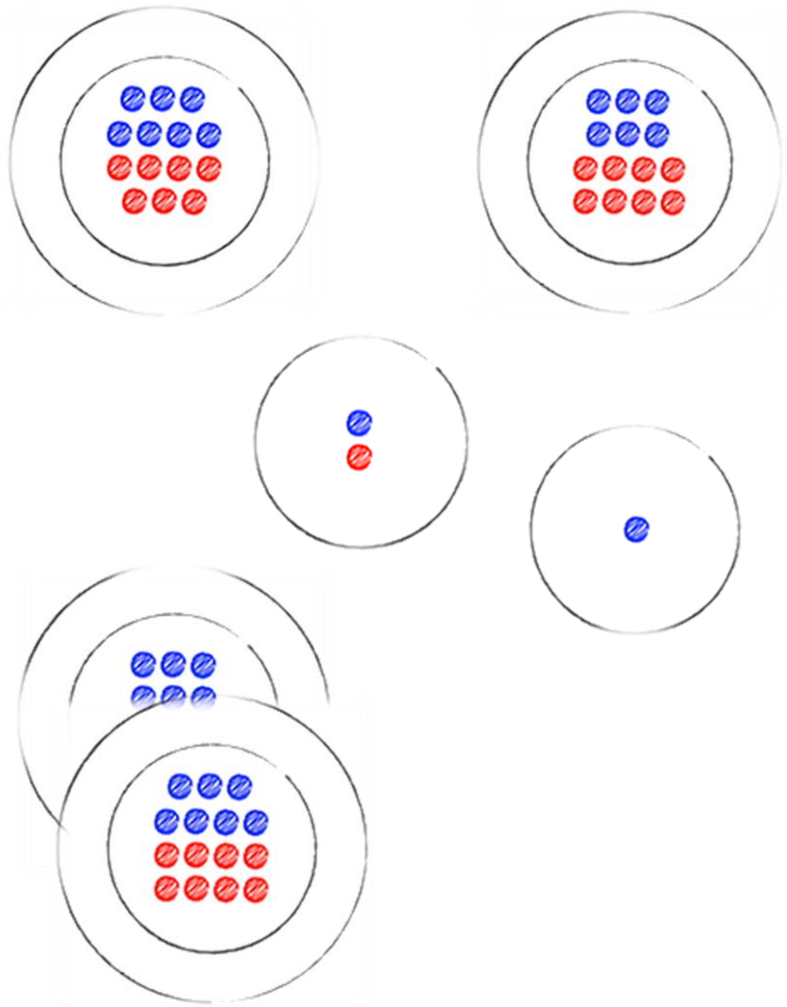
Calculate the **average** atomic mass of a randomly selected oxygen atom.

$$\text{average} = \frac{\text{sum of terms}}{\text{number of terms}}$$

$$= \frac{\overbrace{16+16+16+\ldots}^{?\times 16}+17+17+17+17+\overbrace{18+18+18+\ldots}^{20\times 18}}{10{,}000}$$

Looking carefully

Can you match up the pairs of isotopes?



Look at a periodic table and count the protons: can you name the elements?

Heavy water

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?

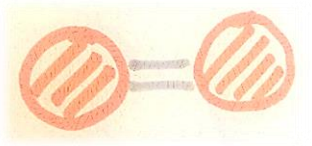
How many atoms are there in each of these molecules?

Carbon dioxide, CO_2

Atoms: ____ **Weight:** ____

Nitrogen, N_2

Atoms: ____ **Weight:** ____



Oxygen, O_2

Atoms: ____ **Weight:** ____

Water, H_2O

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.

Gas	Inhaled air	Exhaled air
Nitrogen	78.1%	78.1%
Oxygen		16%
Water vapour	0-3%	> inhaled air
Carbon dioxide	0.03%	
Noble gases		0.94%

Is exhaled air heavier or lighter than inhaled air?

heavier lighter

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

Observations: _____

_____

Explanation: _____

_____

_____

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**.

Bicarbonate of soda + vinegar = carbon dioxide + salt + 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.

Amount of vinegar added to tube (cm from bottom)	Spoonfuls of bicarbonate added	Too much/too little/just right

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?

Observations: _____

_____

Explanation: _____

_____

_____

Small differences in the mass of molecules can be used to reveal clues about our planet's past. As you saw in the video, every place has a unique balance of oxygen isotopes from rain, depending on how close it is to the poles as well as the planets temperature, weather patterns and other things. When minerals form they take up this water and preserve the isotopes. This is how Ricky can find out about rainfall 140 million years ago.

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.