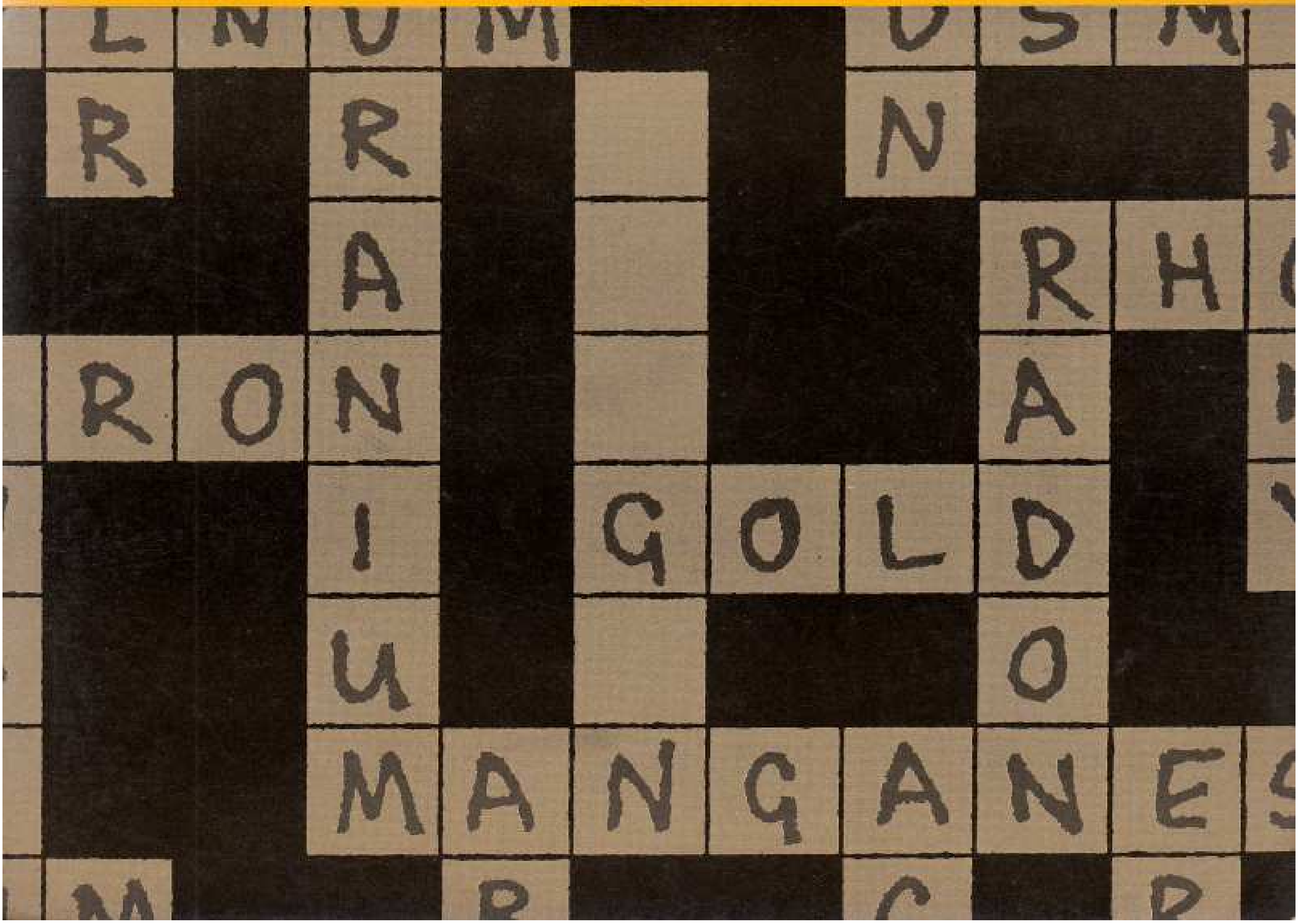
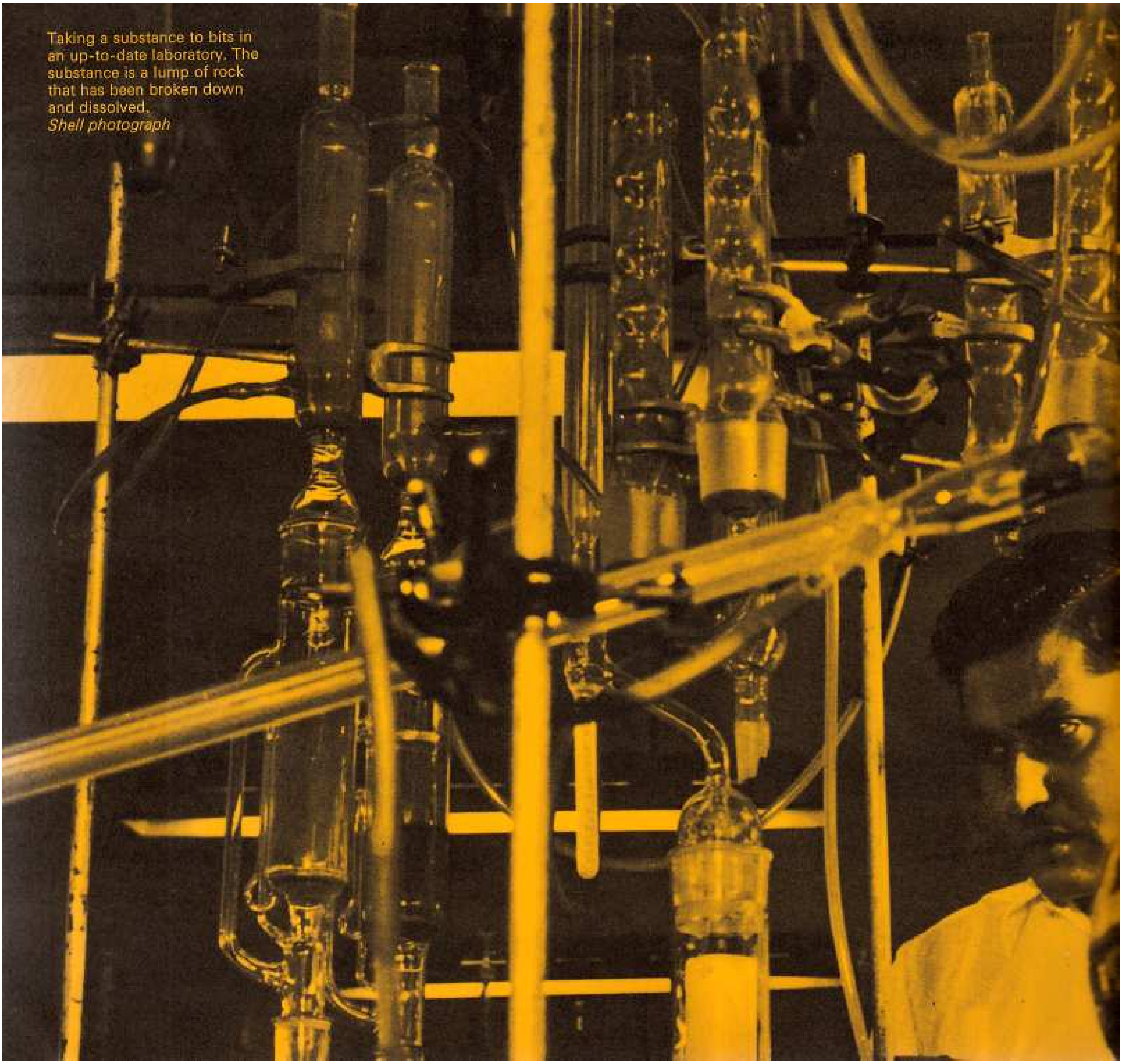
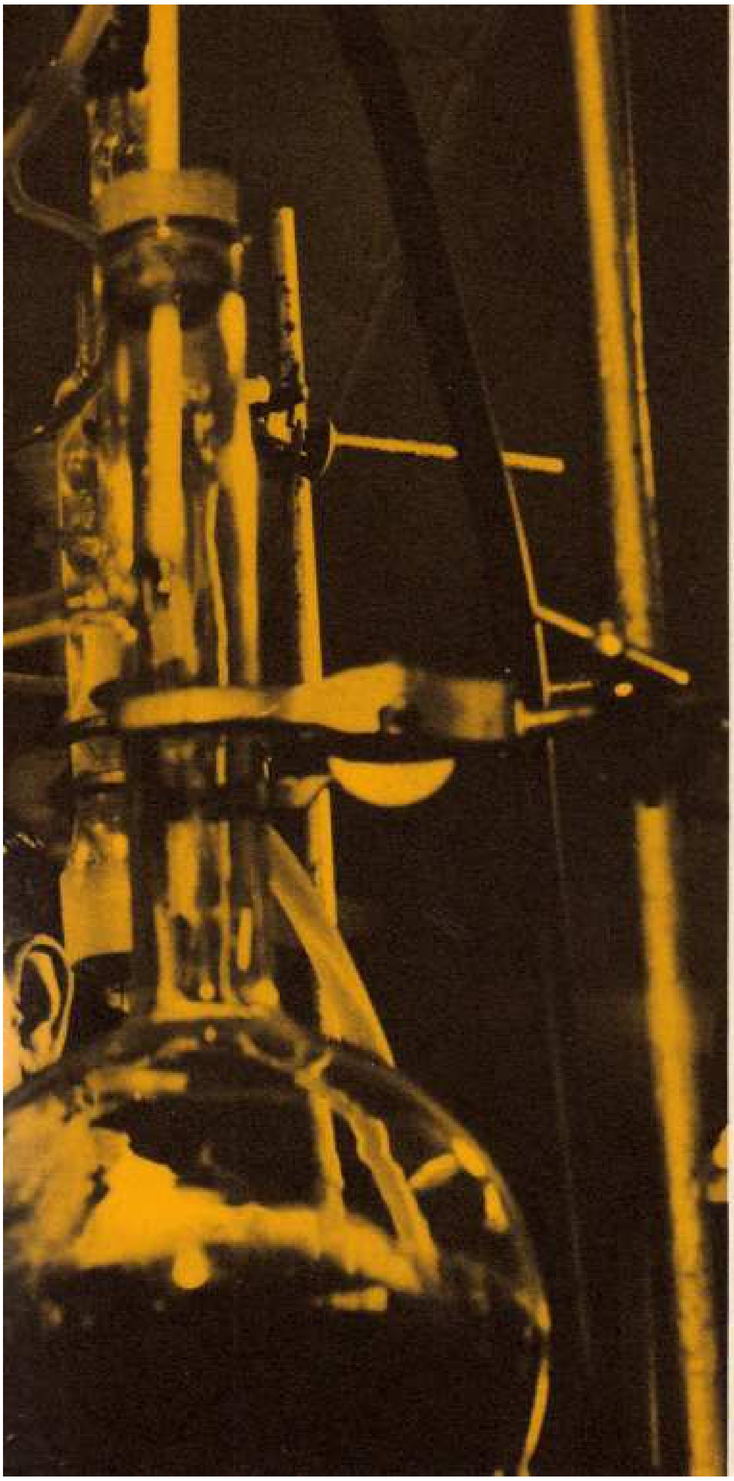
Chemistry Background Book

