Even the youngest children can learn ATOMIC theory!


Figure 1 A 5-year-old exploring a molecular structure

Ian Stuart demonstrates how atomic theory can be part of the primary curriculum

If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generations of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis that all things are made of atoms.
(Richard Feynman)

The atom is science's biggest idea! And we now know that even children from 4 years of age can grasp it, creating science education's biggest worldwide opportunity.

Is teaching atomic theory in primary evidence-based?

Yes, Dr Jenny Donovan and Dr Carole Haeusler of the University of Southern Queensland conducted multiple studies to show that primary-age children, mostly aged 7–9 years in their particular studies, both understand and love learning about atoms. Their research has been written up in prestigious peer-reviewed journals.

Is atomic theory being taught in primary?

Yes, currently formal teaching of atomic theory is delayed until secondary school, yet children are now learning it in over 30 primary schools across six countries, some from 4 years of age. The fantastic *Atomic School* video clips at www.atomicschool.com/classroom show early primary students learning atomic theory. I suggest you watch them before reading on!

Can I teach it?

Yes, it's really easy and we can help to provide you with the resources. The videos referred to show a primary teacher without a science background teaching her 5- to 7-year-olds brilliantly. In fact, primary teachers are *better* at teaching atomic theory than secondary school teachers (like me, for example) because they are experts in communicating with primary-aged children. The actual content is not as important as your repertoire of skills in early childhood pedagogy. As a primary teacher, you have it within your power to transform primary science education and create dramatic knock-on effects in secondary!

Why should I teach it?

We live in the age of science. Children need to become scientifically literate to cope with their increasingly complex world, let alone flourish in it. Being fluent in science is now as relevant to children's life journey as reading and writing. They now need to swim comfortably through a sea of scientific terminology, to adapt to changing technology, become more responsible citizens and get better jobs, and yet science education is in crisis worldwide. We have seen children responding with unbridled enthusiasm to more 'grown-up science' – which we think is a step in the right direction.

This higher-level science is also powerfully *transferable* to other subjects. For example, children who understand the 'super-six molecules' (see below) can cross-link this knowledge to other crucial domains such as health literacy. Our bodies breathe in O_2 to metabolise with glucose, protein and fat, releasing CO_2 and H_2O. This balance of food molecules *in* and CO_2 molecules breathed *out* is the secret of a balanced mass and a healthy lifestyle.

Key words: Atomic theory Chemistry

Understanding this allows children to take control of their own health.

Another cross-linking example is the burning of carbon-based fossil fuels, releasing CO_2 into our atmosphere, which absorbs reflected radiation and leads to global warming. An early understanding of the bonding and geometry of CO_2 molecules may potentially inspire your pupils to solve this existential threat to humankind in the future.

Primary teachers without a science background first need to learn some basic atomic theory in order to teach it, but this is very doable. Then, one of the beautiful things about your time investment is that this learned asset is *enduring*. The periodic table won't change until the end of the universe.

How do I teach atomic theory?

Start simple and build the concepts in small steps to cover Stages 1 and 2 below, enabling you to teach atomic theory across the first two years. The lessons have guided animated videos to guide your children – and you – and are designed for easy delivery in a class by teachers without a science background. Our resources are mostly free. I recommend watching a few of the linked videos in the lesson plans below to get to grips with the early lessons.

The stage numbers correspond to year levels. You can therefore teach Stage 1 (lessons 1 to 7) to year 1 classes, and Stage 2 (lesson 8) to year 2 classes. You can also introduce this sequence at any primary age level.

Stage 1: Atoms are the building blocks of matter

Lesson 1: Magnification

This fun, hands-on, animated video-lesson allows students to see objects magnified 40 to 100 times bigger than their normal size, making them appear radically different (Figure 2). It introduces the idea of *scale*. By extension, magnifying an object by a million times using an electron microscope allows us to see its actual atoms.

