The STARDUST THAT MADE US

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A VISUAL EXPLORATION OF CHEMISTRY, ATOMS, ELEMENTS AND THE UNIVERSE

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The Extraordinary Elements

The Universe is an extraordinary place filled with awe and wonder. Stars twinkle, flowers bloom and animals run, fly and swim as we humans go about our busy lives. Yet even the most ordinary objects have a hidden beauty deep within.

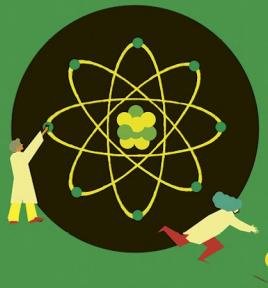
The secret lies in what makes it all work. **Nature has an unseen cookbook full of recipes for making everything you've ever encountered**, from fish to fingernails, sand to Saturn. But what are the ingredients? Scientists call them **ELEMENTS** and we currently know of 118 different ones. Some you will have heard of, like iron and oxygen. Others you probably haven't, like praseodymium and dysprosium. Elements are combined in different ways to make different things. Red blood cells, for example, combine oxygen, hydrogen, nitrogen, iron and carbon to carry oxygen around your body.

Each element has a personality of its own, behaving in a unique way that makes it distinct from every other. It has taken centuries of effort by scientists around the world to uncover them all. Often scientists have gone to great lengths to find a new element – one was discovered by boiling urine (page 37), while others only appeared once we had huge machines to smash particles together at close to the speed of light (page 75). All of them are special and we use many of them every day without even realising.

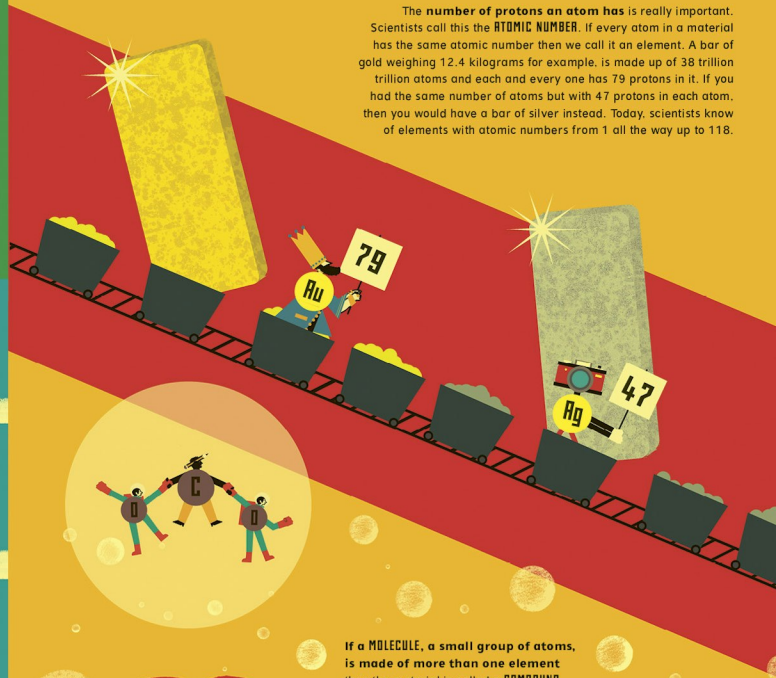
This is the story of the extraordinary elements. Welcome to the world of chemistry!

Elements Basics

All around you, every day of your life, there are tiny **invisible particles** doing extraordinary things. Everything you can touch, taste, see or smell is made up of **ATOMS**. In the **centre of an atom are particles called PROTONS** and **NEUTRONS**, with even lighter electrons journeying around them.



The **number of protons an atom has** is really important. Scientists call this the **ATOMIC NUMBER**. If every atom in a material has the same atomic number then we call it an element. A bar of gold weighing 12.4 kilograms for example, is made up of 38 trillion trillion atoms and each and every one has 79 protons in it. If you had the same number of atoms but with 47 protons in each atom, then you would have a bar of silver instead. Today, scientists know of elements with atomic numbers from 1 all the way up to 118.