The Chemical Elements





Taking a substance to bits in an up-to-date laboratory. The substance is a lump of rock that has been broken down and dissolved.
Shell photograph



part 1
What is an element?

If you wanted to find out what coal is made of, you could take a hammer to it and break it up, but all you would get would be coal dust. But by using other methods – heating it, or passing an electric current through it – you would eventually reduce it to hydrogen, carbon, perhaps some sulphur, and some other substances in smaller amounts. If you thought that these could be broken down again into other substances, it is unlikely that you would succeed for you have reached the elements of which coal is made.

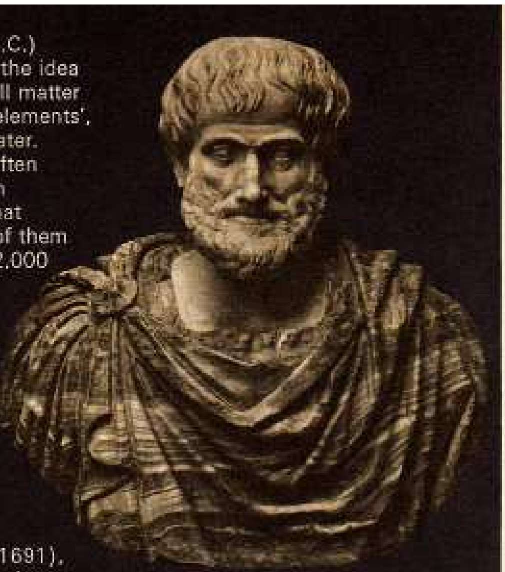
What are these elements? You have already taken several substances to pieces, extracting colouring pigments from plants and metals from their ores. From one complex substance you get several simple ones. You finally reach a limit when each simpler substance can no longer be split up, and these very simple substances you are left with are called elements. Four elements you have met are iron, copper, silver, and gold.

At present 103 elements are known, of which about ninety have been discovered in nature and the remainder have actually been made by chemists in the laboratory. As far as we know, everything that exists is made up of these elements in different combinations and proportions.

These combinations can be quite simple, as when a metal combines with oxygen. Living structures are very much more complicated, as in the case of our own bodies which contain at least thirty-three different elements. Even the colour of a man's hair may depend upon the presence of a certain element in small traces. Molybdenum produces red hair. Copper, cobalt, and iron, brown hair; and blonde hair is probably caused by the presence of titanium.

Earth, air, fire, and water – The idea that all substances are built up from a number of elements is an old one. The Greeks

Aristotle (384–322 B.C.) gave his authority to the idea of Empedocles that all matter is composed of the 'elements', earth, air, fire, and water. These elements are often called the Aristotelian elements. The idea that matter is composed of them persisted for almost 2,000 years.
Mansell Collection



Robert Boyle (1627–1691), author of *The Sceptical Chymist* and the first to state clearly what was meant by a chemical element.
From a portrait at the Royal Institute of Chemistry

even suggested that all things are made from a single element. Some of them thought that the single element was fire, and others that it was water. The Greek scientist Empedocles (490–430 B.C.) put an end to this dispute when he claimed that both fire and water were elements. He also added two more – earth and air – for good measure. According to him, these four elements mixed in different proportions could account for the existence of all the different kinds of substances.

The ideas of the Ancient Greeks about science passed on to the Middle East and then to Western Europe – chiefly through the writings of the Greek philosophers, Plato and Aristotle. Among these ideas was that of the four elements. This was taken over by the medieval alchemists who, because they experimented with substances, are generally regarded as the forerunners of the modern chemist.

The alchemists thus thought that all substances contained only four elements. They felt that it must be possible to change one substance into another. To change the proportions of the four elements was how they tried to do this. Most of all, they wanted to change other metals into gold. But there is no reliable evidence that any alchemist ever made gold. They did invent some useful experimental techniques, but they added very little to the understanding of chemistry.

The trouble with the alchemists was that they were trying to reach the moon before they had learnt how to fly. Before chemistry could make any headway, and certainly before one metal could be converted into another, chemists had to take substances to bits and discover the elements in them.

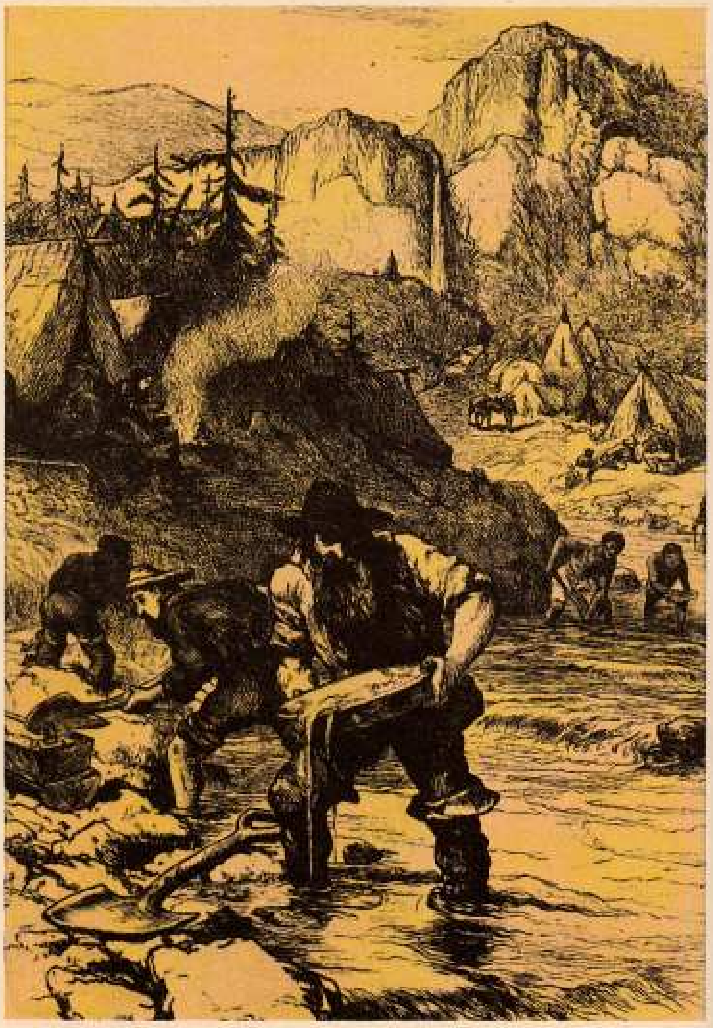
The Sceptical Chymist – About 400 years ago, scientists in western Europe began to question many of the ideas of the Greeks. They tested them by experiment and found that many of them did not fit the facts. This spirit of questioning spread to England, where it influenced the minds of such great thinkers as Isaac Newton and Robert Boyle. You may know of Boyle through his law about gases.

In *The Sceptical Chymist*, published in 1661, Boyle gave the first more or less up-to-date definition of an element. He defined an element as a pure substance that cannot be broken down into, or produced from, simpler pure substances. With some idea what they were looking for, chemists after Boyle were able to take substances to bits and discover the elements of which they were made.