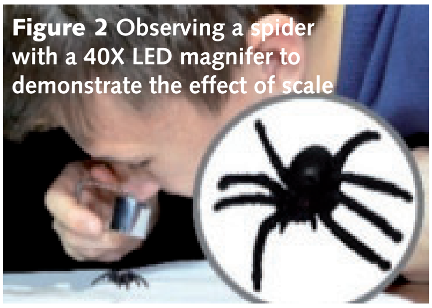

Figure 2 Observing a spider with a 40X LED magnifer to demonstrate the effect of scale

Lesson 2: The world is made of 92 different naturally occurring atoms

Our animated video-lesson magnifies a sand grain so students can see its atoms, oxygen and silicon, and then further explores 92 different kinds of naturally occurring atoms in the world. Most things are made of different kinds of atoms, and their properties (hardness, colour, conductivity) depend on both their kind and arrangement and give rise to the world's vast diversity of things. (All 92 kinds of atoms are further made of just three kinds of smaller particles called protons, electrons, and neutrons, which are covered in later stages.)

Lesson 3: A substance made of only one kind of atom is called an element

If a substance's atoms are all the same, we call it an **element**. For example, a nugget of the element gold contains only gold atoms (Figure 3). Everyday elements include graphite (carbon) in pencils, and copper in pipes. On the other hand, because water (H_2O) is made of two kinds of atoms, hydrogen *and* oxygen, it is called a **compound**.

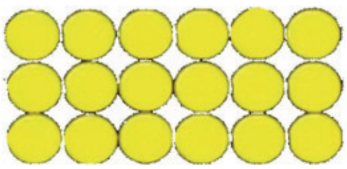

Figure 3 Gold is an element because it contains only gold atoms

Lesson 4: Each element has its own atomic symbol and atomic number

Our video shows how an element's symbol consists of one or two letters, usually the first, or first two, letters of the element's English name. For example, carbon's symbol is C, hydrogen's symbol is H, while helium's symbol is He to make it a bit different to hydrogen's. A symbol's first letter is always a capital letter; if it has two letters, the second one is always lower case.

An element's **atomic number** is its place in the list of elements from the lightest to the heaviest atoms. The most lightweight kind is hydrogen (H), so its atomic number is 1; helium (He) has the second lightest atoms, so its atomic number is 2 (Figure 4). Uranium (U) with the heaviest atoms is 92. (Atomic number also corresponds to the number of protons in the atom's nucleus, covered later.)

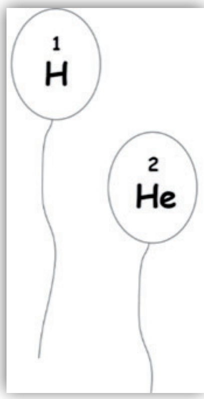

Figure 4 The sequence of the different elements is based on how heavy their atoms are

Lesson 5: Make your own element strip

This novel element strip shows all 92 kinds of naturally occurring atoms from hydrogen (1) to uranium (92) in one list. You can download a master sheet so your students can cut and paste them together, showing all the elements in the universe (Figure 5).

Lesson 6: Students compare the weights of different kinds of atoms

The kit provided contains five element 'lumps' – aluminium, carbon, copper, lead and tin – each containing the same number of atoms, namely 100 billion trillion (Figure 6)! Although this is a huge number, because it is the *same* for each lump, comparing the lumps' weights is equivalent to comparing the individual atom's weights. Children can arrange the different elements from those with the lightest to those with the heaviest atoms, and then place them in a row to show agreement with their atomic numbers.

Figure 6 The kit containing five elements, aluminium, carbon, copper, lead and tin, each with the same number of atoms

Lessons for two years These may be introduced at any age.

