speaks of an explanatory pamphlet which is now before us, and we see from it that the intention of the present system of signals is to give an indication of the *direction* of the wind to be apprehended in every case. The drum is never to be used without the cone. Its signification in Admiral FitzRoy's time was "dangerous winds from nearly opposite quarters successively;" and it accordingly gave no indication of direction *by itself.* Experience has shown that there is a much greater degree of certainty in foreseeing the *direction* than the *force* of a coming strong wind. Furthermore an attempt is made to give a degree of numerical definitiveness to the warnings, which at once admits that they are not infallible. The Committee say :—"Hitherto it has been found that at least three out of five signals of approaching storms (force upwards of 8 Beaufort scale, a 'fresh gale,') and four out of five signals of approaching strong winds (force upwards of 6 Beaufort scale, a 'strong breeze') have been fully justified." We may fairly consider this as a step in the direction of treating weather indications by the laws of exact science.

WE are glad to learn that Prof. Alluard, of Clermont-Ferraud, has at last succeeded in surmounting the various obstacles which he met with in the establishment of his proposed observatory on the Puy de Dome, at an elevation of about 1,660 metres above the surrounding country (NATURE, vol. vii. p. 481). The chief difficulty arose from the opposition of the peasant proprietors to the invasion of their rights by the construction of a road and erection of the building. M. Alluard announces that the observatory will be ready to be inaugurated in September next, and has invited his meteorological friends to visit Auvergne on that occasion.

A LARGE deposit of Moa bones has lately been discovered in a swamp at Hamilton, in Otago. Besides *Dinornis*, the swamp contains bones of *Aptornis, Harpagornis*, &c. The whole have been secured by the curator of the Otago Museum.

The Sedgwick Geological Prize (Cambridge) has been adjudged to J. J. Harris Teale, B.A., St. John's College. The subject for the next prize will be—"The post tertiary deposits of Cambridgeshire and their relation to deposits of the same period in the rest of East Anglia."

THE French Society of Geography has decided upon holding an International Geographical Congress at Paris in 1878. Rules and programmes will be issued shortly.

THERE has recently been concluded in connection with the Liverpool Free Public Library and Museum, a carefully arranged and excellent course of Free Lectures. This is the ninth winter course in connection with the same institution, from which we are glad to infer that these free lectures have been a success. We should like to see similar courses inaugurated in all our large towns ; we believe the results would be in the highest degree beneficial. The following is a summary of the Liverpool course :—Eight Lectures on Art, by Mr. W. J. Bishop ; Three Lectures on Natural History, by Mr. T. J. Moore ; Six Lectures on the Chemistry of Salt, and of the Manufactures depending on it, illustrated with Specimens, Experiments, Diagrams, &c., by Mr. Edward Davies, F.C.S., &c. ; Three Lectures on Geology, by Mr. G. H. Morton, F.G.S., F.R.G.S.I. ; Two Lectures on Mineralogy and Mining, by Mr. F. P. Marrat, M.L.G.S. ; Six Lectures on Navigation and Astronomy, by Mr. J. T. Towson, F.R.G.S. ; Two Lectures on Art and Antiquities, and one on Town Window Gardens, by Mr. Charles T. Gatty ; Three Lectures on the Constitutional History of England, illustrated with Historical Maps, by Mr. James Birchall ; Four Readings, by Mrs. H. J. Gorst.

THE Austrian amateur navigator, Count Wilczek, writing in the *Neue Freie Presse*, says that there is no ground for apprehension as to the fate of the Austrian Polar Expedition which sailed in the *Tegetthoff*, in the year 1872, and that news will probably be received from the expedition in October or November next. Letters for members of the expedition will be despatched by the Austro-Hungarian Government by means of whaling and other vessels bound for the Arctic seas.

MESSRS. TRÜBNER and Co. have in the press and will shortly publish a treatise on "Valleys, and their Relation to Fissures, Fractures, and Faults," by G. H. Kinahan, M.R.I.A., F.R.G.S.I. This work will be dedicated by permission to His Grace the Duke of Argyll.

MR. F. C. S. ROPER, F.L.S., has published a "Supplement to the Fauna and Flora of Eastbourne, together with a list of Eastbourne Cretaceous Fossils."