The Alchemist – by the Flemish painter Peter Breughel the elder (1525–1569). In their efforts to transform other metals into gold, the alchemists learnt some useful practical techniques. Examine the picture carefully and you will see apparatus for weighing, heating and distilling substances.
Mansell Collection

part 2
Discovering elements

Panning for gold in a Californian river: when the pan's contents, dug up from the bed of the river, are washed with a stream of water, the lighter earthy matter is carried away, leaving the gold behind. But this can be a slow way of finding gold, and nowadays gold usually comes from the mining of gold-bearing rocks and the separation of the gold. *Radio Times Hulton Picture Library*



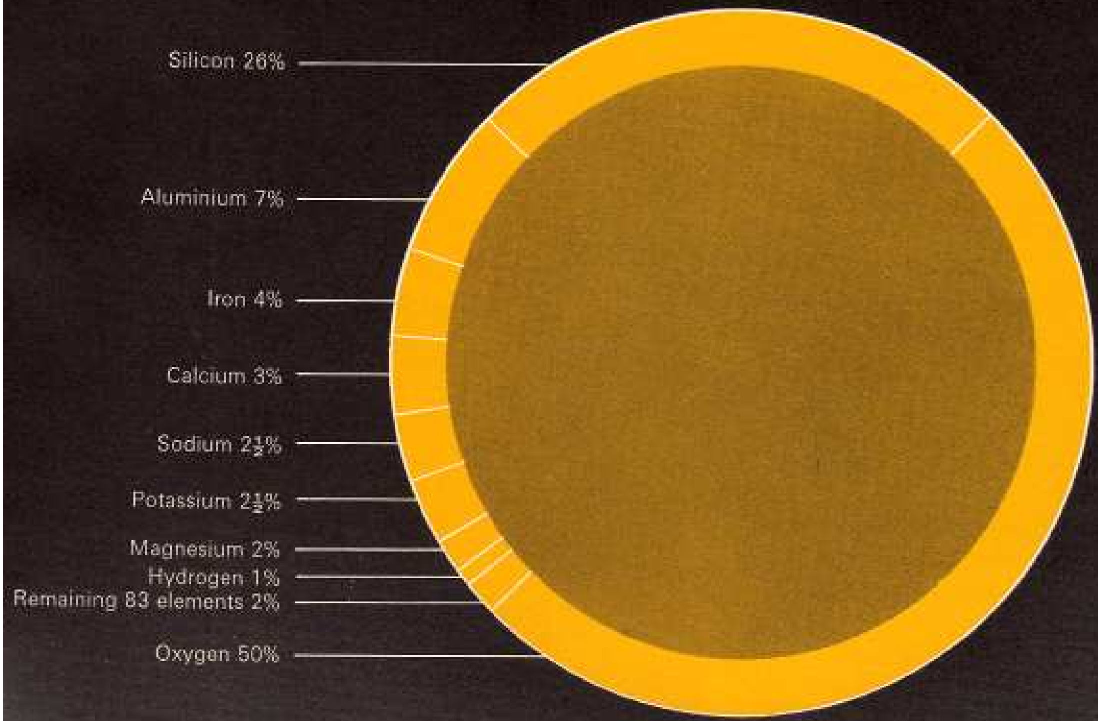
Discoveries of long ago – So far as we know, all matter in the universe is made up of at least ninety different elements. Some are very much more common than others. The proportion by weight of the elements that make up the Earth's crust is shown in the chart opposite.

You will see from the chart that two elements, oxygen and silicon, together make up more than three-quarters of the weight of the Earth's crust. But even if an element is common, it may not be easily found. For example, you could search hard for a very long time and never find a piece of the shiny, dark-grey element silicon – except perhaps in your school laboratory. In nature, all silicon is combined with other elements. Sand, for example, is silicon combined with oxygen. There is, of course, plenty of free oxygen in the air but, if you cannot see something, you cannot be blamed for not knowing it is there. It was not until less than two hundred years ago that oxygen was discovered all around us. But suppose you were to look for silver and gold! These elements are very rare, and are not to be found lying about in the local countryside. But it is quite possible that, in a South American silver mine, you would come across a lump of pure silver; or that prospecting for gold in California, you would find some gleaming yellow nuggets in the bed of a river.

The first elements known to man were, not surprisingly, some of those, like silver and gold, that may be found in nature uncombined with other elements. This is called being found *native*. Copper is another metallic element, and carbon and sulphur are two non-metallic elements, which are found native.

Other elements soon discovered afterwards were those that could be extracted easily from their mineral ores – for example, the metals tin, iron, lead, and mercury. With these dis-

Proportion by weight of the elements in the Earth's crust.

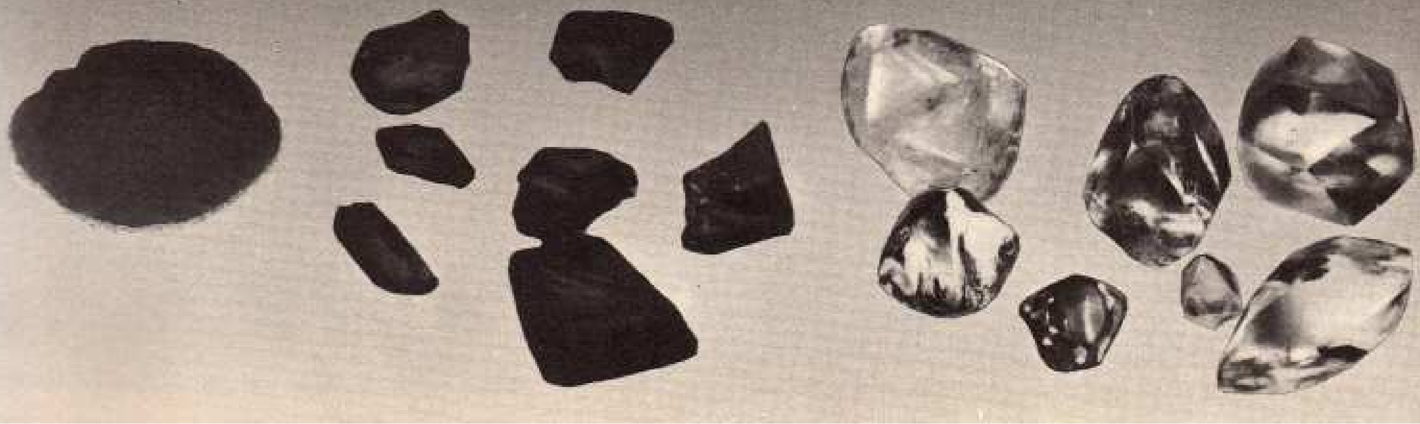


Three forms of the same element carbon:

Graphite – which has a soft flaky structure and is used to make pencil leads

Charcoal – which is the black deposit from the burning of wood

Diamond – which is the hardest of all substances



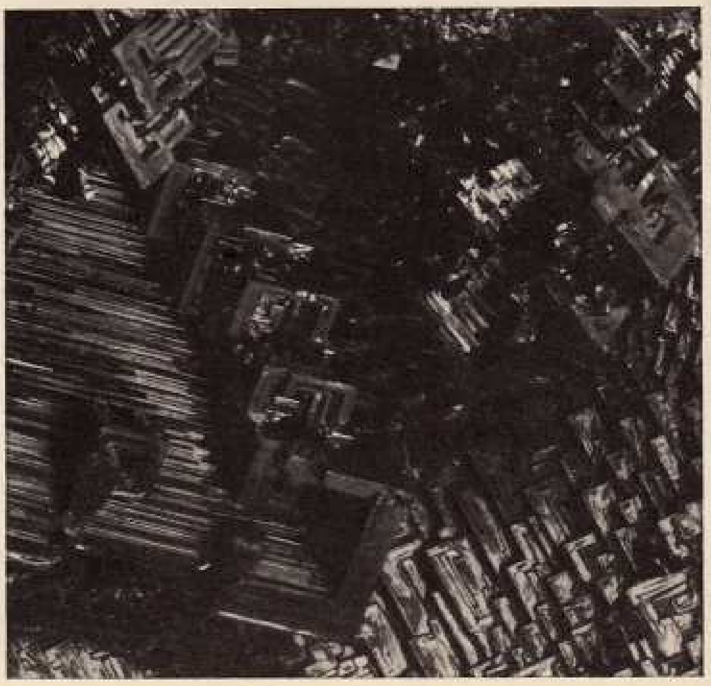
coveries, man advanced from the Age of Stone to the Age of Bronze (an alloy of copper and tin) and the Age of Iron. No records exist to show who discovered these elements and, of course, at the time it was not understood that they *were* elements.

The light bearer – After the ancients, a long time passed before any more elements were discovered. This was done by the alchemists who did unearth four of the elements – arsenic, antimony, bismuth, and phosphorus. Only the discoverer of phosphorus is known with any certainty. He was Dr Hennig Brand, a merchant with an interest in alchemy, who lived in Hamburg. At the time of his discovery (1669) it was the opinion among alchemists that most yellow substances contained gold, and Brand was therefore tempted to try to recover gold from urine. Instead, he obtained a white pasty substance which easily caught fire and which glowed in the dark.

This strange stuff which Brand found in his flask was a substance which nobody had met before. Consequently, it had to be given a name – like all the elements on their discovery. Some elements were named after towns and countries, others after the planets, and still others after the ancient gods of mythology. Many recently discovered elements have been named after famous scientists. Brand's new substance was named after its most distinctive chemical property: it was called phosphorus from the Greek 'light-bearer'.

Robert Boyle devised a better way of preparing the phosphorus, and his assistant, Hanckwitz, used this method to make it on a fairly large scale. One of his advertisements reads: 'Ambrose Godfrey Hanckwitz, chemist in London, Southampton Street, Covent Garden, continues faithfully to prepare all sorts of remedies, chemical and galenical. . . . For the information of the curious, he is the only one in London who makes inflammable phosphorus, black phosphorus, and that made with acid, oil and other varieties. All unadulterated. . . . Solid phosphorus, wholesale 50*s* an ounce, and retail £3 sterling, the ounce.'

In those days, even the wholesale price of 50*s* represented a great deal of money – about six months' pay for a schoolmaster. It was therefore not surprising that, for a long time, phosphorus remained nothing more than a chemical curiosity. However, it was later found, much to everybody's surprise, that this poisonous stuff phosphorus was a constituent of bone



Two metals discovered by the alchemists – antimony and bismuth. Note the regular crystalline structure of these metals.
Crown Copyright
Science Museum, London

A painting showing the discovery of phosphorus in 1669 by the German alchemist Hennig Brand.
Radio Times
Hulton Picture Library

and an important food for plants. Bones and plants proved to be a more convenient source of the element than urine, and the price of phosphorus has now fallen to about 3*d* an ounce. It is used to make many different things, including match heads, fertilizers, rat poison, and incendiary bombs.

The way of discovery – Following upon Boyle's definition of an element, chemists realized they must search for these simple substances by breaking down more complex substances. Any substance they could lay their hands on, they took to pieces and carefully examined the bits. In 1789 the great French chemist Lavoisier drew up a table of the elements – which, rather oddly, included caloric (heat) and light. (See the Background Book, *The Periodic Table*). Thereafter, more and more new elements were discovered. It was an exciting time for chemists.