For Stage 1 and Stage 2 **lesson plans** scan the QR code or visit
www.atomicschool.com/aselessonplans

For recommended **physical resources** scan the QR code or visit
www.atomicschool.com/aseresources

Figure 5 Part of a downloadable element strip available at www.atomicschool.com/elementstrip

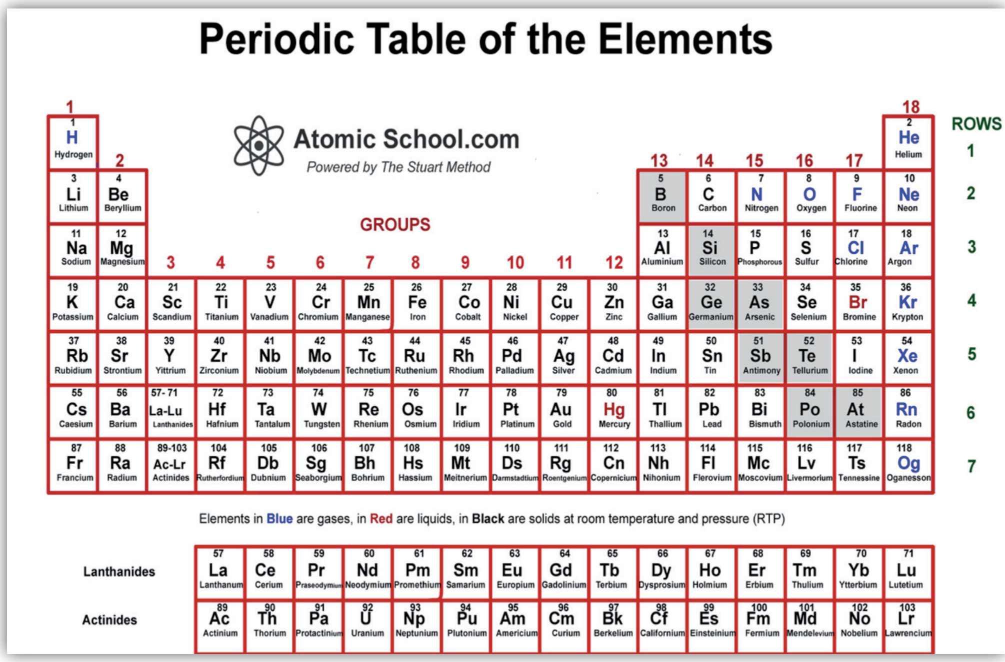

Figure 7 A downloadable periodic table of elements available at www.atomicschool.com/periodictable

Lesson 7: The periodic table lists all the elements arranged in seven horizontal rows and 18 vertical groups

The periodic table (Figure 7) could be thought of as an 'alphabet of the universe', enabling scientists to combine symbols to make words, that is, molecules as shown below. The table shows elements in order of increasing atomic number and is read from left to right like a book. Understanding the periodic table is as vital to science as the alphabet is to reading and writing.

Each vertical group contains similar elements. For example, lithium and sodium in group 1 are both soft, shiny metals. Fluorine and chlorine in group 17 are both yellow-green poisonous gases. The elements trend across each horizontal row from metals on the left to non-metals on the right.

Children love the periodic table. They recognise many elements, like oxygen, iron and sulfur, while discovering new ones like praseodymium and francium. They enjoy spotting elements named after planets (mercury, plutonium), countries (germanium, americium) and people (einsteinium, curium). They are surprised that some common substances, such as aluminium, are elements, while others, such as water, are not. You cannot tell if something's an element just by looking at it because its atoms are too small to see.

Stage 2: Atoms bond together to make molecules

Having outlined the introductory content that teaches conceptual knowledge of the atoms and elements, the second stage of lessons considers how different elements can form the 'super-six molecules'.

Lesson 8: Super-six molecules

Stage 2 lessons require molecular model kits. I developed 'Sticky Atoms' especially for primary students because they join together in a fun and effortless way (Figure 8). See the resources page for supplies and alternative molecular model options.