MESSRS. S. W. SILVER & Co. have just published a "Handbook for Australia and New Zealand," containing a large amount of varied and useful information about the various colonies in that quarter of the world. It is accompanied by a "Seasons'-Chart of the World."

THE additions to the Zoological Society's Gardens during the last week include two Palm Squirrels (*Sciurus palmarum*) from Ceylon, presented by Capt. Forster ; a Sonnerat's Jungle Fowl (*Gallus sonnerati*) from South India, presented by Mrs. White ; two Tench (*Tinca vulgaris*) British, presented by Mr. W. Arnold ; a Black-eared Marmoset (*Hapale penicillata*) from Brazil, presented by Mr. F. Graham ; a Leadbeater's Cockatoo (*Cacatua leadbeateri*) from Australia, presented by Colonel Carington ; two Boat-bills (*Cancroma cochlearia*) from South America, deposited.

CELESTIAL CHEMISTRY*

IT now and then happens in the history of the human race upon this planet, that one particular generation witnesses the most stupendous advancement of knowledge, this advancement generally coming from what one might consider an exceeding small germ of thought. You will at once call to mind several such instances. You will recollect how once a Dutchman experimenting with two spectacle-glasses produced the Telescope ; and how the field of the known and the knowable has been enlarged by the invention of that wonderful instrument. Again, you recollect how once Sir Isaac Newton was in a garden and saw an apple fall, and how the germ of thought which was started in his mind by that simple incident fructified into the theory of universal gravitation. You will also acknowledge that each step of this kind has more firmly knit the universe together, has welded it into a more and more perfect whole, and has enhanced the marvellous beauty of its structure.

I think that future times will say that either this generation, or perhaps the next, is as favoured a one as that which saw the invention of the telescope or the immortal discovery of Newton : for as by the invention of the telescope the universe was almost infinitely extended ; as from Newton's discovery we learned that like forces were acting in like manner everywhere ; so in our time does the wonderful instrument called the Spectroscope show us that like matter is acting in like manner everywhere ; so that if matter and force be not identical, then these two, namely, matter and force, may be termed the foundation stones of the universe in which we dwell.

My present object is to bring before you as well as I can some first notions which are to be got out of this general examination of all matter beyond our own planet, in its chemical relations ; this examination having been rendered possible by the spectroscope.

In the first instance, before I attempt to deal with chemical ideas in relation to the heavenly bodies, I have two things to do. I must first refer to our earthly notions of chemistry, not of course in their generality, for that would be impossible in the time at my disposal, but to that side of them which touches most intimately what I shall have to say by and by ; and I must also refer to the results which we have already obtained with regard to the constitution, so to speak, of terrestrial matter, as it is brought before us by the spectroscope.

* Revised from short-hand notes of a Lecture delivered at the Quebec Institute, on Tuesday, December 16, 1873.

First, then, with regard to chemistry. What is chemistry? It is a science which deals with the matter which surrounds us, and of which the whole planet and we ourselves are built up. We see everywhere around us an enormous number of apparently perfectly distinct things, some of them having vital properties, some of them lifeless, motionless ; but out of this apparently infinite diversity chemistry presents us with an almost perfect simplicity. It tells us that everything which exists here is really made up of only sixty-three different things ; that the whole of the animal kingdom, the vegetable kingdom, the mineral kingdom—everything—is made up of only sixty-three different substances. That is a wonderful simplification, and science always simplifies.

Now we may look upon those sixty-three elements in two distinct points of view. We may consider them in their physical relations, or we may regard them in a more purely chemical aspect. If we look upon them in relation to their physical conditions, we find that amongst them are fifty-six solids, two liquids, and five gases. If we look upon them chemically, dropping all distinctions between solids, liquids, and gases, we say that some of them are metals, some metalloids ; and of some, it may be truly said that it is very difficult to place them exactly—to determine whether they are on the side of the metals or on the side of the metalloids—in the same way as the biologist finds it absolutely impossible to put his finger upon any particular part of the organic world and say, Here the vegetable, or here the animal, kingdom begins. All these chemical distinctions, then, are quite independent of physical conditions. For instance, I shall have to show you that amongst the most metallic of the metals is a gas. Again, among the metals we have a liquid—mercury ; so that we have a complete chain of gas, liquid and solid among the metals, although popularly the term metal is often imagined to apply only to such solids as gold, silver, and iron. On the metalloid side, again, we have gases among them the familiar oxygen and nitrogen ; we have the liquid bromine, and so on, added to other unmistakable metalloids, such as phosphorus, sulphur, carbon, and iodine, generally thought of in their solid form.