The way that most of these discoveries were made was thus. Chemists were sent specimens of mineral ore from all over the world. They then treated these with chemicals to see what happened. If the ore behaved in a strange fashion, a new element might well be hidden in it. The colour, or weight, of the sample, if unusual, might also give the chemist a clue. If he suspected that something new was there, he would try to isolate a compound of it. He would do this by treating the mineral with another chemical, or heating it, or both. When he had managed to make the compound, he then used it to prepare some of the pure element.

The final substance was accepted as an element when it was proved that no one could break it down any further. With the limited chemical knowledge of the time, this sometimes led to mistakes. Lime, for example, was for many years thought to be an element until, in 1808, the English chemist Humphry Davy managed to separate it with electricity into the two elements, calcium and oxygen. Calcium (Latin *calx:* lime) was then unknown and oxygen (Greek: acid producer) had been discovered some twenty years earlier by Priestley in England and Scheele in Sweden. (The Background Book, *Burning*, tells of the discovery of oxygen.)

The story of thorium – The discovery of thorium by the Swedish chemist, Jöns Jacob Berzelius (1778–1848), is a typical example of the way in which elements were found in mineral ores. Sweden is a country rich in different minerals, and dur-

Some of the chemical symbols in use in 1789. See how many chemical elements you can pick out from among them. There are thirteen shown.

ing the eighteenth and nineteenth centuries many brilliant chemists came forward to study them. Of these, the greatest was certainly Berzelius. Students of chemistry from all over Europe flocked to Stockholm to visit him. There he was usually to be found either lecturing in the school of medicine or busy at work in his small laboratory. His contributions to chemistry ranged far beyond looking for elements, but of these he discovered four – selenium (Greek: the moon), silicon (Latin: flint), cerium (after the minor planet Ceres) and thorium. He also helped to find several others.

However, even the great Berzelius sometimes made mistakes. In 1815 he examined a rare mineral specimen from Fahlun, a mining town a hundred miles to the north of Stockholm. On breaking the mineral down, he found a substance that he thought was a new element. He named it thorium in honour of the old Scandinavian god Thor. Several years later, he examined this element thorium again, and found that it was not an element at all but broke down further into two known elements – yttrium (after the Swedish mining town Ytterby) and phosphorus. However, he must have liked the name thorium because, in 1829, when he really did discover a new element, that is what he called it.

Berzelius found the real element thorium in a lump of black mineral. This mineral was sent to him by a Norwegian professor who had noticed that it was unusually heavy. But, before Berzelius could claim to have made a new discovery, he had to extract some of the pure element. Doing this was difficult because thorium is a metal which forms very strong compounds with other elements. Berzelius pondered over this problem, and decided that he would have to prise out the thorium by replacing it with a metal that formed even stronger compounds. There was one metal he knew of that would do this – the very reactive element potassium which his friend Humphry Davy had discovered some years earlier. Davy was one of the first to use the energy of an electric battery to break down substances into their elements. (Using a battery, he discovered six elements before he was thirty years old, a story told in the Background Book, *Humphry Davy*).

The reason why it was important to prepare pure samples of newly discovered elements was to make sure that their properties could be studied. Each element has its own special properties – melting point, chemical reactivity, etc. – and, knowing these, the element can always be recognized. Even

Jōns Jacob Berzelius (1779–1848) prepares a specimen of the element thorium by heating a compound of thorium with potassium in a flask.

so, mistakes are sometimes made: some twenty years after Berzelius's discovery of thorium, two chemists separately claimed to have found new metallic elements, and both of these so-called 'new' elements later turned out to be thorium.

In the days when houses were lit by gas, a compound of thorium was used to make gas mantles. These mantles when heated with a non-luminous flame (as in a bunsen burner) gave out a brilliant white light. Nowadays, thorium is better known for its radioactive properties. Its radioactivity was discovered in 1898 by Madame Curie who also discovered two radioactive elements, polonium (named after her homeland, Martin Heinrich Klaproth (1743–1817), German discoverer of the elements uranium, zirconium and cerium.

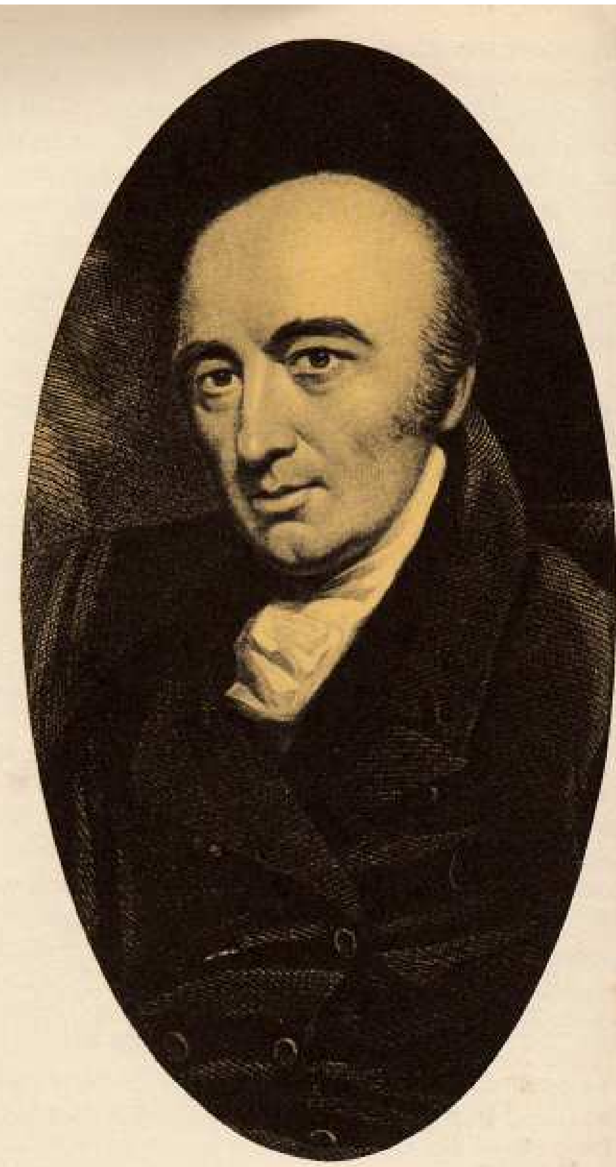
Poland) and radium. You will learn more about radioactivity later. In the meantime, it is worth knowing that radioactive elements break down naturally to form simpler elements. Therefore, Boyle's belief that all elements were unchangeable is not completely true.

Questions

Two books that tell the story of the elements in much greater detail than this one are *Discovery of the Elements* by Mary Weeks and *Man and the Chemical Elements* by J. Newton Friend. Try to get hold of a copy of one or other of these books (from your school or public library) and look up the answers to these questions.

1. What is the story behind the discovery of the following elements: *a.* tellurium *b.* chromium *c.* nitrogen *d.* magnesium *e.* uranium *f.* iodine

2. Why were the following elements so named: *a.* bromine *b.* sodium *c.* beryllium *d.* caesium



William Hyde Wollaston (1766–1828), English discoverer of the elements palladium and rhodium.

