Your Mission: The case of the elusive elements

Greetings! I am Sherlock Ohms, the super scientific detective. Join me on a curious chemical case: A SEARCH FOR THE ELUSIVE ELEMENTS. Track down the amazing matter around you and it can give you clues to the universe itself!

Key

- Look for this
- Experiment!
- Appearance
- Element of danger
- Superpower

Everything in our homes, in the world, in the universe – from microbes to mountains, from grandmas to galaxies – is made from incredibly tiny building blocks. There are over 100 different types of these building blocks, which scientists call the 'elements'.

Some elements date back to the start of time. Some are manmade and only exist in laboratories. But most occur naturally on Earth, and many can be found in your home. All matter we can detect is made from them and – amazingly – most were first formed inside stars. But you don't need a spaceship to search for them. You just need to know what to look for and where.

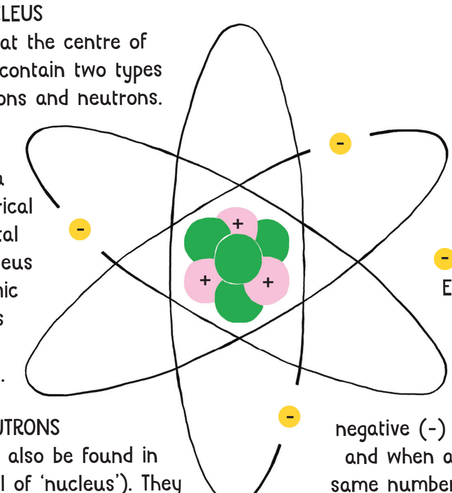
That's what this book is about. Along with my friends Ratley and Hattie, we will reveal what elements are, how they behave, and how YOU can detect them in your home. So join us on the hunt for... The Element in the Room!

Utterly elementary: atoms

The matter that makes up everything on Earth – air, water, cheese, *you* – is made from tiny particles called atoms. These are composed of even tinier particles known as protons, neutrons and electrons. Each of the 118 known elements is a unique atom with a different number – from 1 to 118 – of protons in its nucleus. That's what makes them elements! Elements are the building blocks of ordinary matter and can't be broken down into simpler substances by a chemical reaction. But their atoms can be 'smashed' apart using powerful radiation!

NUCLEUS
The nucleus is at the centre of an atom. It can contain two types of particles: protons and neutrons.

PROTONS
Protons have a positive (+) electrical charge. Their total number in a nucleus (called its 'atomic number') gives an element its chemical identity.



ELECTRONS
Electrons orbit the nucleus at many millions of miles per hour. They have a negative (-) electrical charge, and when an atom has the same number of electrons as protons it has no overall charge.

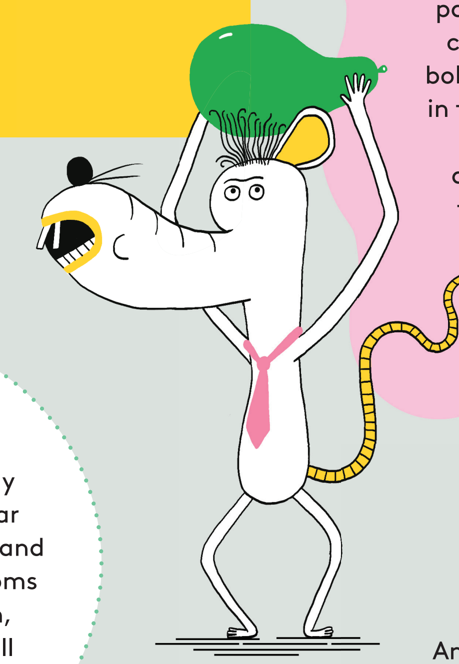
NEUTRONS
Neutrons may also be found in nuclei (the plural of 'nucleus'). They have a neutral electrical charge.

The case of the hair-raising balloon

To demonstrate the effect of electrons for yourself, rub a blown-up balloon against your hair. Electrons are stripped from the atoms in your hair onto the balloon's surface. The extra electrons give the balloon a negative charge, which we call 'static electricity'. This negative charge will attract your hair and small pieces of paper to the balloon. And if the balloon has a high enough charge, it will even 'stick' to a wall!

