River. Not a trace of coal was found along the whole course of the river, though it was reported by the natives to be seen in abundance protruding on the river banks. The whole country is thickly covered with wood. Mr. Thomson contemplates setting out on his second expedition during the present month. He intends to visit the little-known region between the sea and Mount Kilimanjaro, extending from Melinda on the north to Pangani on the south. Mr. Thomson hopes to make important discoveries in geology and botany.

A PRETTY full account of the proceedings of the recent International Geographical Congress at Venice will be found in the new *Bollettino* (for August) of the Italian Geographical Society, which reports in full the papers on the question of oscillations on the coast of Italy. It contains besides a map showing the various arcs of meridian and parallels that have been measured all over the world, and a map of Europe showing the present state of the various trigonometrical surveys in that continent. Russia, Turkey, and Greece are almost blank, and the Scandinavian peninsula is far behind; the other countries are shown covered with triangles.

LUNAR DISTURBANCE OF GRAVITY[1]

IN November, 1878, Sir William Thomson suggested to Mr. G. H. Darwin that he should investigate, experimentally, the lunar disturbance of gravity and the question of the tidal yielding of the solid earth. This Committee of the British Association was subsequently reappointed, and the authors' names were added to the list of its members. In May, 1879, the authors visited Sir William Thomson at Glasgow, and there saw an instrument which, although roughly put together, he believed to contain the principle by which success might perhaps be attained. The instrument was erected in the physical laboratory of the University of Glasgow. The following are the rough details:—

A solid lead cylinder, weighing perhaps a pound or two, was suspended by a fine brass wire, about five feet in length, from the centre of the lintel or cross-beam of the solid stone gallows which is erected there for the purpose of pendulum experiments. A spike projected a little way out of the bottom of the cylindrical weight; a single silk fibre, several inches in length, was cemented to this spike, and the other end of the fibre was cemented to the edge of an ordinary galvanometer-mirror. A second silk fibre, of equal length, was cemented to the edge of the mirror, at a point near to the attachment of the former fibre. The other end of this second fibre was then attached to a support, which was connected with the base of the stone gallows. The support was so placed that it stood very near to the spike at the bottom of the pendulum, and the mirror thus hung by the bifilar suspension of two silks, which stood exceedingly near to one another in their upper parts.

It is obvious that a small displacement of the pendulum, in a direction perpendicular to the two silks, will cause the mirror to turn about a vertical axis.

A lamp and slit were arranged, as in a galvanometer, for exhibiting the movement of the mirror by means of the beam of light reflected from the mirror. It was found to be in incessant movement, of so irregular a character that it was hardly possible to localise the mean position of the spot of light on the screen, within five or six inches. On returning to the instrument after several hours, the observer frequently found that the light had wandered to quite a different part of the room, and it was sometimes necessary to search through nearly a semicircle before finding it again. The cause of this extreme irregularity of the movement of the pendulum was obscure; and as Sir William Thomson was of opinion that the instrument was well worthy of careful study, the authors determined to undertake a series of experiments at the Cavendish Laboratory at Cambridge.

Accordingly throughout 1880 they proceeded to make experiments with an instrument which involved the principle above explained. Several modifications of some importance were introduced. The pendulum was hung in fluid, in order to quickly destroy the oscillations generated by local tremors, and, being suspended by two wires, it was only free to oscillate in one direction, namely, the meridian. There was also introduced an apparatus, which we have not space to explain, by which a known very small horizontal thrust might be applied to the pendulum. By means of this the actual displacements of the pendulum were determinable from the observed displacements of the spot of light on the screen.

The image on the screen was found to be in a state of continual agitation of an irregular character, so that it was not possible to take a reading with very great accuracy. But as the pendulum was hung in fluid, the agitation was not nearly so great as it had been in the instrument at Glasgow.

The observers also found that the pendulum was subject to a diurnal oscillation, and that it stood furthest north towards 6 p.m., and furthest south towards 6 a.m. Superposed on this motion was a gradual change of the mean diurnal position, for during two months the pendulum moved northwards.

The instrument was found to exhibit the flexure of the stone piers of the gallows, even when the force employed was only a slight pressure with one finger. Water poured on the ground round the basement of the stone gallows tilted the whole structure over, and very small changes of temperature in the stone piers were found to give distinct effects. It was concluded that 1 foot of displacement in the spot of light on the scale corresponded with 1″ of change in the direction of the plumb-line with reference to the base of the gallows.

From these experiments the authors concluded that the instrument was susceptible of all the delicacy requisite, but that the mode of suspension was unsatisfactory.

