that regulation is insufficient. In winter time we use thicker clothing, we need more food, and if the cold is very great, we produce more heat by muscular action. In accordance with that experience, I found that animals produce more heat in winter than in summer. If nourished with the same food, sufficient to maintain their weight constant in winter, they do not oxidize the whole in summer, and therefore they gain in weight. It is remarkable that similar changes were observed by Dr. Karl Theodor, Duke of Bavaria, in the amount of carbonic acid expired by a cat, in the case of which he measured the expiration of this gas during five months.

Many experiments have been made to find the combustion heat of our food-stuffs. For want of direct animal calorimetry, physiologists used these data for calculating the heat produced by living beings; but as my experiments show, there is frequently no exact accordance between the two.

Richly nourished animals produce less, sparely nourished ones more, heat than the calculation gives. Between the two cases there is a third one in animals *sufficiently* nourished, viz. such as take in so much nutriment as serves to maintain their weight unchanged for a long time. In this case only the amount of heat produced is really equal to that calculated upon the combustion of the constituents of food. But also in this case variations are observed, caused by change of temperature, muscular motion or other circumstances, so that only the middle figures correspond exactly to the theoretical value.

Thus, if a well-nourished animal is starved the heat production remains unchanged from three to four days, the animal burning its stored-up materials and losing much of its weight; only then is it suddenly reduced to a lower amount. If now food is given again, heat production remains small, the weight increases, and then, three or four days later, the heat production increases and reaches its former amount.

If a sufficiently nourished animal takes in all its food once a day, the heat production varies very regularly in the twenty-four hours. Two hours after the meal it begins to rise, comes to its maximum point between the fifth and seventh hour, falls suddenly between the eleventh and twelfth hour. In the second half of the period the changes are small, the minimum point being usually in the twenty-third hour.

Similar changes go on in the expiration of carbonic acid. But after the meal it rises much more rapidly, and therefore comes earlier to its maximum point. Thus the ratio between heat production and expiration of carbonic acid is not a constant. This is true not only in the daily period. The variations are seen to be still greater when we compare different animals, or the same animal at different times and in different states of nutrition.

By such researches we are enabled to examine more exactly what chemical changes are going on in the animal system. The materials afforded by food are all oxidized at last, and leave the body in the form of carbonic acid and nitrogenous matter like urea. What in a longer period is burnt in such a way, we can, with a certain degree of exactness, make out by chemical examination of the constituents of food on the one hand, and of the excretions on the other. We can make up, in such a way, a balance account for gain and loss of the animal, like the balance account of a merchant. But such an account gives no exact knowledge, because we have no means of completing it by taking an inventory. We are, as regards the living body, in the same position as a political economist, who knows the amount of goods imported into and exported out of a country, but does not know what has become of the goods stored up or used up in the country itself. Therefore political economists do not now regard the mere balance of trade as being so important as they formerly thought.

Physiology, like all branches of science, begins with a mere description of processes observed. With the progress of our knowledge, reason tries to connect these processes one with another, and with those going on in lifeless nature. What we call *understanding* is nothing else than knowing such connections. Now in the case of bodily income and expenditure, it is easy to observe that all materials going out of the system are more oxidized than those taken in as food, and reason tells us that the combination of these food materials with the oxygen inspired must be the source of animal heat. Hence, we have no doubt that the amount of heat produced must correspond to the amount of chemical processes going on during the same time. But these processes we cannot observe directly; we can only observe the final products carbonic acids and others, when they leave the body. But by some of the processes heat may be produced or absorbed without any visible change of the body as a whole, viz. by solution of solid matter, by splitting highly complex substances into more simple ones, by forming sugar out of starch or glycogen out of sugar. Considering this, we need not wonder that for a long time it was impossible to answer the question whether there is any other source of heat production in animals besides oxidation. Only long continued calorimetric measurements have enabled me to fill up this gap.[1] This done, I thought it possible to discover also something about these inner processes, by comparing, hour for hour, the heat production with the excretion of carbonic acid, and with the absorption of oxygen.