Now what are the chemist's tools by which he has brought about this marvellous simplicity, what the processes by which he carries on his operations? I answer, in the main *vibrations*. He finds the world composed of molecules in millionfold complexities, combinations, and sizes, and he acts upon these molecules by vibrations. For gross molecules he finds in heat most that he wants, but when the molecules are more delicate, then electricity is called in, and electricity does for these what heat did for the others.

Let me here endeavour to make my meaning clear. I want you to assume a long series of vibrations, long at one end of the series and short at the other. We know that heat consists of vibrations, we know that light consists of vibrations. I will also ask you to think of electricity as connected with vibrations, and I ask you further to assume these vibrations to be short. We get heat from the sun, and among these vibrations are some to which our eye is tuned. We get an immense vibration of heat from the oxyhydrogen flame, a flame the heat of which is due to the formation of the gaseous molecules of water, but we get, practically speaking, no light. Many of the electrical phenomena with which we are acquainted take place unseen, and without heat, showing they are not long-wave phenomena ; others are exquisitely visible to us, because the vibrations are within our ken ; but, to get associated heat, we want pressure, and with pressure we can render the oxyhydrogen flame luminous. In fact—and here let me be perfectly frank with you—I call your attention to the "*as if* "—it is *as if* we have long heat-waves at one end of a long scale, and short electricity-waves at the other, each with different functions, heat giving us with solids and liquids *visible* phemonena, because of added shorter waves, electricity giving us visible phenomena with gases and vapours, because of added longer waves ; heat passing invisibly through gases, electricity passing invisibly through solids ; heat bringing about chemical changes in solids and liquids, electricity bringing about similar changes in the case of gases.

Now, this being so, let us assume, for the purposes of the present statement, that the mode of motion heat, with its long waves, chiefly affects the larger molecules, that is, compound bodies, and the mode of motion electricity, whatever electricity may be, chiefly affects the smaller molecules, that is, the atoms of simple substances. We shall find, in accordance with this assumption, that if a chemist wishes to reduce the millions of compound molecules in that very compound molecule a piece of ice, he applies heat, and he gets a physical simplification, but not a chemical one, when water is produced ; a still further, and exactly similar, stage is reached when this water takes the form of steam, but it is not till an enormous temperature, with its added short vibrations, or electricity, is employed, that the compound molecule breaks up into the simple things oxygen and hydrogen, unless another vibration is superadded of a molecule of another simple thing (or element) which shall aid in shaking them apart.

As instances of the action of heat, I will show you one or two experiments to indicate that in a great deal of chemical action the heat vibration requisite to bring about that simplification by means of which the simple bodies have been determined to exist as such is supplied by the chemical action itself ; it is the heat of arrested motion. In other cases we have to supply the heat artificially ; but also bear this in mind, that whenever we apply artificial heat the heat is none of our making. It also is the result of a chemical combination. For instance, if I take some potassium and throw it into water, that potassium will instantly burst into flame. You will see that we have a perfectly cool metal put into perfectly cool water, and, as you see, it at once takes fire in consequence of the heat of combination which has been brought about by the attraction between the potassium and the water. And if I had time I could show you that as the result of that heat-vibration thus introduced the water has been simplified, one of its constituent simple things, hydrogen, has been liberated, and I might have collected it in a bell jar.

Another illustration is to be got from a mixture of water and sulphuric acid. I have, in a test-tube, some ether, and I have the water. When I pour the water into a glass you will see that the ether in the test-tube placed in the glass will remain as if nothing had happened. But now I will pour some sulphuric acid into the water, and what happens? We get an attraction between these two things : we get a heat vibration as the result of chemical combination ; and, as the result of the heat vibration produced in that manner, the water gets hot and the ether boils, the boiling point of ether being below that of water.