Accordingly in 1881 they proceeded to erect a new instrument in which the support for the pendulum was a copper tube, which itself formed the envelope for containing the fluid in which the pendulum was suspended. The whole apparatus was immersed in a large mass of water, and the observations were taken from outside of the room by means of a telescope. The unsteadiness of the image was diminished, probably on account of the precautions taken against inequalities of temperature in various parts of the instrument, and because the pendulum was hung in a very confined space. The accuracy with which readings could be taken was thus increased.

Similar diurnal oscillations of the pendulum were again observed, and a similar slow change in the mean diurnal position. The authors therefore concluded that these changes are a real phenomenon, and do not depend upon changes of temperature in the instrument itself.

They also noted that there are periods lasting for several days in which the pendulum is in a state of continual agitation, so that the readings taken at a few seconds apart do not agree *inter se*, and that there are other periods of abnormal quiescence. These periods do not seem intimately connected with the external meteorological conditions, at least as far as the experiments have been hitherto carried.

The pendulum was found to be practically insensible to the effect of local tremors, such as are produced by hitting the stone support or stamping on the ground in the immediate neighbourhood of the instrument. But it was extraordinarily sensitive to steady forces. If a force be applied at a point on the floor a dimple is produced in consequence of the elastic yielding of the soil, and any object on the floor is slightly tilted towards the point where the force is applied. Now when a person stood in the room at sixteen feet away from the instrument, and again at seventeen feet, the difference was rendered distinctly evident between the amounts of inclination towards the point of pressure of the stone basement supporting the pendulum in the two cases.

Although no great pains had been taken to render the instrument as sensitive as possible, it was found that an alteration of the plumb-line through 1-100th of a second of arc was distinctly measurable.

The second part of the paper contains an account of the work of some of the previous observers on the same subject.

M. Zöllner's instrument, the "horizontal pendulum," is described. It does not appear that any extensive series of observations have been made with it.

An account of M. d'Abbadie's work is next given. He made his observations by means of reflections from a pool of mercury, and the site of his experiments was at Abbadia, near Hendaye, in the south of France. He found that there were periods of agitation and of quiescence in the mercury, apparently without reference to any perceptible external causes. There were also gradual changes of level extending over several months, and the

[1] Report of the Committee, consisting of Mr. G. H. Darwin, Prof. Sir William Thomson, Prof. Tait, Prof. Grant, Dr. Siemens, Prof. Purser, Prof. G. Forbes, and Mr. Horace Darwin, appointed for the Measurement of the Lunar Disturbance of Gravity. Account of experiments by G. H. Darwin and H. Darwin, read at the British Association, York, September 1881.

experience of several years showed that there was something like an annual inequality of level. There were sometimes changes through 2″ or 3″ which took place in a few hours.

At Geneva M. Plantamour has been making observations concerning variations of the plumb-line, by means of delicate levels, and has arrived at results in general accordance with those of M. d'Abbadie.

The experiments of the authors present a general confirmation of these conclusions, and show that the earth's surface is in a state of continual movement.

With reference to this continual oscillation the authors adduce an experiment which was commenced about three and a half years ago by Mr. Horace Darwin at Down, in Kent. The experiment was undertaken in connection with Mr. Darwin's investigation of the geological activity of earthworms. There are two stout metal rods, one of iron and the other of copper. The ends were sharpened, and they were hammered down vertically about eight feet deep into the soil, and they are in contact with one another, or nearly so. The ends were then cut off about three inches above the ground.

A stone was obtained like a small grindstone, with a circular hole in the middle. This stone was laid on the ground with the two metal rods appearing through the hole. An arrangement with a micrometer screw enables the observer to take contact measurements of the position of the upper surface of the stone with regard to the rods. The stone has, on the whole, always continued to fall, but the general descent can only be gathered from observations taken at many months apart, for it is found to be in a state of continual vertical oscillation.

The measurements are so delicate that the raising of the stone produced by one or two cans full of water poured on the ground can easily be perceived. The effect of frost and the wet season combined is strongly marked, for on January 23, 1881, the stone was 4·12 mm. higher than it had been on September 7, 1880. The prolonged drought of the present summer has had a great effect, for between May 8 and June 29 the stone sank through 5·79 mm.

The changes produced in the height of the stone are, of course, entirely due to superficial causes; but the amounts of the oscillations are certainly surprising, and although the basements of astronomical instruments may be very deep, they cannot entirely escape from similar oscillations.

The last part of the paper contains a discussion of the present aspects of the question, and a criticism of the various forms of instrument which have been used hitherto for the detection of small variations in the position of the plumb-line.

The authors suggest that greater precautions should be taken in the protection of the piers of transit instruments from changes of temperature, and in the drainage of the soil round the basements of the piers; they also draw attention to the disturbing effect of the weight of the observer's body. They express a hope that systematic observations of changes of level may be undertaken at a number of observatories by some instrument analogous to that with which they are working. They are still prosecuting their experiments, and they are in hopes of being able to reduce their instrument to a convenient form, so that it may not be difficult to transport or to erect.