Nicolas-Louis Vauquelin (1763–1829), French discoverer of the elements chromium and beryllium.
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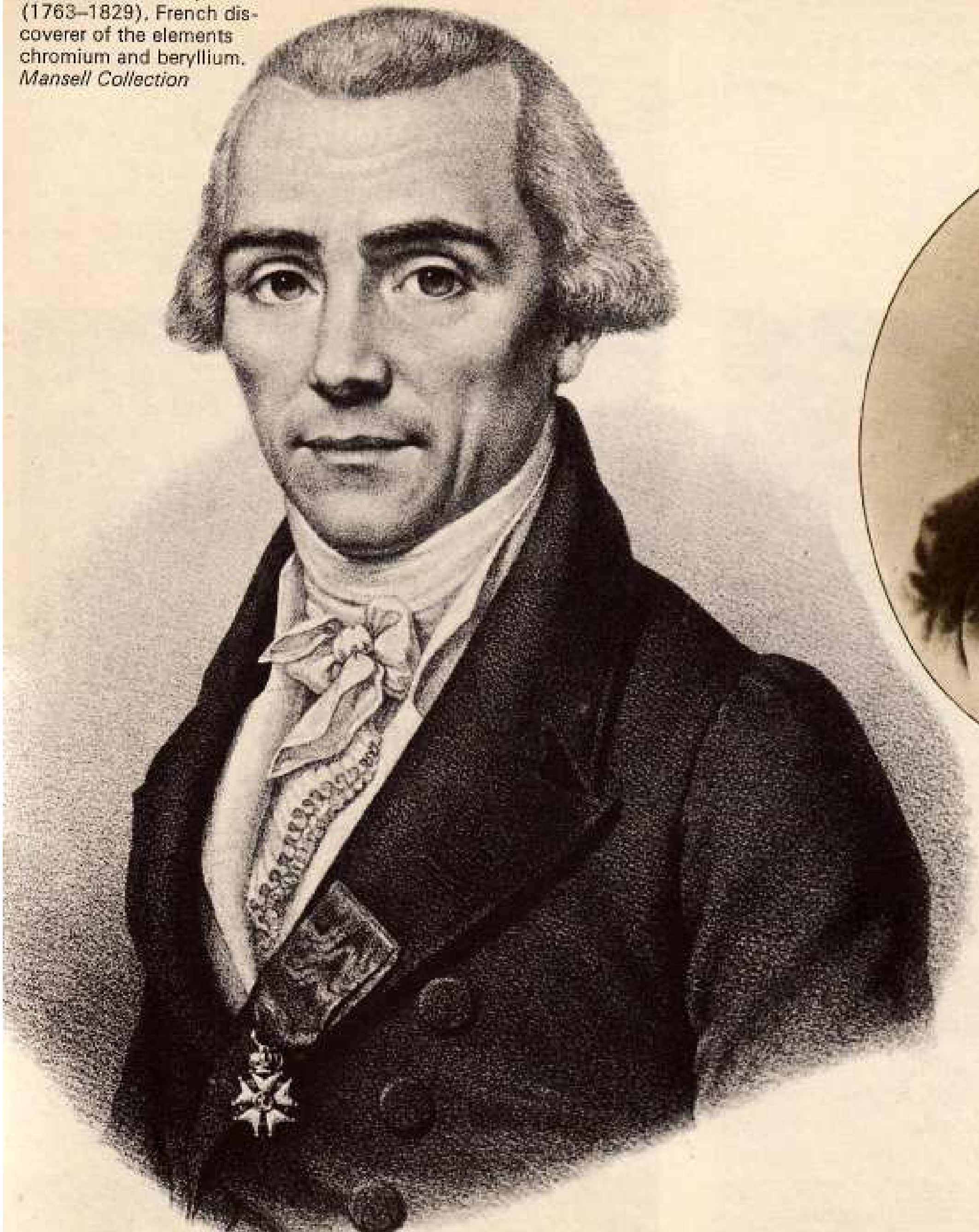
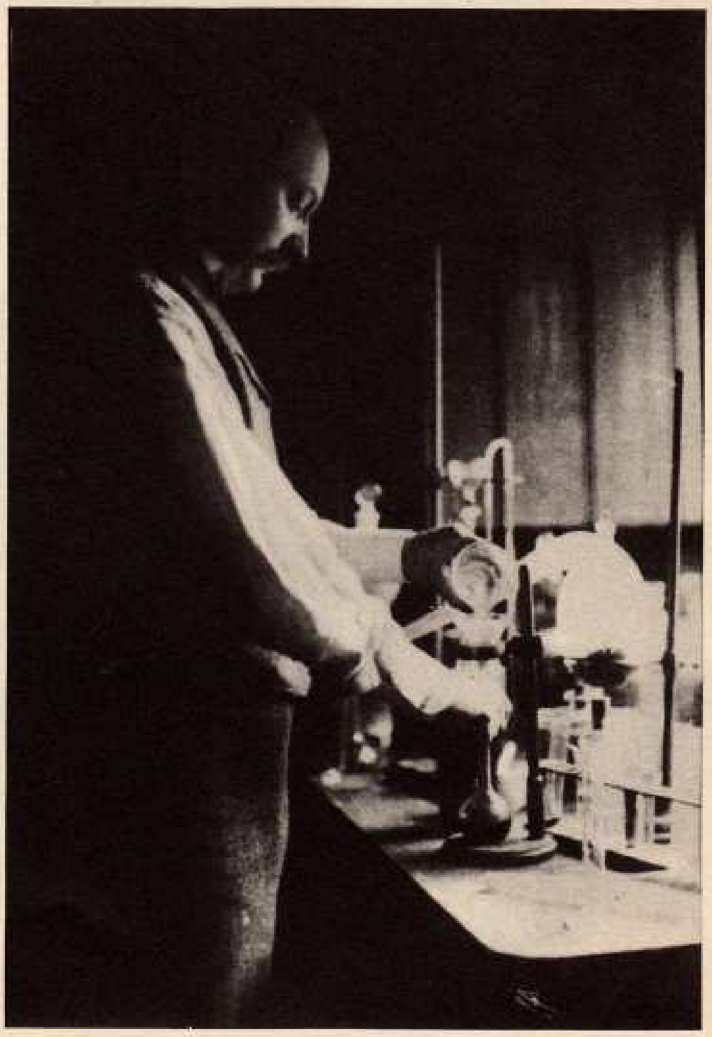


Robert Wilhelm Bunsen (1811–1899) who, with his colleague Kirchoff, invented the spectroscope and used it to discover the elements caesium and rubidium.

part 3
Recent discoveries

Lord Rayleigh (1842–1919) initiated work that led to the discovery of the inert-gas elements and with Ramsay discovered argon.
Radio Times
Hulton Picture Library

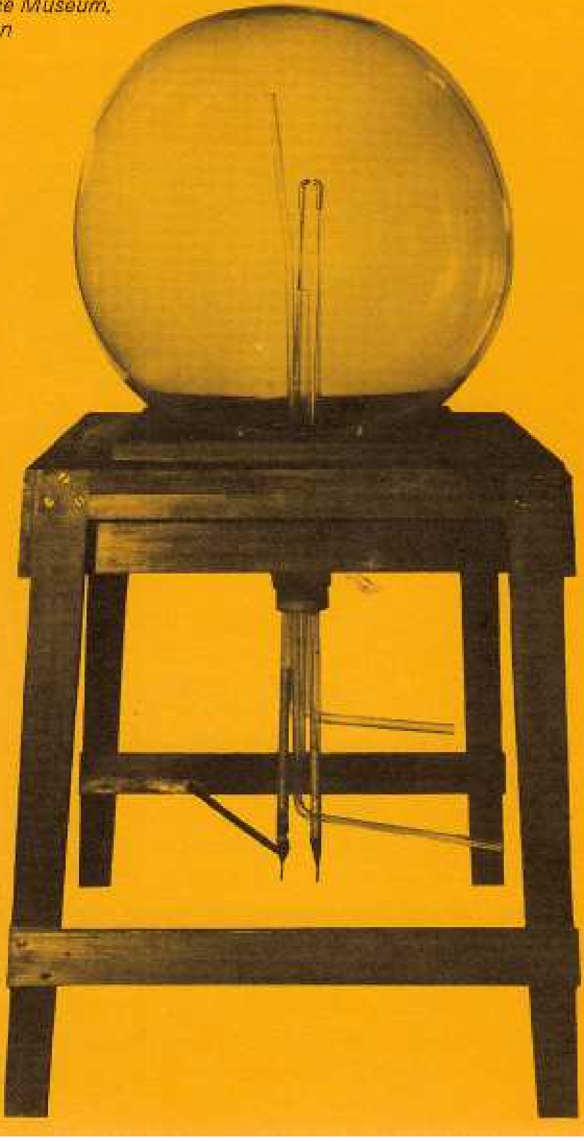


Gases that would not react – By 1890, over two-thirds of the elements to be found in nature had been discovered. Most of them were solids, some were gases and two – mercury and bromine – were liquids. The gases in the air had been carefully studied and had been shown to consist largely of the two elements oxygen and nitrogen. However, in 1894 the British chemist Lord Rayleigh noticed that the nitrogen he got from the air was denser than the nitrogen he got by extracting the gas from chemicals which contain nitrogen.

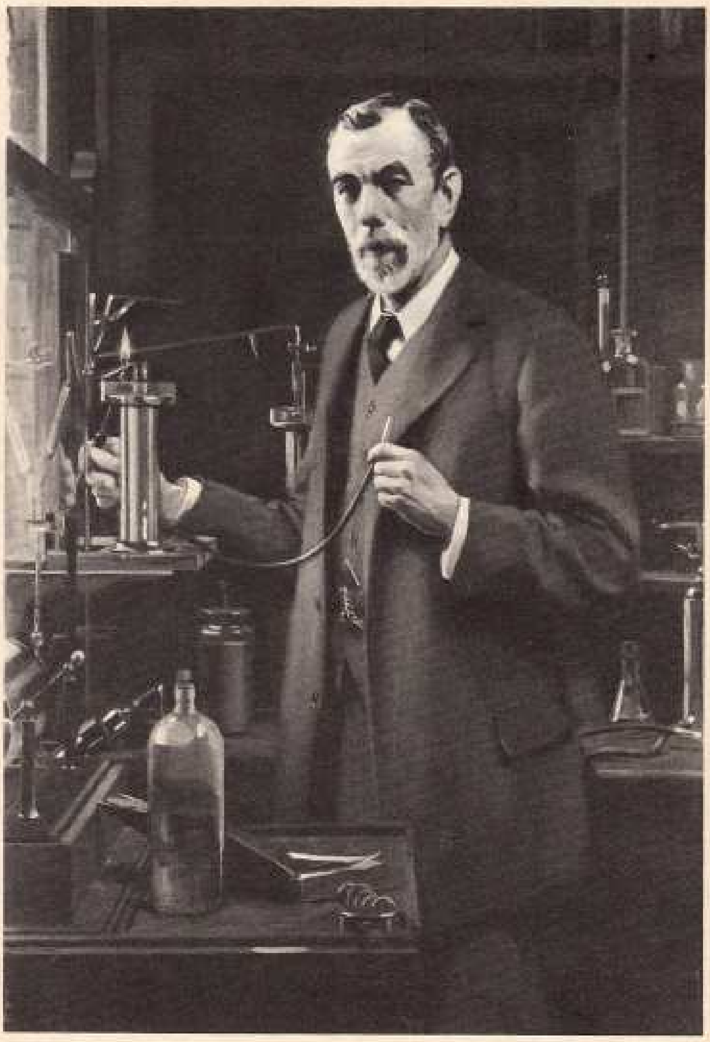
Over a hundred years before, Henry Cavendish, the discoverer of the element hydrogen (Greek: water producer), had separated from the air a very small portion of a gas which seemed even less reactive than the sluggish nitrogen. At the time, gases were not properly understood, and Cavendish had been unable to follow up his marvellously delicate separation. But, thought Rayleigh, was this a new gas that Cavendish had discovered? And, if so, could its presence explain the difference in density between nitrogen from the air and chemically prepared nitrogen? In collaboration with Sir William Ramsay, Rayleigh managed to prepare a sample of the gas. But how do you study an invisible substance like a gas when it will not react with anything else?