If the ratio between the heat produced and the carbonic acid expired changes, this cannot be explained otherwise than by the fact that different chemical substances are burned. Each substance, according to its chemical constitution, gives out, when oxidized, a certain amount of carbonic acid, and produces a certain amount of heat. But in the system it is a mixture of different substances which come to be oxidized. This mixture changes, not only in animals differently nourished, but also in the same animal in different periods of digestion. After a rich meal, what comes into the circulation first must be that part of the food that is easily and rapidly digested and easily and rapidly absorbed. Such substances are the proteid matters. Later, the other constituents of the food, especially fat, come to the tissues, where they are burned. Now *fats*, for the same amount of carbonic acid, produce far more heat than proteids; so, during the first hours of digestion the afflux of oxidizable matter to the tissues being very great, both heat production and expiration of carbonic acid increase, but the latter in a far higher degree than the former.

The animal body may be compared, as Prof. Huxley so well says, to an eddy in a river, which may retain its shape for an indefinite length of time, though no one particle of the water remains in it for more than a brief period. But there is not only the difference between the animal eddy and the eddy of the river, viz. that the matter which flows into it has a different chemical composition from the matter which flows out of it, but in addition, matters which make up the eddy in a given time, change, if I may so say, their chemical value, combine with or separate from each other, without any visible change of the whole system.

The study of heat production is of the greatest value. No doubt, the study of the vital processes becomes more complicated when we take into account the invisible internal changes occurring in the body. But simplicity is not the highest aim in scientific inquiries; the highest possible exactness is that to which we must aspire. Happily, the history of science shows that after trying several ways to solve complex problems, we find that one of them leads to a higher point of view, whence things appear in all their completeness, simplicity and distinctness. Towards such a point of view my researches are but the first step. Let us hope that the united forces of many physiologists will shorten the time necessary for the completion of the work.

MAGNETIC PROPERTIES OF LIQUID OXYGEN.[2]

AFTER alluding to the generous aid which he had received both from the Royal Institution and from others in connection with his researches on the properties of liquid oxygen, and to the untiring assistance rendered him by his co-workers in the laboratory, Prof. Dewar said that on the occasion of the commemoration of the centenary of the birth of Michael Faraday he had demonstrated some of the properties of liquid oxygen. He hoped that evening to go several steps further, and to show liquid air, and to render visible some of its more extraordinary properties.

The apparatus employed consisted of the gas-engine down stairs, which was driving two compressors. The chamber containing the oxygen to be liquefied was surrounded by two circuits, one traversed by ethylene, the other by nitrous oxide. Some liquid ethylene was admitted to the chamber belonging to its circuit, and there evaporated. It was then returned to the

[1] See also my address delivered to the general meeting of the German Association of Naturalists at Bremen, 1890.

[2] Abstract of Friday evening discourse delivered at the Royal Institution by Prof. Dewar, F.R.S.

compressor as gas and liquefied, and thence, again, into the chamber as required. A similar cycle of operations was carried out with the nitrous oxide. There was a hundredweight of liquid ethylene prepared for the experiment. Ethylene was obtained from alcohol by the action of strong sulphuric acid. Its manufacture was exceedingly difficult, because dangerous, and as the efficiency of the process only amounted to 15 or 20 per cent. the preparation of a hundredweight of liquid was no light task. The cycle of operations, which, for want of time, was not fully explained, was the same as that commonly employed in refrigerating machinery working with ether or ammonia.

The lecturer then exhibited to the audience a pint of liquid oxygen, which by its cloudy appearance showed that it contained traces of impurity. The oxygen was filtered, and then appeared as a clear transparent liquid with a slightly blue tinge. The density of oxygen gas at − 182° C. is normal, and the latent heat of volatilisation of the liquid is about 80 units. The capillarity of liquid oxygen at its boiling-point was about one-sixth that of water. The temperature of liquid oxygen at atmospheric pressure, determined by the specific heat method, using platinum and silver, was − 180° C.

Reference was then made to a remarkable experimental corroboration of the correctness for exceedingly low temperatures of Lord Kelvin and Prof. Tait's thermo-electric diagram. If the lines of copper and platinum were prolonged in the direction of negative temperature, they would intersect at − 95° C. Similarly, the copper and palladium lines would cut one another at − 170° C. Now, if this diagram were correct, the E.M.F. of the thermo-electric junctions of these two pairs of metals should reverse at these points. A Cu − Pt junction connected to a reflecting galvanometer was then placed in oxygen vapour and cooled down. At − 100° C. the spot of light stopped and reversed. A Cu − Pd junction was afterwards placed in a tube containing liquid oxygen, and a similar reversal took place at about − 170° C.