Here is another experiment, and I have chosen these out of many others which might have been brought before you, to show the changes brought about by heat vibrations. Here we have some bichromate of potassium, and on the application of heat it will be instantly reduced. When I say instantly reduced, probably a few seconds will be required in order to allow the heat vibration to act, and you will then have a change of colour in the solution brought about by the application of heat, artificial, so to speak, in this case, although, as I have already cautioned you, the heat of the Bunsen burner which we employ is really an effect of chemical combination.

But not only have we heat with its long waves to bring about chemical action and its result, simplification, but, as I have said, we have another agent, electricity. I have here two tubes filled with water, and a battery, and in each tube connected with this battery is a strip of platinum. The instant that the circuit is made complete you see that the water is decomposed, bubbles rise from the platinum foil, which bubbles in the one case are bubbles of hydrogen, and in the other case bubbles of the other constituent of the water—oxygen. Here you see, by means not of the long waves of heat, but by means of electricity, we bring about a complete dissociation or a complete separation of the elements of the water which originally was in these two tubes. And if we were to allow the experiment to go on a little longer, you would see that not only is there the evolution of gas in each of the tubes, but that the evolution will be greater in one tube than in the other, for this reason, that in the water there are two equivalents of hydrogen to one of oxygen.

These then are instances of simplification brought about by heat and electricity. I quit this part of the subject by the remark that the ultimate particles of an element are called atoms ; that agglomerations of atoms are termed molecules ; elementary molecules when the atoms are alike ; compound molecules when the atoms are dissimilar. The heat-waves generally help us to get at the molecule, and electricity helps us to get at the atom ; and mark, I only say *generally*. It might be universally true if all elementary atoms were alike ; but on that point we must be content to say that we do not know. But I might place much evidence before you which indicates that they are vastly different. We can only study them by their vibrations ;

for, as Sir Wm. Thomson has calculated, the atoms in a drop of water are so small that if the drop of water were magnified to the size of the earth, the atoms would then be seen not larger than cricket-balls or not smaller than shot.

It must be clearly understood that I here refer to the true atom and not to the atom of the chemists, the weight of which they give as the "atomic weight." It may probably turn out that this is often a molecule, sometimes a complicated one, which great heat or electricity can divide, the latter sometimes more than once. It is clear that if this be so, then the vapour densities as referred to the atomic weight will be "anomalous," because the true atom and not the chemist's atom is in question at these high temperatures.

It is now time for us to pass to the action of the spectroscope. The spectroscope, as you know, is the instrument which enables us to deal with either the refraction or the diffraction of light ; that is to say, by means of refraction or diffraction we sort out the rays of any beam which we may choose to use into a spectrum, and we then study by means of that spectrum the nature and conditions of the substance which gave us the light.

And there is more than this. Not only can we deal with the giving out of light as light is being given out by this lamp, or that flame, or that gas before me, but we can equally use the absorption of light by various substances, thus studying the nature and conditions of these substances. You know very well that if this lamp, instead of having a shade of ground glass had a red one, the light that would reach your eye would be red. That simply results from the fact that the red glass stops in the main all light but the red, and allows the red to reach your eye. That then is a case of absorption, as the giving out of light by the wick of the lamp is a case of radiation.

