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Analysing the Stars

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IT was possibly in a rash moment that the French philosopher Comte once remarked : " There are some things of which the human race must remain forever in ignorance ; for example, the chemical composition of the heavenly bodies ". Today it is possible to detect iron in the flames of the sun with just as much certainty as one can detect common salt in sea water.

Analysis, one of a number of important phases of chemical investigation, involves finding the answer to two questions : What are the constituents present in the substance under investigation, and how much of each ? For example, you might say to an analyst, here is a piece of beef steak ; does it contain sodium sulphite, and if so, how much ? It is a relatively simple matter to carry out tests for the presence of sodium sulphite, i.e. to make a qualitative analysis. One simply chooses conditions such that upon treatment of the substance to be analysed with suitable chemicals an easily identifiable, characteristically coloured and sometimes insoluble substance is formed. Now it is obvious that such a method cannot be applied to the sun and other stars. Since, then, apart from meteorites of unknown origin, pieces of the sun and other stars are not available for examination in test-tubes, some other kind of detectable signs from the material in those bodies must be obtained. These are at hand in the light that shines from atoms in the stars. Each kind of atom of the ninety-two different kinds which make up the universe, under appropriate conditions (such as occur in flames and electric arcs) sends out characteristic light signals which may be used as a means of detecting them—finger-printing them, as it were. Copper atoms send out certain kinds of light : light of definite wave-lengths ; gold atoms send out another set, and so on. Atoms have been compared to tiny broadcasting stations. Instead of broadcasting on one particular wave-length (like 2 BL, for example), atoms of copper broadcast on several hundred different very much shorter wave-lengths, while iron atoms, more versatile still, broadcast on as many as 20,000 different wave-lengths. Wherever *iron atoms* are—in the flames of the sun or in the most distant stars—they always broadcast on the same set of wave-lengths. The set of waves they emitted a million years ago is just the same as the waves they emit in the laboratory today. The same may be said of all other kinds of atoms. The special receiver used for their reception is also capable of sorting out the waves as well. It is known as the spectroscope, and this instrument has played the part of master-key in unlocking the secrets of the composition of the stars. Before proceeding to explore, by means of the spectroscope, the stars in the vast oceans of space beyond the earth, it will be necessary to consider briefly the laboratory experiments on which the method of spectrum analysis, as it is called, is based.

When a chord is struck on the piano, the practised ear is able to distinguish the several individual notes of which it is composed. The eye, however, is unable to recognize the separate wave-lengths of light coming from a source emitting a number of different kinds of waves. Perhaps you have noticed at some time or other the intense green light which is produced on the tram wires when a powerful electric current jumps across a small space between the trolley pole and the overhead copper wire. Mixed up with the dominant waves of green light emitted by the copper atoms there are waves of red and blue light which the eye is quite unable to sort out from the green. The sorting out of the waves of different coloured light can be achieved by means of a glass prism, the essential part of many spectroscopes. When light from the sun is made to pass through a prism, it becomes separated by refraction into the different colours of the rainbow. The rainbow is a natural spectrum produced by the refraction of sunlight in raindrops. The band of colours shading from red at one end to violet at the other, produced by glowing solids—the filament of an electric light bulb, for example—is known as a continuous spectrum. Glowing gases such as you see in the now familiar neon advertising signs produce what is called a line spectrum, that is, in place of the continuous gradation of colours there are bright narrow coloured lines on a black background. Each line represents waves of given wave-length. Each kind of atom produces its own special set of coloured lines, and thus when it comes to identifying the atoms in stars, one may say : By their spectral lines you shall know them.

It is important to realize that it is only when atoms are violently jostled about as they are in flames and electric arcs that they can be made to emit their characteristic light signals.

If a little common salt be sprinkled on to a non-luminous gas flame, the flame is immediately coloured a brilliant yellow. The same yellow colouration is produced by very small amounts of dissolved sodium salts present in tap-water when the kettle boils over on a gas stove. You see the same colouration on adding to the flame baking soda or for that matter any compound containing sodium atoms. Examination of the bright yellow flame by means of a spectroscope reveals an extremely simple spectrum—merely two yellow lines very close together. The light from the brilliant arc produced by passing an electric current across a short gap between two pieces of iron gives rise to a whole host of lines—red, yellow, green, blue, and so on. The sets of lines produced by a great many of the known elements or simple substances have now been very carefully mapped out. Once we find sets of lines of the appropriate wave-lengths in the light from any source, be it a star, a comet's tail, or an electric arc, we may be sure that atoms which are known by laboratory experiments to emit these waves are present in the source of light under examination.