Liquid oxygen is a non-conductor of electricity: a spark taken from an induction coil, one millimetre long in the liquid requires a potential equal to a striking distance in air of 25 millimetres. It gave a flash now and then, when a bubble of the oxygen vapour in the boiling liquid came between the terminals. Thus liquid oxygen is a high insulator. When the spark is taken from a Wimshurst machine the oxygen appears to allow the passage of a discharge to take place with much greater ease. The spectrum of the spark taken in the liquid is a continuous one, showing all the absorption bands.

As to its absorption spectrum, the lines A and B of the solar spectrum are due to oxygen, and they came out strongly when the liquid was interposed in the path of the rays from the electric lamp. Both the liquid and the highly compressed gas show a series of five absorption bands, situated respectively in the orange, yellow, green, and blue of the spectrum.

Experiments prove that gaseous and liquid oxygen have substantially the same absorption spectra. This is a very noteworthy conclusion considering that no compound of oxygen, so far as is known, gives the absorptions of oxygen. The persistency of the absorption through the stages of gaseous condensation towards complete liquidity implies a persistency of molecular constitution which we should hardly have expected. The absorptions of the class to which A and B belong must be those most easily assumed by the diatomic molecules (O_2) of ordinary oxygen; whereas the diffuse bands above referred to, seeing they have intensities proportional to the square of the density of the gas, must depend on a change produced by compression. This may be brought about in two ways, either by the formation of more complex molecules, or by the constraint to which the molecules are subjected during their encounters with one another.

When the evaporation of liquid oxygen is accelerated by the action of a high expansion pump and an open test-tube is inserted into it, the tube begins to fill up with liquid atmospheric air, produced at the ordinary barometric pressure.

Dr. Janssen had recently been making prolonged and careful experiments on Mont Blanc, and he found that these oxygen lines disappeared more and more from the solar spectrum as he reached higher altitudes. The lines at all elevations come out more strongly when the sun is low, because the rays then have to traverse greater thicknesses of the earth's atmosphere.

Michael Faraday's experiments made in 1849 on the action of magnetism on gases opened up a new field of investigation. The following table, in which + means "magnetic" and − means "negative," summarises the results of Faraday's experiments.

Magnetic Relations of Gases (Faraday).

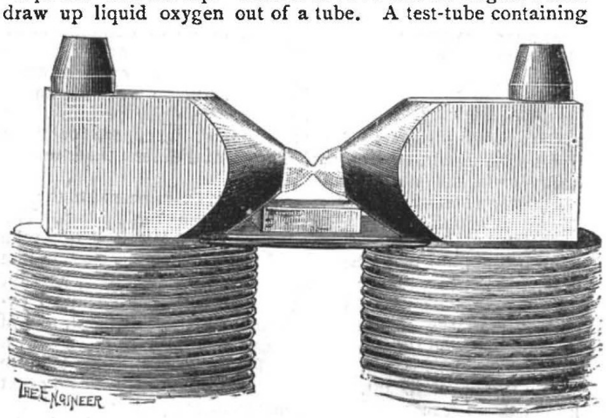
	In Air.	In Carbonic Acid.	In Hydrogen.	In Coal Gas.
Air	o	+	+ weak	+
Nitrogen	−	−	− strong	−
Oxygen	+	+	+ strong	+ strong
Carbonic acid ...		o	−	− weak
Carbonic oxide...	−	−	−	− weak
Nitric oxide ...	− weak	+	+	...
Ethylene ...	−	−	−	− weak
Ammonia ...	−	−	−	...
Hydrochloric acid	−	−	− weak	...

Becquerel was before Faraday in experimenting upon this subject. Becquerel allowed charcoal to absorb gases, and then examined the properties of such charcoal in the magnetic field. He thus discovered the magnetic properties of oxygen to be strong, even in relation to a solution of ferrous chloride, as set forth in the following table:—

Specific Magnetism, Equal Weights (Becquerel).

Iron	+	1,000,000
Oxygen...	+	377
Ferrous chloride solution, sp. gr. 1·4334	+	140
Air	+	88
Water	−	3

The lecturer took a cup made of rock salt, and put in it some liquid oxygen. The liquid did not wet rock salt, but remained in a spheroidal state. The cup and its contents were placed between and a little below the poles of an electro-magnet. Whenever the circuit was completed, the liquid oxygen rose from the cup and connected the two poles, as represented in the cut, which is copied from a photograph of the phenomenon. Then it boiled away, sometimes more on one pole than the other, and when the circuit was broken it fell off the pole in drops back into the cup. He also showed that the magnet would draw up liquid oxygen out of a tube. A test-tube containing



Magnetic ttraction of Liquid Oxygen.

liquid oxygen, when placed in the Hughes balance, produced no disturbing effect. The magnetic moment of liquid oxygen is about 1000 when the magnetic moment of iron is taken as 1,000,000. On cooling some bodies increased in magnetic power. Cotton wool, moistened with liquid oxygen, was strongly attracted by the magnet, and the liquid oxygen was actually sucked out of it on to the poles. A crystal of ferrous sulphate, similarly cooled, stuck to one of the poles.

