The system is simpler, clearer, saves repetition and time (five months instead of six and a half), is less burdensome to the memory, and gives a fairly uniform system for inorganic and organic chemistry. This in itself is an advantage not to be lightly estimated.

The table is not to be pushed too far—one must be careful not to go to lengths incapable of direct proof. The position in which the elements fall should not be used as having any reference to their genesis, derivation or composition.

As to graphic representations of the Natural System, I have examined all and rejected all as unsuited to teaching the science. All are open to the serious objection of carrying analogies too far, and leading the student on to deductions and dreams for which the chemist of to-day has no possible proof.

Take for example the pendulum oscillations of Spring and Reynolds, inseparably connected now with Crookes' speculation as to the Genesis of the Elements or take Preyer's condensation-steps and generation pyramids, all full of this idea of the genesis. Mendeleeff dismisses the idea of such curves of properties as Meyer devised, and there is much weight in his criticisms. Such curves are, at any rate, instructive only to those who are capable of reading mathematics critically.

I would counsel the use of the simple table without the questionable aid of curves or diagrams of any kind.

The summing up of the whole matter is this: If the Natural System is true it cannot be relegated to a side place in your teaching. It forms the basis of your entire course, and unless you utilize it you are occupying a false possition and depriving yourself of the most valuable aid which the teacher of to-day has at his command.

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THE STATUS OF THE SOLAR MAGNETIC PROBLEM.

A SERIES of papers has been published in different journals during the past four years giving a very brief account of the steps taken in the investigation of the general problem of the transference of energy from the Sun to the Earth. It is probable that the main thread of the argument may be obscure to some readers for want of a consecutive statement of the case, and it is therefore proposed to summarize the evidence already obtained, as well as to indicate the nature of the scientific questions immediately at hand.

The research has been one of peculiar difficulty to successfully prosecute to definite conclusions, not because the line of operations was obscure, nor on account of the intricate mathematical conditions, but chiefly in consequence of the looseness of the phenomenon under consideration. By looseness is meant the wide deviations from the normal laws, whatever these may be, arising from the actual spasmodic actions of the sun on the one hand, and the very indirect effect of the solar energy thus generated upon the terrestrial, magnetic and meteorological fields, as recorded by the instruments employed in observations. This is an ordinary difficulty when the ether is the medium of the transference of energy between masses of matter widely separated in space, and in our case it is especially complex by reason of the complicated nature of the transmitter and the receiver, namely, the sun and the earth respectively. The solution of the problem must necessarily be by a system of approximations, in which unknown terms are carried hidden in the residuals during one operation, until the result obtained enables a repetition of the work under clearer conceptions. Also the complication of terms is so great that it is only by the successful treatment of an enormous mass of material that the im-

pressed force desired will emerge by the mutual destruction of other terms. Hence the work is laborious and the residuals small at the end of the first trip through the observations.

To obtain any result whatever it has been necessary to adhere closely to certain precepts, and also it has been requisite to learn to look beneath the apparent discordances of curves which purported, but on the surface seemed not, to be a record of the same fundamental pulsation. It was very natural that those who seek to verify the results of an investigator should expect to do so with a brief treatment of the material involved, and it could be easily shown that certain criticisms which have been published were based upon this process. Some highly discordant curves are shown as arguments against the truth of my conclusions, but in every case so far as known some of the precepts were violated and only a little material was used. Negative results to be valid against positive must be at least as exhaustive, both as to the concepts employed and the amount of material in evidence. In publishing conclusions it has been my practice to retain partially tested work till such advance had taken place as to become a pretty sure criticism of the results communicated, and it has therefore been regarded as conducive to the progress of the research not to complicate it with discussions of the negative arguments, which were obviously violating certain precise rules of procedure as yet unexplained to the public.

The ultimate goal of interest to the Weather Bureau is the improvement of the forecasts, whether in reading the daily maps or in predicting seasonal conditions for a year or more. Meteorology had contented itself with combinations of three forces, the earth's gravitation, the earth's rotation and equatorial insolation, acting upon the fluid atmosphere, in order to explain the observed effects in the motions of the air. The result has not satisfied students of the subject. The first point to determine was whether the sun did or did not transmit other energy to the earth, and, if it did, what kind of energy. The probability was that the auroras, the magnetic storms and earth currents, certain spasmodic actions in the electricity and magnetism of the earth's field and motions of the atmosphere, the sun spots and the coronal output, all belonged to one fundamental system, though no intelligible notion had been proposed that could explain the interrelation philosophically. The great distance of the earth from the sun seemed a barrier to one obvious explanation, so that the work was never seriously undertaken to test the validity of it.