The case of the balloon lightning

Lightning is a giant discharge of static electricity caused by ice particles colliding inside clouds. You can make a similar mini-lightning bolt by rubbing a balloon with a cloth in the dark on a dry day and bringing it close to a metal object like a doorknob. A spark leaps between the two and the crackle you hear is a tiny thunderclap!



Tiny atoms

Atoms are unimaginably tiny! A teaspoon of sugar contains about 396 thousand million million million atoms of the elements carbon, hydrogen and oxygen all combined together.

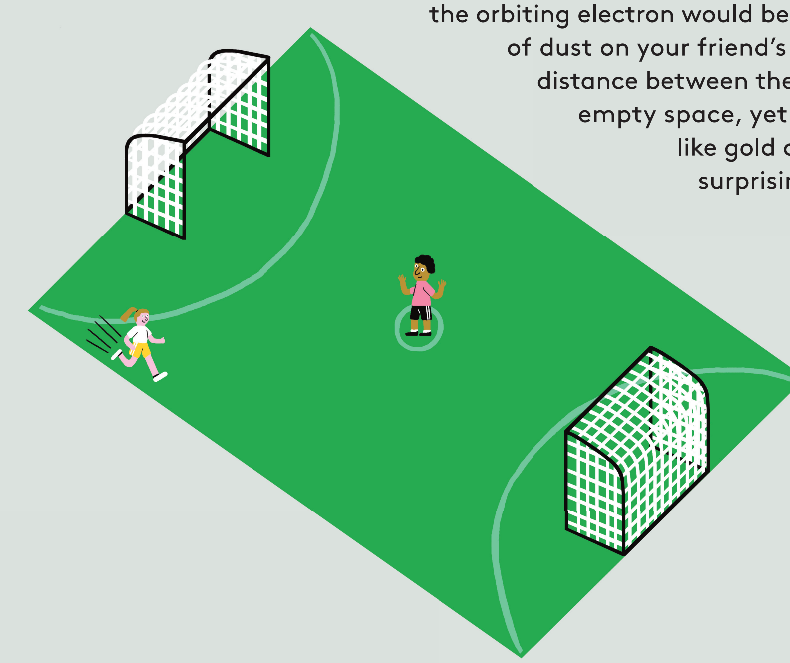
396,000,000,000,000,000,000,000

The empty atom

Amazingly, atoms are mostly empty space. Hold up a pin in the middle of a football field and ask a friend to run around its furthest edge. If the pin's head is taken to represent the size of a single proton in the nucleus of a hydrogen atom, then the orbiting electron would be a tiny speck of dust on your friend's nose. The distance between the two is just empty space, yet an element like gold can feel surprisingly solid!

Why did the balloon stick to the wall?

Elementary! Matching charges (+/+ or -/-) always repel. So the negative charge of the balloon repels the negative electrons in the atoms of the wall. This leaves the atoms of the wall with a positive charge from the remaining protons. Opposite charges (+/-) always attract, so the balloon sticks.



The First Mystery: The Big Bang

Our detective hunt begins 13.8 billion years ago! Back then, there was… nothing. No sun, no stars, no planets, no galaxies, no teachers, no homework, no elements, no matter, no clues. Then came the mind-blowing, monumental moment known as the Big Bang. This was when the universe was born, and it was the start of the incredible process that led to the elements being formed…