What, then, does the spectroscope tell us with regard to the physical differences in matter? It tells us that if we have matter in a solid state, that is matter the molecules of which are large and are near together, agitated by the waves of heat, or by electricity, we get a spectrum from it of a particular kind, called a "continuous spectrum," because the spectrum is absolutely continuous, the red, yellow, orange, green, blue, violet, are all there, as you see them in the rainbow ; whereas, if we deal with a gas or vapour not too dense, that is with a substance the atoms or molecules of which are smaller and further apart than in the former case, similarly agitated by electricity or, in some cases, by heat, you find that instead of having what is called a continuous spectrum, you have a spectrum in which the light is not continuous, but broken. The result of this broken condition is that we have light as it were only here and there in the spectrum. We have in fact bright lines representing a few images of the slit, instead of a rainbow band, complete from the red to the violet, representing continuous images of the slit. This you see at once enables the spectroscope to tell us the difference between the rare and the dense states of matter quite independently of what that matter may be, and whether we use radiation or absorption as the test ; since a substance with a certain molecular arrangement absorbs precisely the same undulations as it gives out with the same molecular arrangement. No matter what it is, the spectroscope at once tells us whether this matter is in a gaseous or vaporous state, in which case we have lines or bands ; or in a state in which the molecules are nearer together, when we get a more or less complete continuous spectrum. This at once partly explains why the almost invisible long waves of the oxyhydrogen flame soon fill a mass of the most refractory metal with waves of all lengths, until it shines out almost like the sun. It would appear that molecules or atoms, when once set vibrating by either long or short waves, perform *all* the vibrations proper to them under the conditions present.

How then about the chemical differences? Here the information afforded by the spectroscope is of a much closer character. In the first place it tells us that if you take any substance whatever in a state of gas or vapour, not only do you get bright lines, which tell you that you are dealing with a gas, but you get different bright lines for every substance, so that you not only know that you are dealing with a gas or vapour, but you know at the same time what particular gas or what particular vapour. This is qualitative spectrum analysis, as the effects depend upon the quality of the atoms or molecules present. Further, we see a change in the spectrum from simplicity to complexity, by which I mean that the lines increase in number and broaden, and that the bands become more complete and their channelled structure,

where it exists, comes out better, as we pass from a low to a high pressure. This is quantitative spectrum analysis, the change depends upon the quantity of the atoms or molecules present.

Again, the spectroscope at once enables us in the main (and I say in the main, because I have already referred to the borderland between the metals and the metalloids) to differentiate quite as sharply between metals and metalloids as it does between solids and gases.

A metallic spectrum is always a line spectrum when we employ electricity to produce the vapour. Only certain metals give us line spectra at low temperatures : these are mostly monad metals which vaporise easily.

A metalloidal spectrum is only a line-spectrum when we employ electricity. Long heat-waves in their action upon the molecules only produce bands and channelled spaces. Thus the vapour of sulphur has three spectra, two to be obtained by heat, the line spectrum only being obtained by electricity..

Nor is this all. As we can distinguish the spectrum of a metal from the spectrum of a metalloid by the appearance of the spectrum, so also does the spectroscope enable us to see a difference between the spectrum of a compound molecule and an elemental molecule. Let me explain what I mean :—If we are dealing with a metallic element, we get a spectrum of a particular kind so sharply defined that when any one has once seen it, he always knows that an atom of a metal is being dealt with. In the same way when we are dealing with metalloids, the spectrum is generally so entirely distinct from the spectrum of a metal, that when you have once seen the spectrum of a metalloid produced by the long heat-waves, you will always be able to tell it again, there is no possibility of mistaking it for the spectrum of a metal. So far we have been dealing with the elemental molecules, or perchance atoms of metals and metalloids, but we can take a compound molecule. Let us take the combination between metalloids and metals, such as some of the salts of strontium—the chloride of strontium, iodide of strontium, and so on : here we have compound molecules, that is, molecules no longer built up of one substance, but of two ; and the long heat-waves, although they can set them vibrating and therefore make them radiate light, do not shake them asunder as high tension electricity does.

We find that the spectroscope is perfectly competent to separate such spectra from all others, so that when we have once seen the spectrum of, say, iodide of strontium, we shall for ever afterwards know that such spectra are given by such a compound molecule as iodide of strontium. The same remark applies to the compound molecules in which oxygen enters as one of the substances. Such spectra closely resemble the spectra of the metalloids, but the bands are farther apart and lie nearer the violet as a rule, so that it is not difficult to distinguish them.

Now when we have to do with a compound molecule, that is to say, with an association of two molecules or atoms of two different chemical substances, we shall at once see that this question of vibrations instantly comes into play ; for if the function of vibration, whether we deal with large molecules and long heat-waves, or small molecules and electricity, is to render more simple what in the first instance was compound, then we ought to get spectroscopic differences.