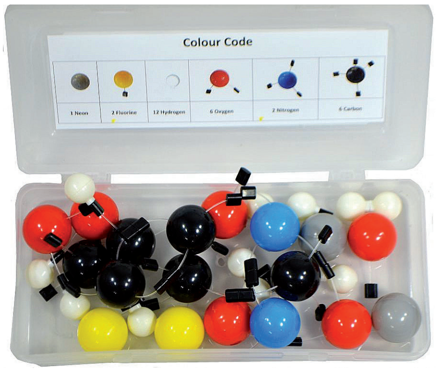

Figure 8 Sticky Atoms kit for building molecular models (other modelling kits are available)

These 'super-six molecules' are arguably the most important in the world and are a springboard for making more complex molecules such as carbohydrates, fats and proteins. Children can quickly build them all using Sticky Atoms.

Chemical bonding follows simple rules, for example:

- **hydrogen bonds only *once* with other atoms;**
- **oxygen bonds *twice* with other atoms;**
- **nitrogen bonds *three* times with other atoms;**
- **carbon bonds *four* times with other atoms.**

This bonding capacity is called the element's **valency**.

The images in Table 1 show Sticky Atoms. When their magnetic tips touch, the links snap together to mimic a chemical bond between two atoms. Any combination of atoms that uses all the bonds will probably be found in nature.

Table 1 Four of the Sticky Atoms

Element	H	O	N	C
				
Bonding ability or valency	1	2	3	4

1. Hydrogen, H_2

When two hydrogen atoms collide, they join to make a hydrogen **molecule**, H_2. The subscript 2 denotes the *number* of H atoms in the molecule. The invisible force that holds two atoms together is called a **chemical bond** (Figure 9).

Making the Super-Six Molecules video

Follow this QR code to see an animated classroom video on molecules or visit

https://youtu.be/mH8VapjYUV4

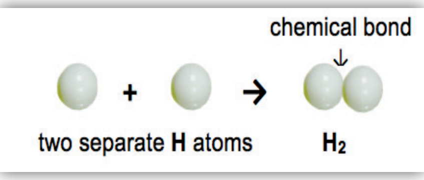

Figure 9 Two hydrogen atoms combining to form an H_2 molecule

A container full of hydrogen atoms will quickly join together to form stable H_2 molecules, collectively making the *substance* hydrogen. The substance hydrogen is a light explosive gas and used as a clean green fuel, including for vehicles and rockets. Hydrogen is potentially the basis of the exciting new 'hydrogen economy'.

2. Water, H_2O

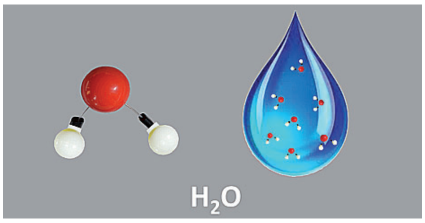

Figure 10 A small drop of liquid water contains about 3 billion trillion H_2O (water) molecules

A water molecule forms when two H atoms bond with an O atom, and is written H_2O. H_2O represents water's *microscopic molecule*, as well as water's *macroscopic substance*, which we can see and feel (Figure 10). Water is critical for plant and animal life. Scientists look for H_2O on other planets as a sign of life.

3. Ammonia, NH_3

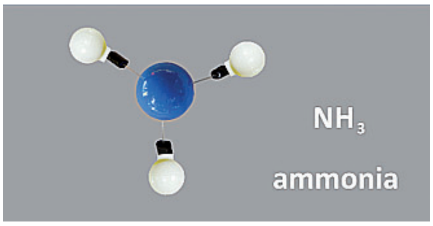

Figure 11 Ammonia molecule formed from nitrogen and hydrogen atoms

An ammonia molecule forms when one nitrogen atom bonds with three hydrogen atoms and is written NH_3 (Figure 11). The *substance* is a stinky gas, dissolves in water, and we use it in cleaning agents. Ammonia molecules combine with organic acids to form amino acids, the building blocks of proteins.