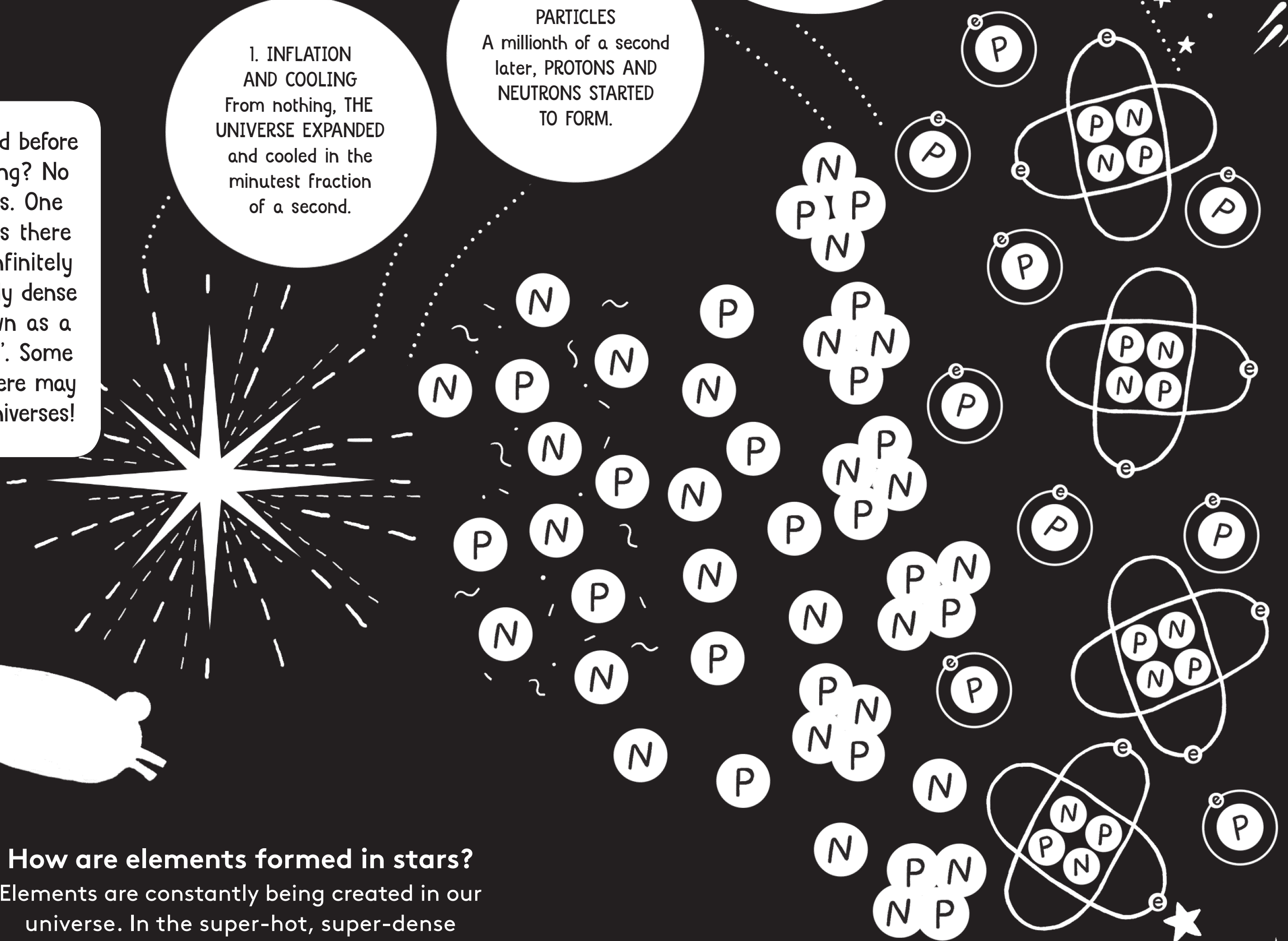
What existed before the Big Bang? No one knows. One theory says there was one infinitely hot, infinitely dense point known as a 'singularity'. Some also say there may be other universes!

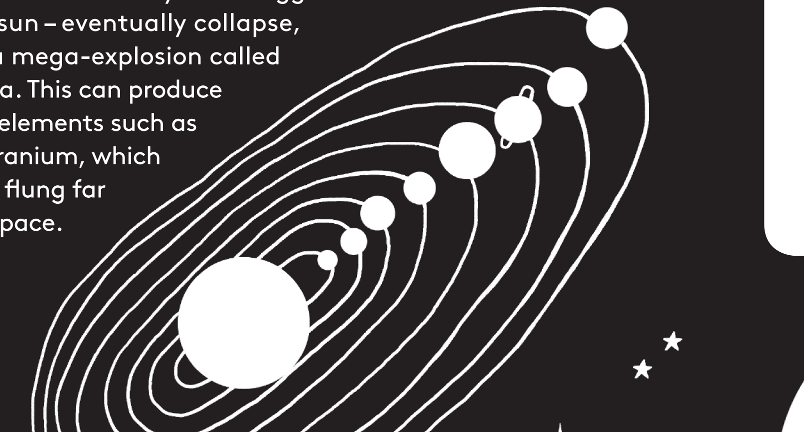
1. INFLATION AND COOLING
From nothing, THE UNIVERSE EXPANDED and cooled in the minutest fraction of a second.