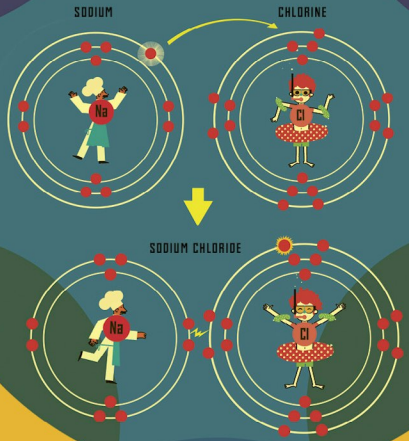
If a MOLECULE, a small group of atoms, is made of more than one element then the material is called a **COMPOUND**. For example, you breathe out carbon dioxide (CO_2) – a compound made of one atom of carbon linked to two atoms of oxygen. The same compound is taken in by plants.

Let's Talk Chemistry

Scientists who study the elements and the way they behave and co-operate to form new substances are called **CHEMISTS**. The subject they study is known as chemistry.

A lot of chemistry boils down to the electrons whizzing around inside atoms. All atoms have a nucleus at their centre, which is surrounded by rings called shells. It is inside these shells, that we find **ELECTRONS – tiny, negatively-charged particles orbiting around the nucleus at impossible speeds**. Each shell can only hold a certain number of electrons.

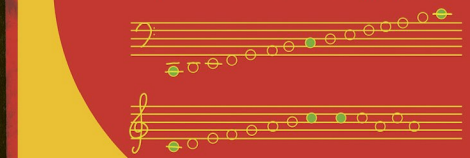
An atom is happiest (chemically stable) when its outer shell is full of electrons and there are different ways it can achieve this. In **IONIC BONDING, an atom can donate a few electrons to another that is missing some, which causes them to cling together**. This happens when a sodium atom lends a chlorine atom an electron, forming sodium chloride, or table salt.



In **COVALENT BONDING, atoms end up sharing electrons so that they both have complete outer shells.** Take a molecule of water, for example. Its chemical symbol is H_2O – two atoms of hydrogen bonded to one atom of oxygen. An atom of hydrogen has a single electron in its outer shell and an atom of oxygen has six. In a water molecule, the electrons from the two hydrogen atoms are shared to give oxygen a full outer shell of eight electrons.

Mendeleev

Have you ever been to the zoo? It's amazing to see all the creatures that make up the animal kingdom and the differences in the way they look and behave. Over centuries of study, biologists have worked out how the animals fit into groups. Lions and tigers are both members of the cat family. Horses and zebras belong together too.



As chemists began to find new elements in the 1600s they also started to put them into groups based on properties they had in common. By the 1860s more than 50 elements had been discovered and the English chemist **JOHN NEWLANDS** spotted a pattern. **If you organised the known elements by atomic number then every eighth one shared similar properties**, just like the eighth note of an octave in music. This became known as **THE LAW OF OCTAVES**.

DMITRI MENDELEEV soon stepped in to continue investigations. In 1869, the Russian chemist had a dream in which he saw the **elements arranged into a table according to patterns in their behaviour.** As these behaviours repeat periodically (in a regular way), it became known as **THE PERIODIC TABLE**. Mendeleev woke from his dream and hastily scribbled down the first ever periodic table on a piece of paper. It contained all 63 elements known at the time.

MENDELEEV'S PERIODIC TABLE, 1869

I	II	III	IV	V	VI	VII	VIII		
H									
Li	Be	B	C	N	O	F			
Na	Mg	Al	Si	P	S	Cl			
K	Ca		Ti	V	Cr	Mn	Fe	Co	Ni
Cu	Zn			As	Se	Br			
Rb	Sr	Yt	Zr	Nb	Mo		Ru	Rh	Pd
Ag	Cd	In	Sn	Sb	Te	I			
Ce	Ba	La		Ta	W		Os	Ir	Pt
Au	Hg	Tl	Pb	Bi					
			Th		U				

One of the clever things about Mendeleev's table is that it had gaps. Observing the patterns, he correctly guessed that new elements yet to be discovered belonged in these spaces. It was even possible to predict their properties based on their position in the repeating pattern. Later, the elements germanium, gallium and scandium were found, and the gaps were filled in.