In conclusion they state that they have no hope of being able to observe the lunar attraction in the present site of observation, but they think it possible that they may devise a portable instrument which shall be amply sensitive enough for such a purpose, if the bottom of a deep mine should be found to give a sufficiently invariable support for the instrument.

AN ERROR IN THE COMMONLY ACCEPTED THEORY OF CHEMISTRY

At a public meeting of the University College Chemical and Physical Society Prof. A. W. Williamson, F.R.S., gave an address on "An Error in the Commonly Accepted Theory of Chemistry."

He began by saying that he had been frequently struck by the fact that two theories believed at one time to be conflicting had often been shown by the progress of study to be both true. As an instance in point he took the rival theories, one of which represented molecules as constituted after the pattern of three or four types, while the other viewed them as containing complex groups called radicles.

There was at one time opposition between those who made use of atomic weights and those who employed equivalent weights; the most important slip that has of late been taken is the introduction of the notion of equivalence into the atomic theory; an inspection of the series HCl, H_2O, H_3N, H_4C showed that the atom of chlorine has a different value to that of oxygen, nitrogen, or carbon; thus ammonia may be viewed as being formed by replacing three atoms of chlorine in three molecules of hydric chloride by one atom of nitrogen. Thus nitrogen was said to be trivalent or a triad, and other elements, such as phosphorus, boron, &c., were found to resemble it in this respect; oxygen was called a dyad, and it was found that sulphur, calcium, &c., might also be classed as divalent; in short every element might be placed in one or other of the groups, monad, dyad, triad, &c. That an element can belong to one only of these groups was the view still held by one distinguished chemist, who, for instance, said that nitrogen was trivalent only, and that in sal-ammoniac it was not pentavalent, but that the body in question was a molecular compound of two chemical compounds, ammonia and hydric chloride.

He (Prof. Williamson) thought this was little else than a return to Berzelius' mode of representing compounds, though it was open to an objection from which the theory of the Swedish chemist was free; for Berzelius said that the force which united the two molecules that made up the compound molecule was identical with that which held together the atoms of the constituent molecules, the force being in each case electrical; whereas Prof. Kekulé assumes the forces in the two cases to differ, the one being molecular, and the other chemical.

Now as long as we knew neither of these forces, he (Prof. Williamson) thought it hazardous to assert that there was a difference between them. A study of the evolution of heat in chemical processes threw some light on the subject; Berthelot and Thomsen had shown that when you placed a number of substances within the influence of one another, that reaction or decomposition took place which could evolve the most heat, and we must take into account not merely the heat given out by what we considered the purely chemical process, but also that due to the passage of the product from one state of aggregation to another—from the liquid to the solid state when a precipitate was formed.

Thus the chemical process was determined by the heat due to the chemical reaction plus that due to change of physical condition; and this indicated an identity between chemical and physical force. We might learn the same lesson from Deville's truly remarkable researches on dissociation or strictly reversible decompositions. Thus calcic carbonate was decomposed by heat into lime and carbonic acid, but no sooner was the temperature sufficiently lowered than the two recombined; so, when water was heated, the molecules were separated and formed steam, but on lowering the temperature they recombined to produce water. Ice, water, and steam had in many respects different properties—differences in specific gravity, specific heat, refractive power, &c., quite analogous to those which were found between different chemical compounds.

We had therefore no grounds for assuming a difference between chemical and physical force; Kekulé's theory that an atom can have one, and only one, atomic value was no longer tenable, for it involved the assumption of molecular compounds. The theory commonly in vogue was that atoms vary in their value within certain narrow limits; that nitrogen, for instance, was either trivalent or pentavalent. It had even been asserted that the combining power of an atom was independent of the nature of the elements with which it combined; in the words of a very distinguished chemist, "No matter what the character of the uniting atoms may be, the combing power of the attracting element is always satisfied by the same number of these atoms." This view appeared to him (Prof. Williamson) to have been due to a habit of mind naturally prevailing in many studies, but which, he thought, we had found reason in our scientific work to abandon—he meant the absolute as opposed to the relative.

Prof. Williamson then went on to say that he knew of no limitation to atomic value; he did not say there were no limitations, but he did know that many elements have atomic values greater than those commonly assumed.

We found that the character of the atoms materially affected the result; thus gold could not combine with more than three atoms of chlorine alone, but it could take up an additional atom of chlorine if supplied with an atom of sodium at the same time. In this way we got the common double chloride of gold and sodium, $NaAuCl_4$, in which the gold is pentavalent.

We were not to consider the sodium as being here combined