Let us again take the iodide of strontium ; the spectroscope is perfectly capable of letting us see the exact effects, not of every degree of temperature which we employ, but of any great differences of temperature. We can follow each increase of temperature by observing the lines or bands which disappear, or which begin to be visible, as the case may be, as the temperature is increased. And similarly, if we have a mixture at a temperature of dissociation, and gradually bring the temperature down until association takes place, then also the spectroscope is just as competent to help us as it was before when we were dealing with an increasing temperature. We find that as the temperature decreases in the latter case, the peculiar compound spectrum to which I have already referred gets more and more visible at the same time as the elemental spectrum gets less and less visible : the order being one of strict law absolutely capable of prediction the moment you know what are the elemental lines, and the lines of any particular compound which longest resists the action of pressure.

Now this is extremely important in its bearing upon the celestial side, so to speak, of this inquiry, and therefore if you will allow me I will still further enlarge what I have said about this distinction between the metals and the metalloids.

If I take sodium vapour at a very low temperature and at the

highest temperature that I can get on the earth either by the long heat-waves or by means of electricity, I find that there is absolutely no difference whatever in the molecular arrangement of that sodium vapour at the extreme points. Spectroscopically it is absolutely the same.

Then if I take, not sodium but another element, such as iron, I find it excessively difficult, by means of the heat-waves, to shake asunder the molecules of iron and the diatomic or polyatomic molecules of iron vapour at all. But we know that by electricity non-atomic iron vapour can be got ; and then we may say, at all events so far as the lines in the spectrum are concerned (I do not mean their position, but their general nature), that we get a spectrum from the vapour of iron, similar in character to that of the vapour of sodium ; but the spectrum has become more complicated as we pass from the monad metal to one with a higher atomicity.

Suppose that, instead of taking a monad metal like a sodium, with its few-lined spectrum, or a metal like iron, with its high atomicity and its many-lined spectrum, we take a *metalloid ;* then we find that those conditions no longer hold good. It is not too much to say that in the case of the metalloids every change of even low temperature brings about a change in the spectrum. It is perfectly true, as I have said before, that by means of electricity we can get a line-spectrum from most of the metalloids. But from the ordinary temperature to the electric spark in the case of a metalloid, instead of getting the perfect similarity that we did in the case of sodium vapour, we get an equally perfect and equally beautiful dissimilarity ; so that whilst we say that in the case of sodium we only know of but one spectrum, in the case of sulphur, to take one case, we certainly know of four.

You must let me again remind you that when we employ electricity the spectra of the metalloids present exactly the same appearance as the spectra of the metallic elements, such as iron and sodium, and that it is only when we employ heat-waves that those other changes to which I have referred take place.

One word more, too, on the fundamental difference between the spectrum of a metalloid and the spectrum of a metal on the one hand, and the spectrum of a compound on the other. The metalloid has a spectrum of channelled spaces or bands, sometimes to be found in the central part, that is to say, in the green part, or thereabouts, of the spectrum, whereas in the case of the vapour of metals such as iron, and so on, we get bright lines only, not bands ; and these lines increase in number generally toward the violet, while in the case of the compound molecules, such as iodide of strontium, to which I referred, we get a something which is half channelled spaces and bands, and half lines, but in all the cases I have examined, excluding oxides, they are limited to the red end of the spectrum.

Let me attempt briefly to summarise what I have stated. With electricity in the case of all elements we obtain line spectra ; as we are here dealing with the most complete simplification of matter that we can attain, let us call this the *atomic spectrum.*

With heat we can obtain a continuous spectrum, from solids, liquids, and some vapours ; with electricity we can even obtain a similar spectrum from dense gases. Let us call this the *molecular spectrum.*

In the case of many of the metalloids we get, between these extremes, a channelled space spectrum. Let us term this the *sub-atomic spectrum.*

In the case of some compound molecules, we get by heat in some cases, and by electricity in others, a spectrum which is dissimilar from all these. Let us call this the *compound atomic spectrum.*　　　　　　　　　　　　J. NORMAN LOCKYER

(*To be continued.*)

SOCIETIES AND ACADEMIES

LONDON

Royal Society, March 19.—Preliminary Notice of Experiments concerning the Chemical Constitution of Saline Solutions, by Walter Noel Hartley, F.C.S., Demonstrator of Chemistry, King's College, London.