My own attempts to solve the question of the meaning of the stream lines seen in the corona during an eclipse of the sun suggested and strengthened the working hypothesis that the whole unexplained system might be referred to the sun as a magnet in dynamic operation, and that live lines of magnetic force originating in the sun were propagated to the earth in wide sweeping curves, where the energy was expended in various operations, such as those just mentioned. Progress was also made in computing and mapping out the system of forces causing the diurnal and annual swings of the magnetic needles, which showed plainly that a complex field of mechanical forces besides gravitation surrounded the earth at its surface. Such forces must necessarily be referred to the electro-magnetic radiation of the sun, because the system was instantaneous and observations covering half a century could be combined without reduction for secular variation; and also because the entire system wanders up and down the earth with the change of the position of the axis of the field, as the sun moves in declination.

Furthermore, the fact that this field exhibits three compensating couples, fulfilling the laws of refraction when a permeable shell is placed within an external magnetic field, renders it certain that we have at last secured the basis of the complete solution of the ancient problem of the distribution of the earth's *quasi* permanent magnetism and its variation in short and long periods.

In order to distinguish the field of force that was supposed to produce the aurora and the other phenomena above mentioned, it was proposed to call it 'coronal,' or 'polar' radiation, in distinction from the sunlight, or equatorial radiation. It is radiation of some kind, if there is any transmission of energy through the ether from the sun to the earth, and it may be simply magnetic, or curved radiations, as opposed to rectilinear, or electro-magnetic radiation, the latter having been practically established as natural by the work of Maxwell and Hertz.

It was evident that if a solar-polar magnetic field existed and extended to the distance of the earth, its presence would be revealed by periodic variations, the period being determined by the synodic rotation of the sun, and the variations by the impressed energy due to the magnetic output on the several meridians. Also for the maintenance of such a normal field, whatever fluctuations it might undergo in itself, it was necessary to suppose that the nucleus of the sun is to some extent rigid, or at least non-vaporous. The detection of the synodic period and the approximate form of the curve representing the solar field at the distance of the earth followed, the period being 26.67-928 days, and the curve the one many times published. The period was found from the years 1878 to 1889, these containing the available European modern observations; since that time an application of the same period carried back from the epoch 1887 to the British Colonial Stations, 1841 to 1848, gives back the same curve, as if begun about one-tenth of a day later. Thus my first period is sufficient for a half century's work, and it is plain that a rediscussion of all the data will enable us to determine the rotation of the sun with extreme accuracy. Since we recognize the fact that the magnetic curves are a true and delicate register of solar action through at least 800 revolutions, it is clear that few natural phenomena have been so continuously recorded as the solar motion and in such detail. The same remark applies to the other physical manifestations of the energy of solar nucleus, if we learn to correctly interpret the changes in the magnetic curves. This unconscious contribution to solar physics by magneticians, through more than fifty years, is abundant justification of the faith in science that has inspired their work, and a sufficient answer to the cavilling question, *cui bono*.

The securing of the solar period was, of course, the foundation of progress in the classification of large masses of hitherto unworkable data. The illustration of its power is contained in the series of results thrust upon us by using it. At first the effort was made to detect a similar curve in meteorological and in solar phenomena by simply massing the observations in this period. The results were tantalizing, if not discouraging, for, while it was evident that a similar synchronous beat existed in the atmospheric elements, yet the residuals were so small, and the curves exhibiting them so rough, when compared with one another, that it seemed for a long while as if further progress might be impossible. However, by persistent study of successive periods during which no little practical skill was developed in detecting the underlying harmony in apparently unrelated curves, it was discovered that the normal curve was subject to inversion. That is to say, the curve was workable for a season, say a few weeks,

or even four months in one position, and then the system conformed to the same curve if inverted. The explanation of this singular and apparently irrational phenomenon was not found for a long while, although the fact that it existed could not be doubted. The mode or law of this inversion is yet a subject of study, and its great irregularity makes it difficult to thoroughly understand.

It was now seen that the result of massing all the observations on one period was to give back very small residuals, which expressed merely the excess of the strength or the energy of one system over the other. Two large inverse types may thus give exceedingly small residuals, if they are nearly equally balanced in power. The form of the curve at first obtained was also partially defective for the same reason, three minor crests being suppressed in the magnetic field. On applying the clue thus obtained to the temperatures of the northwestern districts of the United States the two types emerged unmistakably, and also a curve more precisely representing the normal solar field. Now on reviewing each period of the European magnetic field with this improved curve it was comparatively simple to separate all the observed vectors into two parts corresponding to the direct and the inverse types. Thus the residuals were greatly improved, the forms of the curves steadied, and in every sense the future of the problem greatly strengthened. The critical elements at the earth, the magnetic field and the meteorological temperatures and pressures in the northwest, all agreed in classification under the same double system, and in producing curves that are merely the inverse of one another.