4. Methane, CH_4

A methane molecule forms when one carbon atom bonds with four hydrogen atoms and is written CH_4 (Figure 12). The *substance* methane,

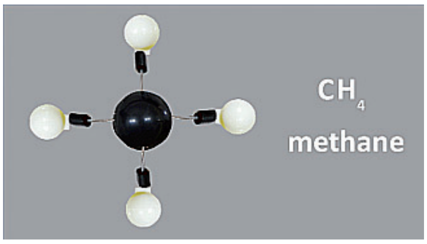

Figure 12 Methane molecule formed from carbon and hydrogen atoms

CH_4, is a light flammable gas, often used in cooking and as a vehicle fuel. It is also called natural gas or coal-seam gas.

5. Oxygen, O_2

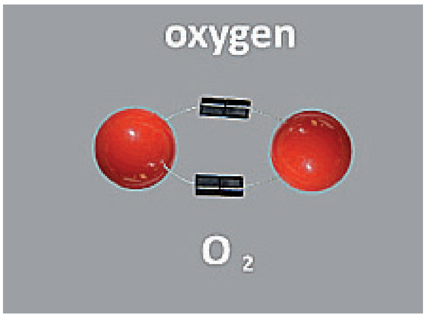

Figure 13 Oxygen molecules have a double bond between their two atoms

When two oxygen atoms bond together *twice*, a **double bond** forms. Because each atom uses both its bonds, oxygen's bonding rules are satisfied (Figure 13). The *substance* oxygen, O_2, is life-supporting gas making up 21% of the air and keeping us alive.

6. Carbon dioxide, CO_2

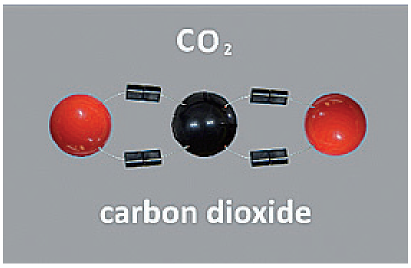

Figure 14 Carbon dioxide molecule formed from carbon and oxygen atoms

When carbon makes double bonds with two oxygen atoms, obeying its valency of four, a carbon dioxide (CO_2) molecule is formed (Figure 14).

CO_2 and H_2O are the raw materials that plants combine to make glucose and O_2. We eat plants and breathe in this O_2, and then breathe out CO_2, returning it to them. How elegant! This is a key principle of plant and animal biology.

Your students are now ready to build hydrocarbons, fats, proteins, carbohydrates and plastics.

Moving on

Our 6-year primary curriculum (Stages 1 to 6) covers atoms, the periodic table, states of matter, chemical reactions. electric charge, atomic structure and bonding.

Although far-fetched, imagine if our society delayed the teaching of the alphabet until our children reached 12 years of age? Knowing that the alphabet is crucial for our children's future progress, we unhesitatingly teach it from early years. However, atomic theory is an alphabet that is delayed until 12 years of age, even though it is just as crucial for children's life journey. You can change that! With confidence and support you can enable your children to engage with the basics of atomic theory and start their science journey earlier.

The language of science

Both children and adults can baulk at the language of science because it contains long technical words that often have a different meaning in everyday life, like 'element'. Scientifically, an element is a substance made of only one kind of atom, whereas in everyday situations, an element can mean earth, fire, water, air or space. So writing water as H_2O reveals that it is made of two kinds of atoms, disqualifying it as an element in the scientific sense. Nevertheless, the vocabulary rules in science are straightforward and consistent, and primary students are fast language learners who easily recruit new terminology. They enjoy the empowerment that mastering scientific language gives them, endearingly illustrated in this short video:

https://youtu.be/sMvsPzsgsF0

For further information visit:
www.atomicschool.com

Ian Stuart taught upper secondary chemistry and physics for 30 years and is the founder of Atomic School, which advocates the teaching of atomic theory to all primary schools in the world!
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