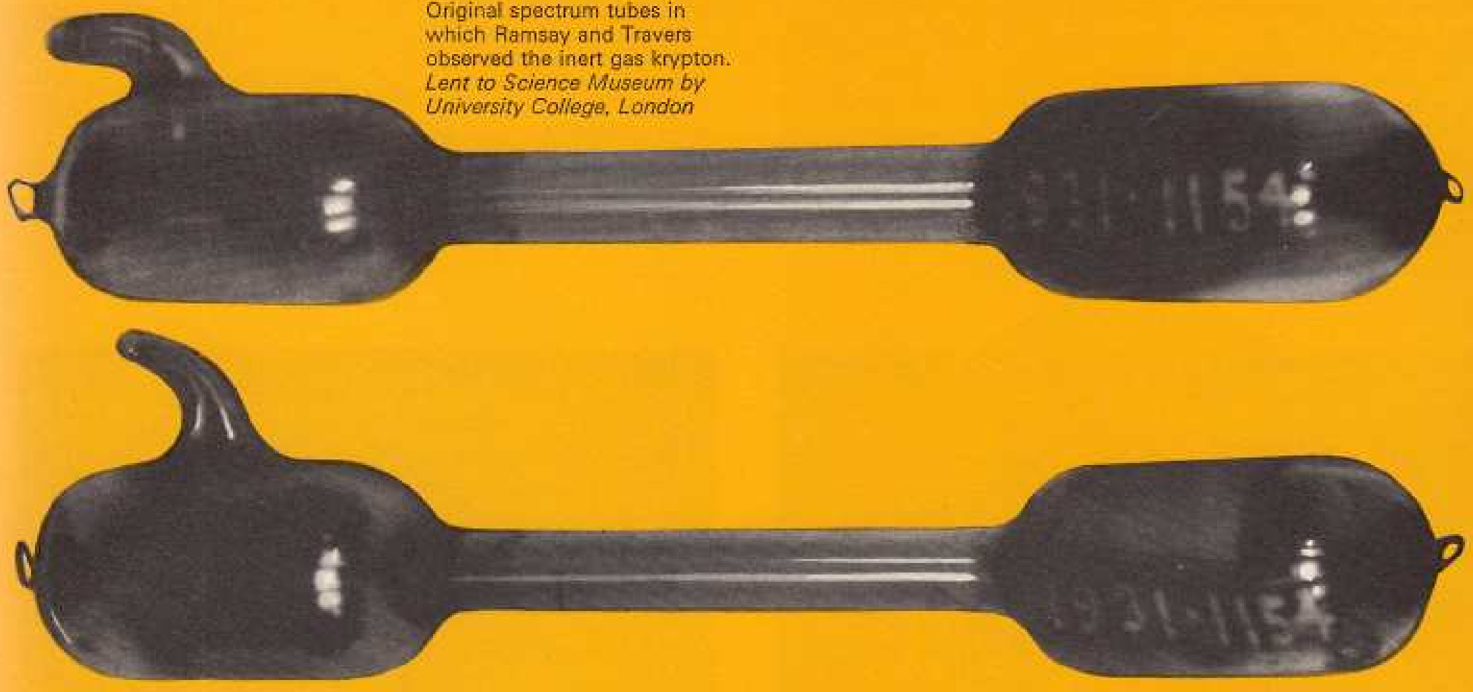
The spectroscope – Next time you are in the laboratory, heat a few substances in the flame of the Bunsen burner. Your teacher will show you how to do this. You will notice that substances containing the element barium make the flame green, those containing calcium or strontium make it red, and those containing sodium make it yellow. Every element, when heated, broadcasts coloured light signals on its own special wavelength. If you can pick up and recognize the signal, you can identify which element is present. But although the flame

Replica of apparatus made by Lord Rayleigh for the preparation in quantity of the inert-gas element argon. The air in the flask is reacted with an electric spark (note the two electric terminals) and the products of the reaction are dissolved in potash. The argon, which does not react, is drawn off.
Crown Copyright Science Museum, London



Sir William Ramsay (1852–1916) who, shortly before the turn of the century, discovered five of the inert-gas elements.
Science Museum





Original spectrum tubes in which Ramsay and Travers observed the inert gas krypton.
Lent to Science Museum by University College, London

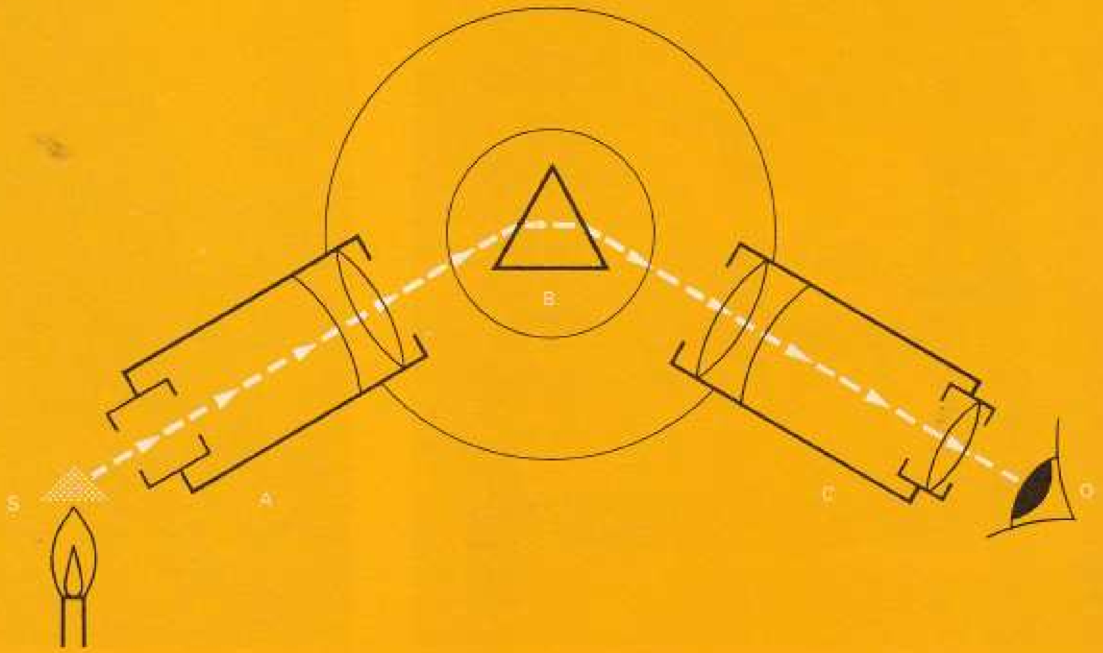


Diagram of a spectroscope: light passes from the heated substance **S**, along the tube **A**, through the glass prism **B**, along the tube **C**, to the observer at **O**. The light is split up by the prism into its separate wavelengths from which elements in the heated substance can be identified.

test is very handy it is not particularly reliable, and only a few elements visibly affect the colour of the flame. A far more exact test is to look at the heated elements through an optical instrument called a spectroscope. The spectroscope was invented by the two German scientists Bunsen (who also invented the burner) and Kirchoff in 1859. If you have not already done so, you will probably see a spectroscope in the physics laboratory. The glass prism splits up the light into its separate wavelengths, and so the observer can pick up these wavelength signals and identify the elements present in the heated substance. If a new signal appears that cannot be traced to any of the known elements, it means that a new element is present in the substance. Using a spectroscope, Bunsen and Kirchoff discovered the elements caesium and rubidium. It was later used by others to discover several more.

To return to the story of the unreactive gas, Rayleigh and Ramsay used a spectroscope to examine their sample. To their great joy, they saw a series of red and green lines which were previously unknown; this confirmed the presence of a new element. At first, they called the element aeron, but they received so many letters asking when they expected to discover Moses that they changed the name to argon (Greek: lazy) because the gas was so unreactive chemically.

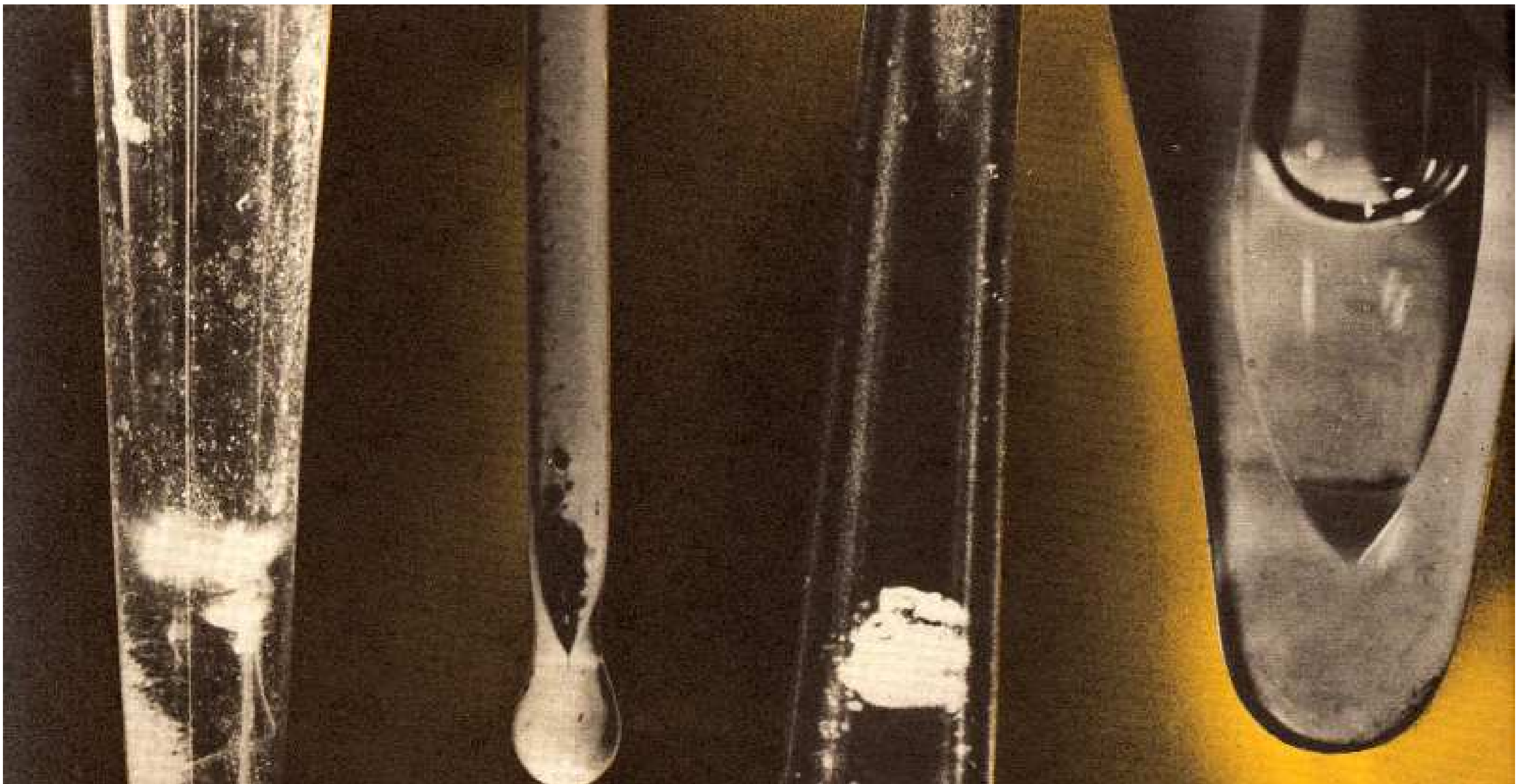
Thereafter Ramsay began searching for easier ways of obtaining argon from the air, and, taking a hint from one of his geologist friends, he examined the mineral cleveite. He broke up the cleveite to release any gas it might contain. On looking at the gas through a spectroscope, he saw to his surprise, as well as the spectral lines of argon, a brilliant yellow line. The line was similar to that of sodium but on a slightly different wavelength. Here again was another unknown gaseous element.