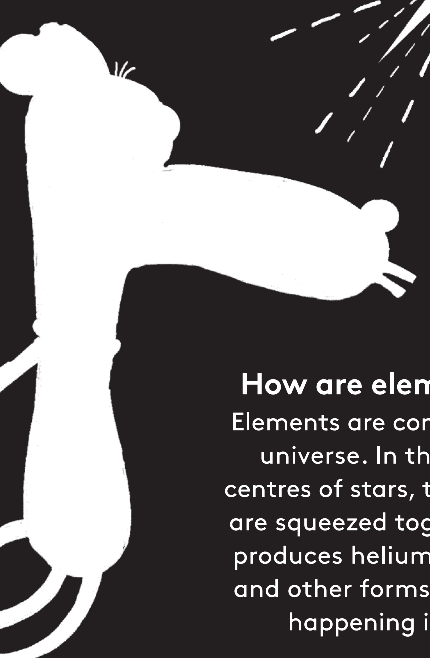
2. THE FIRST PARTICLES
A millionth of a second later, PROTONS AND NEUTRONS STARTED TO FORM.

3. THE FIRST ELEMENTS
Within two minutes, the nuclei of THE FIRST ELEMENT, HYDROGEN, BEGAN TO FORM. A MINUTE LATER, THE NUCLEI OF HELIUM FOLLOWED. After this, it took about 380,000 years for things to cool down enough for these nuclei to form stable atoms.

4. THE FIRST STARS
Clouds of hydrogen and helium were flung out across the newly formed universe. About 200 MILLION YEARS LATER, THE FORCE OF GRAVITY BEGAN TO FORM THEM INTO THE FIRST STARS. And these stars hold your first clue to the secrets of the elements.







Massive stars
Really massive stars – many times bigger than our sun – eventually collapse, producing a mega-explosion called a supernova. This can produce extra-heavy elements such as gold and uranium, which are then flung far into space.

Evidence of the Big Bang can still be discovered almost 14 billion years later. The radiation it released is visible in space as background microwaves, and can be detected by special radio telescopes.

How are elements formed in stars?
Elements are constantly being created in our universe. In the super-hot, super-dense centres of stars, the nuclei of hydrogen atoms are squeezed together. This nuclear reaction produces helium. It also creates visible light and other forms of radiation. That's what is happening in the centre of our sun.

Larger stars
Larger stars continue fusing elements to produce heavier elements (with more protons), from oxygen all the way up to iron, before they also collapse and die. The reactions within them may also produce even heavier elements such as copper and zinc.

The case of the disappearing sun
Our sun is vital for life on Earth but is actually quite a small star. Eventually it will run out of the elements that fuel fusion and will get colder and collapse, shedding its outer layer of heavier elements into space. But don't panic – it won't happen for about 5 billion years.

The mystery of the cosmic rays
Three lighter elements – lithium, beryllium and boron – are thought to be made by 'cosmic rays' splitting heavier elements in space into simpler atoms. Cosmic rays are high-energy particles whose origins are a mystery. They pose a serious health risk to space travellers, but rarely reach Earth's surface thanks to its atmosphere and magnetic field.

Xe Marks the Spot: Periodic Table

Every detective should draw up a list of suspects. Element detectives have a list of 118 to choose from, already arranged in a special table according to their weight and properties. Chemists call this the 'Periodic Table'.