Since the sun is the nearest and brightest star, and therefore one most easily studied with a spectroscope, we may as well make him the first subject for analysis. A glance at the sun's spectrum, however, reveals a state of affairs which is the reverse of any so far described. Instead of many bright, coloured lines, there are numerous fine black lines on a continuous or rainbow-like background. It would take me too far afield to explain fully how this state of affairs comes about, but the reversal need occasion no serious worry, for the black lines on a bright background enable us to identify the elements with just as much certainty as the bright, coloured ones on a black background. The bewildering array of lines in the sun's spectrum has been carefully studied, the lines sorted out and assigned to some sixty different elements. We find in abundance iron, zinc, nickel, chromium, aluminium, calcium and silicon. Less abundant are platinum, silver and arsenic. There are more than thirty kinds of atoms which have not yet been discovered in the sun, some on account of the fact that we do not yet know what sort of light the atoms emit in the laboratory. On the other hand, the reverse—the discovery of an element in the sun before it was isolated on the earth—has actually happened once. It came about something like this : During an eclipse of the sun, visible in India in 1868, two astronomers, Janssen and Lockyer, examined with a spectroscope the outer flames and fiery clouds of the sun rendered easily visible at that time. They noticed in their instrument a yellow line which at first was thought to be produced by sodium atoms. Further careful examination showed that the yellow line was not in the position of either of the yellow lines produced by sodium atoms, and moreover, it appeared in the spectra of many other stars. Lockyer suggested that the yellow line, and others found to accompany it, belonged to some as yet undiscovered element, to which he appropriately assigned the provisional name of helium, a name derived from the Greek word for the sun, and there the matter rested for nearly thirty years. In 1895, just after Lord Rayleigh had announced the discovery of argon in the earth's atmosphere, Sir William Ramsay began to hunt about for compounds of argon in the rocks. Following up a clue provided by the American mineralogist Hillebrand, Ramsay examined the gases evolved when the rare mineral clevite was treated with sulphuric acid. Spectroscopic examination showed a number of new lines, and Ramsay put these down to a new gas which he tentatively called crypton. Ramsay's spectroscope was not a particularly good one. He therefore sent samples of the new gas to Sir William Crookes for a detailed analysis of its spectrum. Crookes reported, tersely, " Crypton is helium ; come and see it " ; and so twenty-seven years after its discovery in the sun, helium was run to earth. Helium is a first cousin, chemically speaking, to neon, which now blushes so conspicuously in the numerous advertising signs to be seen about the city.

Helium is not the only element to be discovered by the spectroscope ; the discovery of some ten new elements stands to its credit. One of the earliest discoveries made by its aid was that of the two rather rare metals rubidium and cæsium, a discovery made by two German chemists about fifty years ago. Ruby red and blue lines which could not be assigned to any known elements appeared in the spectrum of a liquid obtained by concentrating certain German mineral waters. Convinced that these lines were produced by some undiscovered element, these two chemists forthwith proceeded to evaporate forty tons of the mineral water. Their efforts resulted in the isolation of about one-quarter of an ounce of two new substances containing the metals rubidium and cæsium. Incidentally this gives some idea of the sensitivity of spectrum analysis. It is possible on occasion to detect as little as one part in 100,000 millions of an element like lithium.

But to return to the sun and stars. One of the most remarkable features of the results of spectrum analysis of the heavenly bodies is what wherever we look—at the blazing surfaces of terrifically hot stars, in the relatively cool comets, in the sun, or the remote nebulæ—we find the same kinds of atoms as here on the earth.

> "White orbs like angels pass
> Before the triple glass,
> That men may scan the record of each flame
> Of spectral line and line,
> The legendry divine.
> Finding their mould the same, and aye the same,
> The atoms that we knew before,
> Of which ourselves are made, dust and no more."

The resemblance between one star and another goes even further, for our knowledge, relatively crude as it is at present, of the quantitative analyses of stars, reveals a striking uniformity in their composition. Careful studies of the structure of spectral lines, their width, and so on, has enabled analysis to be put on a quantitative basis. Thus in a recent scientific paper on the subject one reads that in the upper layers of the sun's atmosphere there are 500 million tons of platinum. From a perusal of this same contribution to the study of the composition of the sun it appears that there is no evidence for the existence of gold in the sun's atmosphere, but as it would be even more difficult to transport it therefrom than to shift it across the Atlantic from west to east, this need not trouble us.

The comparison of the compositions of the sun and earth is necessarily very rough and crude, since in each case we have direct knowledge only of the make-up of the surface layers. We know that oxygen, silicon and aluminium are the major constituents of the outer mantle or crust of the earth. What lies beneath is a matter of conjecture. Geochemists, whose business it is to study the distribution of elements in the earth, tell us that the centre of the earth consists largely of an iron-nickel core.