The lecturer remarked that fluorine is so much like oxygen in its properties, that he ventured to predict that it will turn out to be a magnetic gas.

Nitrogen liquefies at a lower temperature than oxygen, and one would expect the oxygen to come down before the nitrogen when air is liquefied, as stated in some text-books, but unfortunately it is not true. They liquefy together. In evaporating, however, the nitrogen boils off before the oxygen. He poured two or three ounces of liquid air into a large test-tube, and a smouldering splinter of wood dipped into the mouth of the tube was not re-ignited; the bulk of the nitrogen was nearly five minutes in boiling off, after which a smouldering splinter dipped into the mouth of the test-tube burst into flame.

Between the poles of the magnet all the liquefied air went to the poles; there was no separation of the oxygen and nitrogen. Liquid air has the same high insulating power as liquid oxygen. The phenomena presented by liquefied gases present an unlimited field for investigation. At – 200° C. the molecules of oxygen had only one-half of their ordinary velocity, and had lost three-fourths of their energy. At such low temperatures they seemed to be drawing near what might be called "the death of matter," so far as chemical action was concerned; liquid oxygen, for instance, had no action upon a piece of phosphorus and potassium or sodium dropped into it; and once he thought, and publicly stated, that at such temperatures all chemical action ceased. That statement required some qualification, because a photographic plate placed in liquid oxygen could be acted upon by radiant energy, and at a temperature of – 200° C. was still sensitive to light.

Prof. M'Kendrick had tried the effect of these low temperatures upon the spores of microbic organisms, by submitting in sealed glass tubes blood, milk, flesh, and such-like substances, for one hour to a temperature of –182° C., and subsequently keeping them at blood heat for some days. The tubes on being opened were all putrid. Seeds also withstood the action of a similar amount of cold. He thought, therefore, that this experiment had proved the possibility of Lord Kelvin's suggestion, that life might have been brought to the newly-cooled earth upon a seed-bearing meteorite.

In concluding, the lecturer heartily thanked his two assistants, Mr. R. N. Lennox and Mr. J. W. Heath, for the arduous work they had had in preparing such elaborate demonstrations.

SCIENTIFIC SERIALS.

IN the *Journal of the Royal Agricultural Society of England* (third series, vol. iv. pt. 1) there is an interesting paper on the home produce, imports, consumption, and price of wheat over forty harvest years, 1852–3 to 1891-2, by Sir J. B. Lawes and Dr. J. H. Gilbert. This paper, extending to fifty-five pages, contains a general review of the produce of the experimental plots at Rothamsted, from which they have annually calculated the wheat crop of this country.—The first of the official reports is that of the Royal Veterinary College on investigations conducted for the Royal Agricultural Society during the year 1892. An interesting case of actinomycosis is related; a heifer with tongue badly diseased was put under Thomassen's treatment. Potassium iodide administered at first in doses of one drachm, twice daily, and the doses gradually increased to three drachms, effected a complete cure in about ten weeks.—Experiments have lately been made at the Veterinary College with Koch's tuberculin. The results in the case of seventy-two animals inoculated and afterwards killed show that "the tuberculin pointed out correctly the existence of tuberculosis in twenty-seven animals and wrongly in five, and it failed to indicate the existence of the disease in nineteen. In only three of the twenty-seven animals in which the tuberculin correctly pointed out the existence of tuberculosis could a positive diagnosis have been made by any other means." Experiments have also been made with Kalning's mallein, and "the results warrant the statement that mallein is an agent of greater precision than tuberculin, and that it is likely to render most important service in any attempt to stamp out glanders."