The idea for the table originally came from a brilliant Russian boffin called Dmitri Mendeleev. And it was such a good idea that Mendeleev was able to use his table to predict the existence of elements that hadn't yet been discovered! However, the information the table contains today is the result of hundreds of years of detective work by lots of clever chemists, many of whom you will meet in our amazing Atomic Comics scattered throughout the book!

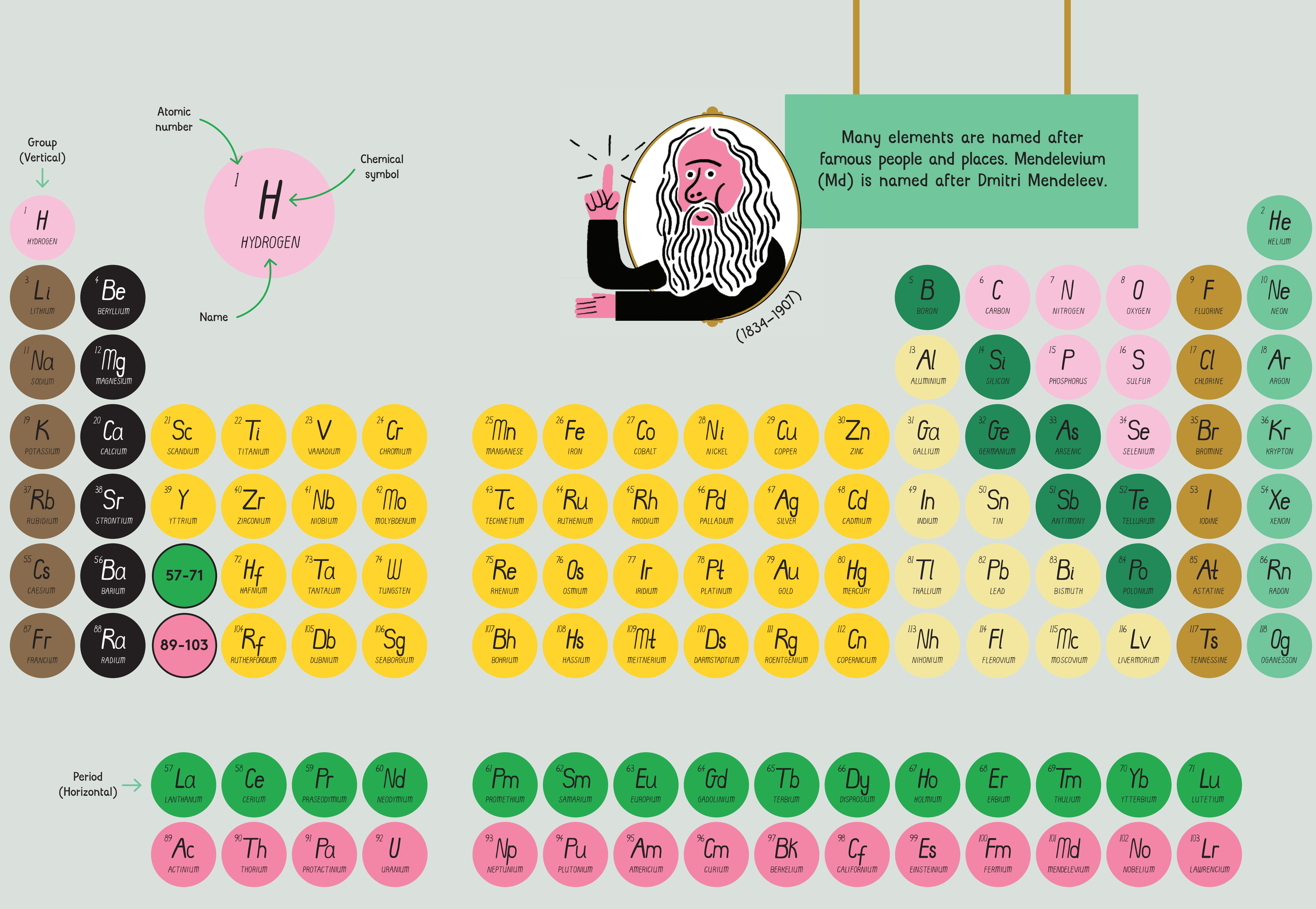
As you can see, the elements are arranged into rows and columns. The horizontal rows are known as 'periods', giving the Periodic Table its name. The vertical columns are called 'groups'. Today's Periodic Table includes the 118 elements known so far, from hydrogen to oganesson, but could still acquire new members.