In fact, the element was not completely unknown. It had been detected some twenty-five years earlier on the Sun. For it is a wonderful attribute of the spectroscope that it can be used to find out the elements in heated substances at almost any distance away. It can therefore be used to find out what elements are present in the Sun and the stars. In 1868, during an eclipse, the astronomer Janssen turned his spectroscope on the Sun and saw the same brilliant yellow line which Ramsay was later to see. The British scientists Frankland and Lockyer suggested that this yellow line in the Sun's spectrum represented a new element then unknown on Earth. They called it helium (Greek: the sun). With the discovery of yet another unreactive gas, Ramsay was encouraged to make a thorough search for more. He began by heating rare minerals, but without success. Then, with his young assistant Travers, he tried distilling liquid air. One day, as Travers was returning to the laboratory after lunch, a colleague called gaily to him 'It will be the new gas this time, Travers!' 'Of course it will be', replied Travers with assumed confidence. And it was! For, after distilling the liquid air, they looked at a heated sample of the remaining gas through the spectroscope and saw two new lines. They called the gas krypton (Greek: hidden one). Later they discovered two more gases: neon (Greek: new one); and xenon (Greek: stranger).

These gases were called the *inert* gases because they could not be made to react with any other elements. Very recently it has been found that they can be made to react and are therefore not completely inert – but that is a story which you will hear about another time. For many years, the only one of them to be used in any large quantity was helium. It was used in airships instead of hydrogen because it does not catch fire. However, argon is now used extensively as the gas for filling electric light bulbs, and neon strip lighting illuminates many of our houses, shops, and streets.

Making new elements – At the present time we can say with some confidence that all elements to be found in nature have now been discovered. How can we be sure of such a statement? To Robert Boyle, it would have seemed an odd thing to say. How do you know, he would have argued, that you won't come across other simple substances that you can't break down? The answer to this question is that, nowadays, we no longer think of elements exactly as Boyle did. For one thing, we now know something of their chemical structure. For another, we now know that, in very special circumstances, elements can be both built up and broken down.

When radioactivity was discovered at the end of the last century, scientists first realized that some elements break down to form simpler ones. This happens naturally. The next step was for scientists to make the change happen themselves. The first person to do so was the forthright New Zealander Lord Rutherford. In 1919 at the famous Cavendish Laboratory in Cambridge, he bombarded the gas nitrogen with atomic particles from a radioactive element and so converted a



The first neptunium compound – at the base of the capillary tube (magnified about 20 times)

The first americium compound – with the eye of a needle for comparison of size (magnified about 10 times)

The first curium compound – at the base of a centrifuge tube (magnified about 5 times)

The first californium compound (magnified about 100 times)

Some of the elements made by man:

few atoms of it into a few atoms of oxygen. After Rutherford, numerous other people carried out similar *transmutations*. The alchemists' dream of changing other metals into gold had at last come true, although the gold was very expensive.

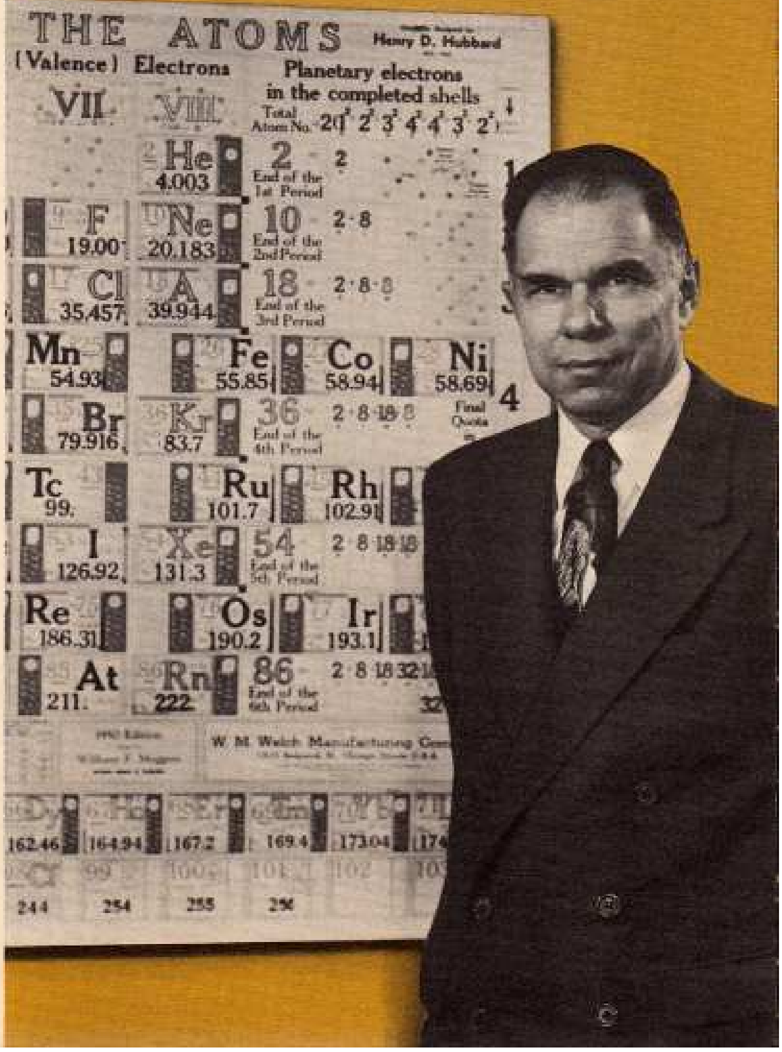
At first the transmutations that scientists brought about were always from one known element into another. But, starting in 1940, American chemists working at Berkeley, in California, have been making a series of new elements. Most of these elements, which are built up by bombarding the heaviest known natural element uranium, can be made only in minute quantities. All of them are radioactive and in time break down to form simpler known elements. For this reason, they may once have existed on Earth but, so far as is known, do so no longer. The chemists chiefly responsible for this exciting work are the Americans Dr G. T. Seaborg and Dr A. Ghiorso. So far, eleven new elements have been made, which means we now know of 103 elements altogether.

Where do the elements come from? – The famous biologist Charles Darwin once remarked: 'Talk about the origin of life! You might just as well talk of the origin of the elements!' But, now that man is able to make elements himself, their origin is no longer such an unreasonable subject to talk about.

In the last few years it has become clear from the study of stars in different parts of the Universe, that the formation of the elements is linked with processes going on in all stars. In the Sun, for example, energy is being produced continually by a process in which atoms of hydrogen are converted into atoms of helium. In other stars helium is being turned into carbon. Elsewhere elements whose atoms are still heavier are constructed from smaller fragments. It also seems that entire stars can sometimes explode, forming other kinds of atoms, and scattering these through a vast region of space.

In ways like these, it seems that stars are turning elements with small atoms into elements with larger atoms. In one theory of how the Universe itself came about, it is supposed that matter is being continuously created in the formation of hydrogen atoms. If that is correct, then the process going on in stars must be the only one responsible for making more complicated elements. But another theory of the Universe – the 'big bang' theory – supposes that the universe was once a giant solid core of simple atomic particles which was shattered ten thousand million years ago with such force as to fuse some

Dr G. T. Seaborg who, with Dr E. M. McMillan, was awarded the 1951 Nobel Prize in Chemistry for his work in making new elements.



of the atomic particles together and provide the energy which has ever since kept the Universe expanding. On that theory, some of the heavier elements would have been made at the beginning of the Universe, and others would have been constructed afterwards by the processes going on in stars.

Both these theories have their champions but neither of them really explains all the facts. Yet it is a considerable step forward to know that there is now a chance of explaining where the elements come from, and how.