Wiedemann's Annalen der Physik und Chemie, No 4.—On electric discharges; the production of electric oscillations, and their relations to discharge tubes, by H. Ebert and E. Wiedemann. The influence of electric oscillations of given frequency in producing glow in vacuum tubes without electrodes was investigated by means of Lecher's wire system. The oscillations in the primary circuit were produced by means of an influence machine throughout. The terminals of the machine were connected to the primary condenser, consisting of four plates, to the further two of which the two Lecher wires, copper wires or thick metal tubes, were attached, running parallel for distances varying from 2 to 14 m., and ending in another condenser of variable capacity. The sensitive tubes were placed in various positions between or near the plates of the secondary condenser. It was found that wide tubes, not too short, glowed most readily. Nodes along the wires were discovered by means of wire bridges, which were moved along the wires until the tube glowed, or, if it was glowing already, until it reached a point where the glow became more intense and uniform. It was found that the position of the nodes was independent of the pressure in the tube, but that as evacuation proceeded the limits within which the tube would glow grew wider. Hence the most accurate method for finding the nodes, was by finding them for the highest possible pressure of gas in the tube.—On the comparison of intensities of light, by the photoelectric method, by J. Elster and H. Geitel. Apart from the dissipation of an electric charge from a negative zinc pole by ultra-violet radiation, it is also possible to measure the intensity of optically active light by an electric method. If a clean surface of potassium is joined to the negative pole of a battery, and a platinum or aluminium electrode to the positive pole, and the two electrodes are placed in a vacuum cell, the illumination of the potassium surface will allow a current to flow whose strength will be proportional to the intensity of the light source, and can be measured by means of a galvanometer. That this is really the case was proved by measuring independently in this way the intensities of two luminous sources, and then combining them, when the resultant reading was found to be equal to the sum of the other two, within the limits of constancy of the sources themselves. The greatest effect is produced by the blue rays.—Also papers by Messrs. Bjerknes, Zahn, Voigt, Richarz, Ambronn, Christiansen, Goldhammer, and Oberbeck.

Meteorologische Zeitschrift, March.—Iridescent clouds, by H. Mohn.—The paper contains observations made at Christiania during the years 1871-1892, together with a detailed investigation of the formulæ recently employed. During this period iridescent clouds were only visible on forty-two days; in some years the phenomenon failed entirely, and was not observed during the whole lustrum 1876-80. The great majority of cases occurred in December and January, but a few occurred in summer; the phenomenon was also seen somewhat more frequently at sunset than at sunrise or mid-day, but the difference is so small as to make it appear that its occurrence is independent of the time of day. The height of the clouds varied from about fourteen to more than eighty miles, the lower level being about twice the height at which ordinary cirrus clouds are usually seen at Christiania. The phenomenon appears to have some connection with the state of the weather, as an examination of the synoptic charts showed that it mostly occurred during the prevalence of stormy weather in the North Atlantic and over Northern Europe, and when the air was dry and warm at Christiania.—On the determination of wind force during gusts of a Bora storm, by E. Mazelle. From an investigation of the anemometer observations at Trieste for the ten years 1882-1891, the greatest hourly velocity recorded was seventy miles. But as hourly values give little idea of the violence of individual gusts, the author adapted an ingenious electrical arrangement to the anemometer, by which he could record the number of revolutions of the cups in each second. During a storm on January 16 last, the gusts during the space of a few seconds reached the velocity equivalent to 100 to 140 miles an hour. Presuming the instrument to have been a large-sized anemometer, this high velocity is not unlikely, as in a paper read before the Royal Meteorological Society on May 18, 1881, by R. H. Curtis, a velocity at the rate of 120 miles an hour at Aberdeen is quoted as recorded in gusts lasting two minutes, while shorter intervals, if they could be measured, would no doubt show higher velocities; and at Sydney a velocity of 153 miles an hour was recorded during one or two minutes. In all these cases the factor 3 has been used for the ratio of the movement of the cups to that of the wind, but this factor has been shown to give a velocity which is nearly 30 per cent. too high.

Bulletin de la Société des Naturalistes de Moscou, 1892.—(No. 1.) The chief papers are:—The development of the gemmulæ in *Ephydatia fluviatilis*, by W. Zykoff.—Catalogue of Kazan Lepidoptera, continued, by L. Kroulikovsky.—Analogy between the solution of a gas and of a salt in indifferent solutions of salts, by I. M. Syetchenoff. The author's law, which was found or carbon dioxide $\left(y = \alpha e - \frac{k}{x}\right)$, holds good within certain limits, for the solution of salts in the same solutions; but the latter must only be taken either weak or of medium strength.—New plants and insects from Sarepta, by Alex. Becker.—On a