Each element has a chemical symbol, like a code name, which is made up of one or more letters. So Xe is the symbol for xenon.

Know your suspects

Like a map, the Periodic Table is full of information. Each element has a number at the top, which increases by one as you travel along each row from left to right. This is the element's 'atomic number', and it tells you how many protons it has in its nucleus and is the key to an element's chemical identity. Hydrogen has one proton and therefore the atomic number 1. Helium has two protons and atomic number 2. As you travel along a row, the elements gain protons and become heavier. An electrically neutral atom has the same number of electrons as protons, so the table also reveals that a helium atom (atomic number 2) has two electrons orbiting its nucleus, and so on for all the other elements.

Also as in maps, elements in the table can be colour-coded to indicate they have similarities. Most of the 118 elements are metals (like iron, Fe) – a large category which is then divided into several smaller groups. Then there are 'non-metals', including the halogens and noble gases (like Xe, xenon). There are also some strange in-between elements called 'metalloids'. To make the table easier to show, two groups of metals called the lanthanides and actinides are usually placed in rows underneath the main table.



KEY

Non-Metals: Noble gases | Halogens | Other non-metals

Metals: Metalloids | Alkali metals | Alkaline earth metals | Lanthanides | Actinides | Transition metals | Post-transition metals

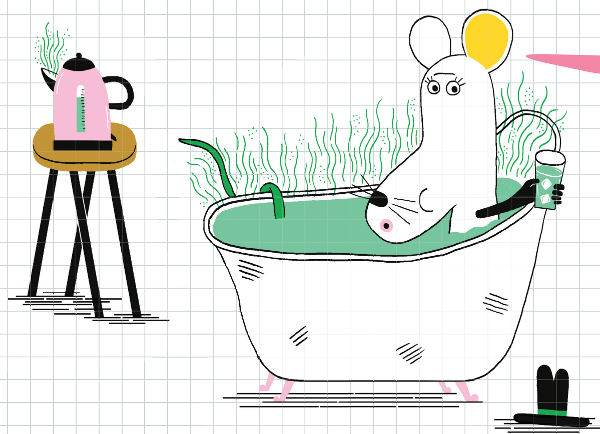
Identity Parade: Masters of Disguise

Although some elements (like gold, Au) can be found on Earth in their simplest form, many are in disguise. Their atoms join up in set ways with the atoms of one or more other elements to form 'gangs' called molecules.

New substances formed from these molecules can often have very different properties to their component elements. As a result, chemists often have to carry out some clever detective work to identify them!

State secrets!

Appearances can be deceptive! Matter in your home can exist in one of three main states – solid, liquid or gas. And some substances can be found in all three disguises. Cunning!



IN A STATE
Water can be found in the room in all three states depending on the temperature: ice in the freezer, water in the bath, steam from a kettle!

In a SOLID, such as a lump of metal, the molecules are closely packed in fixed positions and bonded to their neighbours. They vibrate but can't move about, so solids have a set shape and volume.

In a LIQUID, such as water, the bonds between molecules are weaker and the molecules move around more. Liquids have a set volume but take the shape of the container they are in.

In a GAS, the molecules escape their bonds and can move about freely, with no fixed volume or shape.