That the relative abundance of the elements in the surface of the sun is somewhat similar to those on the earth's surface is not surprising. Astronomers tell us that long ages ago another star very nearly collided with the sun. As a result of the close shave, huge tides were produced in the sun, and large jets of matter flung out—jets that ultimately broke into drops which solidified to Mars, Venus, the earth, and all the other planets.

Occasionally the discovery in the stars of new elements, elements unknown on the earth, has been announced. Two instances come to mind—those of the so-called nebulium and coronium. Strange, unaccounted for lines in the spectra of certain gaseous nebulæ were attributed to a new element, nebulium. It subsequently turned out that the lines were produced by familiar old friends, nitrogen and oxygen, the main constituents of the earth's atmosphere. Under the extremely low pressures existing in gaseous nebulæ, nitrogen and oxygen atoms can emit waves of light which are impossible in the usual terrestrial sources. The element coronium is supposed to exist in the outer and most tenuous atmosphere of the sun. The outermost solar envelope, known as the solar corona, is visible as a beautiful pearly haze only at times of total eclipse. So far, then, there has not been a great deal of time in which to examine its spectrum thoroughly. As far as I can ascertain the nature of coronium is still a mystery. There is a strong suspicion, however, that it is some familiar substance under peculiar or unusual conditions. In point of fact, there appears to be no place left for a new element. The days of element hunting are over, as far as we can see. True, the last of the 92—numbers 85 and 87—have so far been detected, if at all, only in the most minute traces. The discovery of element 85 is doubtful. So well known is the relationship between atomic number (that is the number of planetary electrons in the normal atom) and the spectrum lines that the positions of the X-ray lines can be predicted in advance. This has already happened to number 87, which occurs in minute traces in the mineral samarskite. The X-ray spectrum lines occur just where they should, according to calculations, and now, before it is actually isolated and put in bottles, as it were, the element is considered as discovered. However, it does not appear possible that coronium is either 85 or 87.

One usually thinks of the vast space which exists between the earth, the sun and all other stars as being completely void of all matter. Such is not the case, for the spectroscope reveals the existence of highly attenuated clouds of calcium atoms. There is other evidence of the existence of cosmic clouds. The coal sack in the Southern Cross is a region of the sky which is quite black and apparently void of stars. The stars are really blotted out by an intervening cosmic cloud. The submergence of the solar system in cosmic clouds which would necessarily decrease the amount of the sun's heat falling on the earth has lately been put forward as an explanation of the occurrence of the ice ages which overwhelmed the earth during the past.

The revelations of the spectroscope are not limited to matter in the tremendously hot and glowing condition. Cold vapours or gases may withdraw or absorb from a beam of light containing all wave-lengths certain characteristic waves or groups of waves which may serve for purposes of identification. Thus we find water vapour and oxygen (both necessary for the existence of life, incidentally) in the atmosphere of the planet Mars, while in Venus we find neither gas. The curious white markings which come and go with the Martian winter and summer are possibly polar ice caps formed from the water vapour present in the planet's atmosphere. The atmosphere of Mars appears to be a good deal drier, generally speaking, than our own.

Very high up in our own atmosphere we have of late become aware, spectroscopically, of an interesting, somewhat poisonous modification of oxygen, namely ozone. You are sometimes advised in tourist guide books to tarry a while in the mountains or at the seaside for the benefit of the ozone. There is next to none in either place. To reach the ozone you would have to ascend some thirty miles or more, and even then you would not find very much of the gas. One interesting effect of the ozone is to block out a good deal of the sun's ultra-violet light, and so reduce enormously its power to produce sunburn. Ozone appears to be associated with a beautiful phenomenon sometimes witnessed in these latitudes—the Aurora. The light of the Aurora contains what was for a long time a mysterious green line whose origin has now been traced to oxygen. It is well known that ozone slowly reverts to ordinary oxygen, and it seems quite probable that the production of the green auroral line occurs during this process.

To return once more to the stars. Wherever we look we find, in the countless millions of blazing suns which make up the Milky Way and the more distant "island universes", that matter exists almost entirely in the atomic condition. For the most part it is too hot for atoms to be able to cling together in molecules. The violent smashing about which molecules receive at high temperatures makes it impossible for any but the very simplest and most stable to exist, and even these usually find it too hot in the stars.

In the cooler parts of the huge tongues of flame shot out by tornado-like storms on the sun, storms which we know as sun spots, two atom molecules like magnesium hydride seem to be able to exist, but more complex and less stable molecules, and hence life, are only possible in special instances where some very rare accident produces a cool ash like the earth. In the words of Sir James Jeans, "It does not at present look as though Nature had designed the universe primarily for life; the normal star and the normal nebula have nothing to do with life except make it impossible.

"Life is the end of a chain of by-products; it seems to be the accident, and torrential deluges of life-destroying light the essential."