It next became extremely important to discover some simple, rational cause for this peculiar inversion, so persistent for years and so universal on the earth. In the magnetic field it is common simultaneously to all stations in the northern and the southern hemispheres, in whatsoever longitude. In the meteorological system the principal center of concentration is in the northwest of the American Continent, so far as explored; other centers of action will doubtless be detected. Supposing the seat of inversion to be in the solar action, it was proper to classify the sun-spot areas in two groups, keeping the northern and the southern hemispheres independent of each other, by massing these respectively on this period. The result is very gratifying, for they give back the same fundamental curve, the southern hemisphere corresponding to the direct type, and the northern to the inverse type. This fact may well be regarded as the keystone to our arch, as it gives stability to the entire structure of the research. We must conclude that the sun emits two types of magnetic energy, whose products, to some extent, are the coronal stream lines and the sun-spot system, and probably other phenomena on the sun; while on the earth is to be found the same periodic function displayed in the variations of the magnetic field, and the American meteorological system certainly, acting continuously through the curved lines of magnetic force; spasmodic action within the solar nucleus gives the auroral display, the magnetic storms and electric currents, and possibly other important effects.

On the sun the minor results are the proof that the solar nucleus rotates with very nearly the same motion as the visible equator; the center of the coronal belt is in latitude $\pm 55°$; the sun spots drift anti-rotationally, and by comparison in this period all surface currents can be detected and analyzed in longitude as well as in latitude; the density of the sun must be greatly modified by reason of a distribution of matter into a nucleus and a distant en-

velope or photosphere. On the earth it has been shown that the permeable magnetic material is confined to a shell about 800 miles thick; that in consequence of this the external field divides into an exflected system, accounting for the location and movement of the auroral belt, and an inflected system, in some way related to the energy of tropical hurricanes; that the lacking term needed to account for the spasmodic action of storm generation over our entire hemisphere is to be attributed to the solar field; that the storm tracks of the United States vary in latitude and the eastward drift of storms in longitude, also the temperature annual means and amplitudes with the solar field in the 11-year period; that the storms are formed in the northwest in a procession corresponding to the type prevailing, and that this order is inverted with the type; that the maximum of extra-tropical storms of America, as compared with Siberia, is due to the impression of this variable energy upon the atmosphere in North America; that the prevalence of storms and cold waves in winter is due to the increased action of the magnetic field at lower temperatures; that the glacial epochs may naturally be referred to the long period variations of the sun as respects its magnetic output; that the observed minute variations of terrestrial latitudes may be plausibly ascribed to the action of the stresses in the ether at the surface of the earth, due to the mechanical forces generated in the ether by the transmission of radiant energy.

It is evident that, besides the very practical results to forecasting to be expected from a complete solution of the problem of storm generation in this long period of 26.68 days, we have a large field of study in the relations of magnetism and electricity. If all radiant energy is accompanied by vector stresses in the ether, of the minute amount disclosed by the residuals, it may not be impossible that gravitation is an ether stress generated by the atomic vibrations of ponderable matter, spreading in spherical waves through space, according to the Newtonian law. The fact that the sun's hemispheres exhibit the normal field inverted in them respectively, by which a maximum in one corresponds to a minimum in the other on the same meridian, leads one to doubt that a continuous line of force, as assumed in theory, passes from the positive to the negative pole. At any rate here is an exhibition of what a dynamic magnet is actually doing, our experiments heretofore having been confined to static conditions. The mode of transference of this magnetic energy through the ether is wholly unknown, and its solution must greatly enlighten us upon several important subjects.

This research has been greatly handicapped because no magnetic observations have ever been made in the northern Rocky Mountain regions of the United States, where the interrelation of several primary physical forces can be most successfully studied. The high altitude of this region, bringing the stratum of the atmosphere in which observations are made more nearly into contact with the external field, and its proximity to the polar magnetic cap, suggest that it is the most appropriate place for the establishment of a magnificent permanent solar-terrestrial observatory, equipped with the best instruments available, and managed by men of power in scientific investigations. One such observatory in the Northwest and another in the eastern part of the United States, together with some minor stations, would no doubt amply repay the American people for the expense of equipping and maintaining them through the agency of the Government.

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