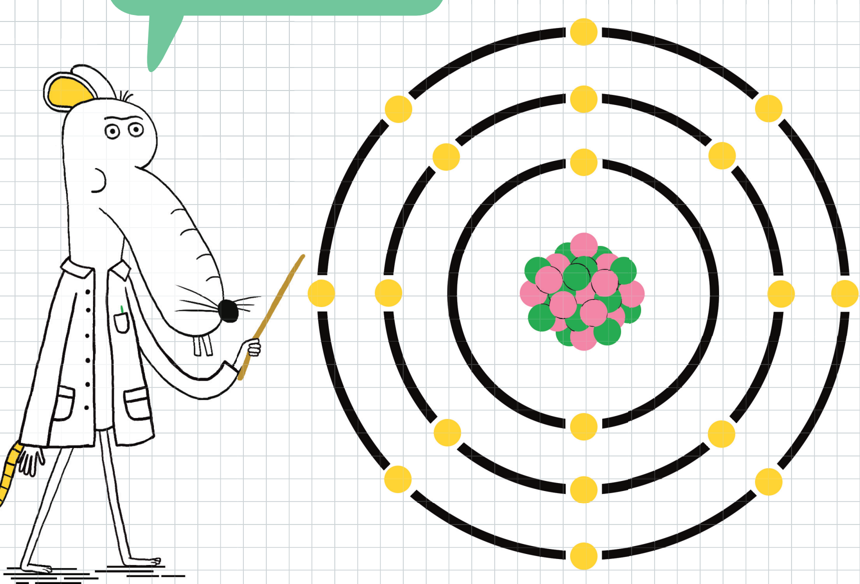
The state of a substance depends on its temperature and the pressure it is under. Gases become liquids if you squash their molecules together, and solids will melt if you heat them enough. In this book, all our elements are described in the state they would take in a home at room temperature and close to sea level.

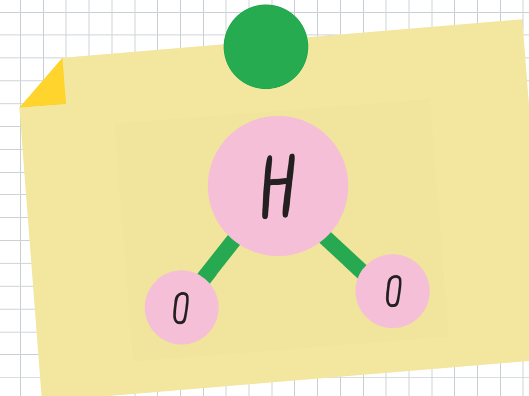
All about sharing

The bonds between the different atoms in a molecule are formed by sharing electrons. An electrically neutral atom has the same number of electrons orbiting its nucleus as its atomic number. Scientists think of these electrons as occupying concentric shells around the nucleus, like the layers of an onion. The shell closest to the nucleus can hold up to two electrons. The next two shells can each have eight, with the numbers increasing as atoms increase in size.

An atom with a 'full' outermost electron shell is less chemically reactive than one with a part-empty shell. In molecules, atoms share electrons to become more stable.

This is an argon (Ar) atom. Its outermost electron shell is full. As a result, argon is so chemically inert that no natural argon compounds exist.



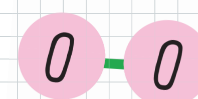


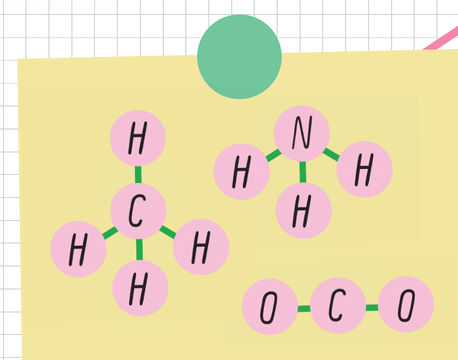
Code name compound

When atoms of more than one element join together chemically the resulting substance is called a compound. Water is a compound formed from the elements hydrogen (H) and oxygen (O). A water molecule always contains two hydrogen atoms and one oxygen atom, giving it the chemical formula H_2O. These 'code names' are clues to the make-up of molecules and how they will behave chemically. Here are some more common household molecules:

methane (CH_4)
carbon dioxide (CO_2)
ammonia (NH_3)