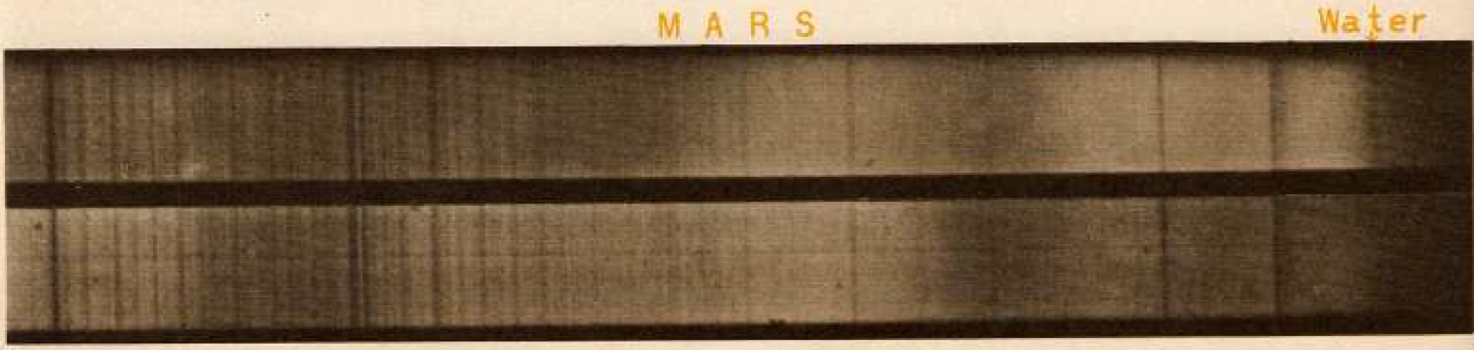
Questions

1. From memory, write down a list of all the elements you can think of. Check the list with the table of elements in this Background Book. Over thirty elements and you have done well. Twenty is about average. Less than ten and you should think again. If, in your list, you have written down a substance that is not an element, find out what elements it is made of.

2. On the cover pages, there are two blank areas on the elements crossword. Try to fill them in. On the front page, down (six letters), is one of the principal gases of the air. On the back page, across (three letters), is a well-known metal of which this country used to be the main producer.

Spectra of the planets and stars can be examined by incorporating a spectroscope in a telescope such as this.

Spectrum of the planet Mars. One of the lines indicates the presence of water (as shown) and therefore of what elements?



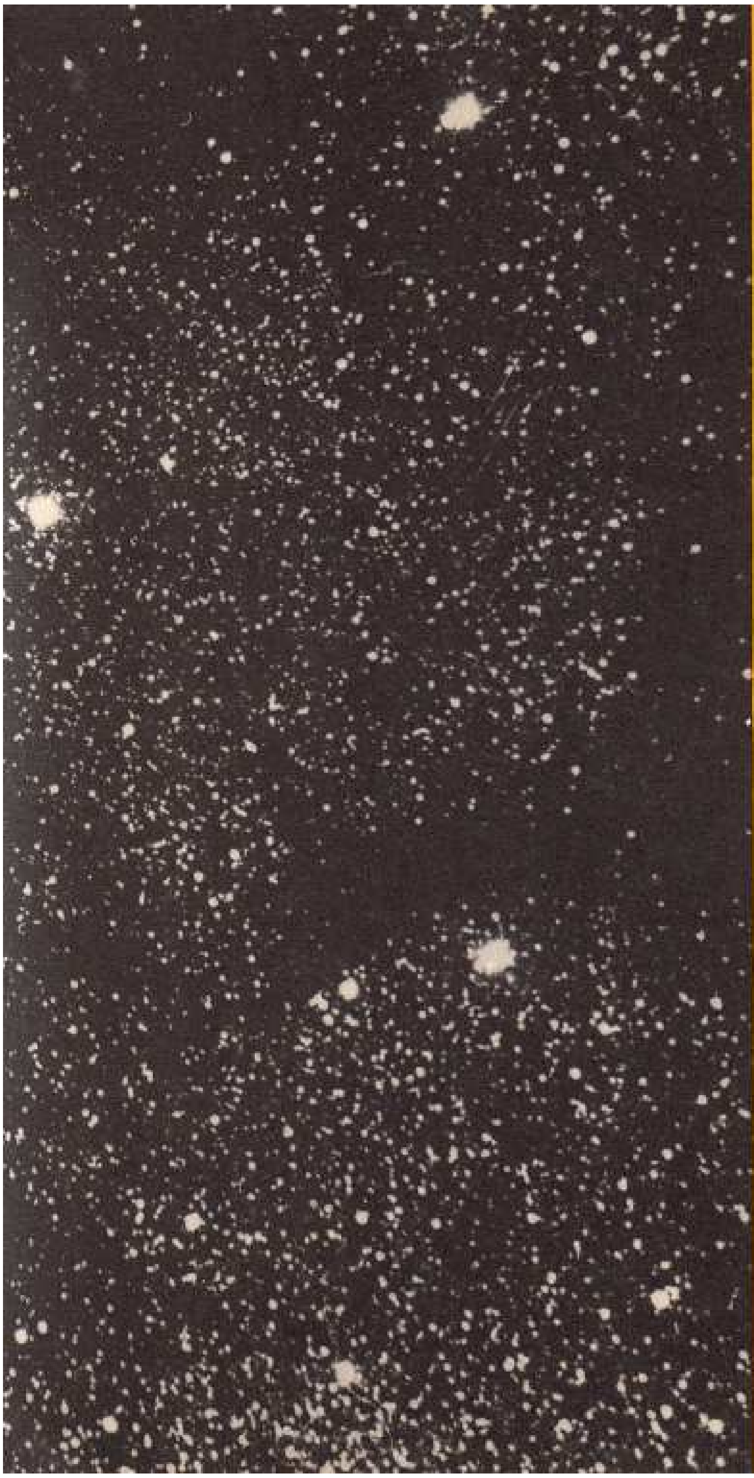


Table of the discovery of the Elements

Element	*Approx. Year*	*Discoverer*
Carbon	Known	Unknown
Copper	before	
Gold	the	
Iron	birth	
Lead	of	
Mercury	Christ	
Silver		
Sulphur		
Tin		
Zinc		
Arsenic	13 Cen.	Albertus Magnus?
Bismuth	16 Cen.	Unknown
Antimony	16 Cen.	Alchemists
Phosphorus	1669	Brand
Cobalt	1735	Brandt
Platinum	1735	Ulloa
Nickel	1751	Cronstedt
Hydrogen	1766	Cavendish
Fluorine	1771	Scheele
Nitrogen	1772	D. Rutherford
Chlorine	1774	Scheele
Manganese	1774	Gahn
Oxygen	1774	Priestley, Scheele
Molybdenum	1782	Hjelm
Tellurium	1782	Von Reichenstein
Tungsten	1783	d'Elhujar
Titanium	1789	Gregor
Uranium	1789	Klaproth
Zirconium	1789	Klaproth
Strontium	1790	Crawford
Yttrium	1794	Gadolin
Chromium	1797	Vauquelin
Beryllium	1798	Vauquelin
Niobium	1801	Hatchett
Tantalum	1802	Eckeberg

Element	*Approx. Year*	*Discoverer*
Cerium	1803	Klaproth, Berzelius
Palladium	1803	Wollaston
Rhodium	1803	Wollaston
Iridium	1804	Tennant
Osmium	1804	Tennant
Potassium	1807	Davy
Sodium	1807	Davy
Barium	1808	Davy
Boron	1808	Davy
Calcium	1808	Davy
Magnesium	1808	Davy
Iodine	1811	Courtois
Cadmium	1817	Stromeyer
Lithium	1817	Arfedson
Selenium	1817	Berzelius
Silicon	1823	Berzelius
Aluminium	1825	Oersted
Bromine	1826	Balard
Thorium	1829	Berzelius
Vanadium	1830	Sefstrom
Lanthanum	1839	Mosander
Erbium	1843	Mosander
Terbium	1843	Mosander
Ruthenium	1845	Claus
Caesium	1861	Bunsen, Kirchoff
Rubidium	1861	Bunsen, Kirchoff
Thallium	1861	Crookes
Indium	1861	Reich, Richter
Helium *on the sun*	1868	Janssen, Frankland, Lockyer
Gallium	1875	Boisbaudran
Ytterbium	1878	Marignac
Holmium	1879	Cleve
Samarium	1879	Boisbaudran
Scandium	1879	Nilson
Thulium	1879	Cleve
Neodymium	1885	Welsbach
Praseodymium	1885	Welsbach
Dysprosium	1886	Boisbaudran
Gadolinium	1886	Marignac
Germanium	1886	Winkler
Argon	1894	Rayleigh, Ramsay
Helium	1895	Ramsay
Krypton	1898	Ramsay, Travers
Neon	1898	Ramsay, Travers
Polonium	1898	P. and M. Curie
Radium	1898	P. and M. Curie, Bemont
Xenon	1898	Ramsay, Travers
Actinium	1899	Debierne
Radon	1900	Dorn
Europium	1901	Demarcay
Lutetium	1907	Welsbach, Urbain
Protactinium	1917	Hahn, Meitner
Hafnium	1923	Coster, Hevesy
Rhenium	1925	Noddack, Tacke
Technetium	1937	Perrier, Segre
Francium	1939	Perey
Astatine	1940	Corson and others
Neptunium	1940	McMillan, Abelson
Plutonium	1940	Seaborg and others
Americium	1944	Seaborg and others
Curium	1944	Seaborg and others
Promethium	1945	Glendenin, Marinsky
Berkelium	1949	S. G. Thompson, Ghiorso, Seaborg
Californium	1950	S. G. Thompson and others
Einsteinium	1952	Ghiorso and others
Fermium	1953	Ghiorso and others
Mendelevium	1955	Ghiorso and others
Nobelium	1958	Ghiorso and others
Lawrencium	1961	Ghiorso and others

Chemistry Background Books
General editor H P H Oliver Author of this book H P H Oliver
Art editor Ivan Dodd
Published for the Nuffield Foundation by Longmans/Penguin Books
Longmans Green and Co Ltd 48 Grosvenor Street London W1
Penguin Books Ltd Harmondsworth Middlesex England
 First published 1967
Reprinted 1967
Made and printed in Great Britain by W S Cowell Limited
CBB04331