The author has been engaged in investigating the above subject during the last eighteen months, and his experiments being still in progress, he thinks it desirable to place the following observations on record :—

In the examination of the absorption-spectra, as seen in wedge-shaped cells, of the principal salts of cerium, cobalt, copper, chromium, didymium, nickel, palladium, and uranium, to the number of sixty different solutions, it was noticed that the tinctorial properties of the substances could be ascertained by noticing the absorption-curves and bands, so that, provided water be without chemical action, it could be foreseen what change would occur on dilution of a saturated solution.

The Effect of Heat on Absorption-spectra

When saturated solutions of coloured salts are heated to 100° C. there are (1) few cases in which no change is noticed ; (2) generally the amount of light transmitted is diminished to a small extent by some of the more refrangible (the less refrangible), or both kinds of rays being obstructed ; (3) there is frequently a complete difference in the nature of the transmitted light. Anhydrous salts not decomposed, hydrated compounds not dehydrated at 100° C., and salts which do not change colour on dehydration, give little or no alteration in their spectra when heated.

Solutions of hydrated salts, and most notably those of haloid compounds, do change ; and the alteration is, if not identical, similar to that produced by dehydration and the action of dehydrating liquids, such as alcohol, acids, and glycerine, on the salts in crystals or solution.

A particular instance of the action of heat on an aqueous solution is that of cobalt chloride, which gives a different series of dark bands in the red part of the spectrum at different temperatures, ranging between 23° C. and 73° C. Band after band of shadow intercepts the red rays as the temperature rises, till finally nothing but the blue are transmitted. Drawings of six different spectra of this remarkable nature have been made. The changes are most marked between 33° and 53°, when the temperature may be told almost to a degree by noting the appearance of the spectrum. Though to the unaided eye cobalt bromide appears to undergo the same change, yet, as seen with the spectroscope, it is not of so curious a character, the bands being not so numerous.

With cobalt iodide a band of red light is transmitted at low temperatures ; this moves towards the opposite end of the spectrum with rise of temperature until it is transferred to such a position that it consists of green rays only. In this instance the change to the eye is more striking when seen without the spectroscope, because the mixtures of red, yellow, and green rays, which are formed during the transition, give rise to very beautiful shades of brown and olive green. Thus a saturated solution at 16° C. was of a brown colour, at – 10° C. it became of a fiery red and crystals separated, at + 10° reddish brown, at 20° the same, at 35° Vandyke brown, 45° a cold brown tint with a tinge of yellowish green, at 55° a decidedly yellowish green in thin layers and yellow brown in thick, 65° greenish brown, thin layers green, 75° olive-green. An examination of this cobalt salt has shown that there are two distinct crystalline hydrates ; the one formed at high temperatures has the formula $CoCl_2.2H_2O$, and is of a dark green colour ; the other, which contains a much larger proportion of crystalline water, is produced at a low temperature, and its colour is generally brown, in cold weather inclining to red.

The action of heat on solutions of didymium is characterised by a broadening of the black lines seen in the spectrum, more especially of the important band in the yellow ; and in the case of potassio-didymium nitrate, this is accompanied by the formation of a new line. In the case of didymium acetate, which decomposes with separation of a basic salt, the lines thickened on heating.

Thermo-chemical experiments

Regnault (Institut, 1864 ; "Jahresbericht," 1864, p. 99) has shown that on diluting a saturated solution of a salt, as a rule there is an absorption of heat, but in one or two cases he noticed that heat was evolved. The change in colour that takes place on the dilution of saturated solutions of cobalt iodide, cupric chloride, bromide and acetate is very remarkable. There is every likelihood that this phenomenon is due in each case to the formation of a liquid hydrate. It is impossible of belief that accompanying such a circumstance there should be no measurable development of heat ; and the author's experiments have proved that in the above cases, at any rate, the heat disengaged is very considerable, amounting, for instance, on the part of cupric chloride, at least to 2,565 "units when 1 gram molecule of the crystalline salt is displaced in its minimum of water at 16° C. and brought into contact with sufficient to