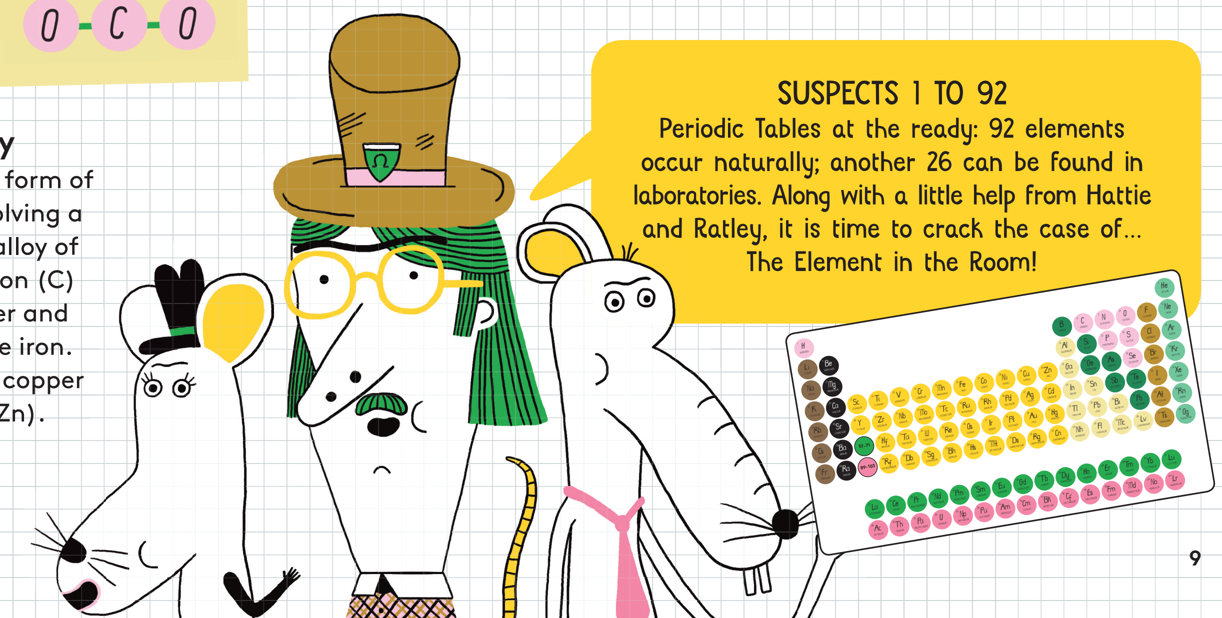
Some elements also form molecules made solely of their own atoms. Oxygen in the air has the molecular form O_2. Oxygen atoms share electrons to form more stable molecules.





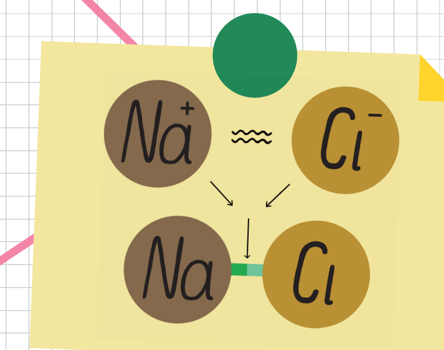
Agent alloy

An alloy is a special form of mixture, often involving a metal. Steel is an alloy of iron (Fe) and carbon (C) that is both harder and stronger than pure iron. Brass is an alloy of copper (Cu) and zinc (Zn).



In the mix

Different chemicals can also be combined together in what chemists call a 'mixture'. Unlike a compound, the components of a mixture are not bonded together and can be separated without resorting to chemical reactions. For example, dissolving sugar in hot water produces a sugar–water mixture. Pour the mixture onto a plate and the water will eventually evaporate away, leaving behind unchanged sugar crystals.



ID: ion

Ions are atoms or molecules that have an overall electrical charge. They become positively charged (+) by losing electrons and negatively charged (-) by gaining electrons.

Bonds formed between oppositely charged ions are some of the strongest in chemistry. Table salt is mostly sodium chloride (NaCl). Its molecules have an ionic bond between a positively charged sodium ion (Na+) and a negatively charged chlorine ion (Cl-). The two charges attract and cancel each other out.

SUSPECTS 1 TO 92
Periodic Tables at the ready: 92 elements occur naturally; another 26 can be found in laboratories. Along with a little help from Hattie and Ratley, it is time to crack the case of... The Element in the Room!