respect to actively functionating and intact cells. It is obvious, therefore, that the first desideratum is a suitable method of obtaining the cell plasma for experimental purposes, and it is only recently that this has been successfully accomplished. The most feasible means of procedure appeared to be the use of *mechanical* agents which, whilst bringing the cell substance within the field of observation, would, at the same time, be least likely to affect its character and constitution. The method consists in a mechanical rupture of the cells and the release of their contents under conditions favouring the conservation of their properties. The first successful application of this description of method was made by Buchner in the particular instance of the yeast cell, and with brilliant results. The researches of Buchner were of wide biological significance, and were suggestive of much more than a cell-free alcoholic fermentation of sugars. They demonstrated the possibilities of the new methods with regard to more general vital problems. The Buchner process consisted in a mechanical trituration of the yeast cell with the aid of sand and a subsequent filtration of the resultant mass under pressure through Kieselguhr. The filtrate contained the expressed constituents of the yeast cell which were capable of passing through Kieselguhr, and the product, in virtue of its fermentative properties, was termed "zymase."

The author and his colleagues have, during the past four years, been engaged in investigating the application of cognate methods to biological research. The advice and help generously afforded by Prof. James Dewar materially forwarded the progress of the research.

It was considered that, by the employment of low temperatures, a disintegration of living cells might possibly be accomplished, and a wide field of inquiry opened to investigation in the biological laboratory. For this purpose the methods of mechanical trituration required refinement in several directions.

The conditions it was desired to fulfil were, a rapid disintegration of the fresh tissues and cells, an avoidance of heat and other modifying agents during the process, and an immediate manipulation of the cellular juices obtained.

It had likewise been noted that ordinary filter pressing through Kieselguhr removed physiologically active substances from the cell juices. Liquid air appeared to be the most convenient means of obtaining the necessary cold, and it presented the advantage of a fluid freezing medium in which the material to be manipulated could be directly immersed. The temperature of this reagent (about $-190°$ C.) would, in addition, prevent heat and chemical changes, whilst reducing the cells to a condition of brittleness favourable to their trituration without the addition of such substances as sand and Kieselguhr, which might modify the composition of the resultant product.

The method, if successful, would meet the conditions desired for the subsequent study of the intracellular juices. It may be briefly and generally stated that, by the application of low temperatures, a mechanical trituration of every variety of cell *per se* has been accomplished, and the fresh cell plasma obtained for the purpose of experiment. A number of control experiments have demonstrated that immersion in liquid air is not necessarily injurious to life—bacteria for example, having survived a continuous exposure for six months to its influence. The actual trituration of the material is accomplished in a specially devised apparatus, which is kept immersed during the operation in liquid air.

The normal and diseased animal tissues have been treated in this manner, and their intracellular constituents obtained, *e.g.* epithelium, cancer tissues, &c.

Moulds, yeasts and bacteria have been rapidly triturated under the same conditions, and the respective cell juices submitted to examination.

The severest test of the capabilities of the method was furnished by the bacteria, an order of cells for which the standard of measurement is the *mikron*. The experiments proved successful in every instance tested. The typhoid bacillus, for example, is triturated in the short space of two to three hours, and the demonstration has been furnished that the typhoid organism contains within itself a toxin. From these and other researches it has become evident that there exists a distinct class of toxins and ferments which are contained and operate within the cell or bacterium, in contradistinction to the now well-known class of toxins which are extracellular, *i.e.* extruded during life from the cell into the surrounding medium. To this latter class belongs the diphtheria toxin, which has been so successfully used in the preparation of diphtheria antitoxin. A number of infective organisms do not produce appreciable extracellular toxins, and the search must therefore be made within the specific cells for the missing toxins to which the intoxication of the body in the course of the disease in question is probably due. The practical utility of investigating these intracellular toxins has already become evident in the preparation from the intracellular toxin of the typhoid bacillus of a serum having antitoxic value as regards this toxin.

The experiments made with the pus organisms have already shown that intracellular toxins exist in this important order of disease germs.

The cell juices of other types of pathogenic bacteria, such as the tubercle and diphtheria bacillus, present characteristics of equal interest.

The application of low temperatures has aided the investigation of certain other biological problems.

The photogenic bacteria preserve their normal luminous properties after exposure to the temperature of liquid air. The effect, however, of a trituration at the same temperature is to abolish the luminosity of the cells in question. This points to the luminosity being essentially a function of the living cell, and dependent for its production on the intact organisation of the cell.

The rabies virus has not yet been detected or isolated, although regarded as an organised entity. The seat of the unknown rabies virus is the nervous system. If the brain substance of a rabid animal be triturated for a given length of time at the temperature of liquid air, its infective properties as regards rabies are abolished. This result appears to be a further indication of the existence in rabies of an organised virus.

The method described admits of a fresh study of the question of immunity from an intracellular standpoint.

The intracellular juices of the white blood cells have been obtained, and tested with regard to bacteriolytic properties and the natural protection that may thus be afforded to the body against the invasions of microparasites.

The application of low temperatures to the study of biological problems has furnished a new and fruitful method of inquiry.

PHYSICS AT THE BRITISH ASSOCIATION.

THE meeting of the International Meteorological Committee at Southport during the week of the meeting of the Association resulted in an unusually large proportion of the papers presented to Section A dealing with cosmical problems, and these were taken in the department of the section devoted to astronomy and meteorology. Of the matters brought before the department devoted to physics, there seems little doubt that the most important were those involved in the discussions on the introduction of vectorial methods into physics, on the treatment of irreversible processes in thermodynamics, and on the nature of the emanations from radio-active substances respectively, and of these a short account follows.

In opening the discussion on the introduction of vectorial methods into physics, Prof. Henrici pointed out that, although vectors were invented for use in dynamics, the ideas involved were fully introduced into physics by Faraday's representation of the stresses in a medium by lines of force. Maxwell was aware of this, and devoted some sections of the opening chapter of his "Electricity and Magnetism" to an exposition of the properties of vectors, and expressed many of his later equations in vectorial form.

So long as we have to deal with quantities which involve magnitude and direction, but which are not specified as starting from a definite point, *i.e.* with non-localised vectors, a very simple algebra is all that is necessary, and when at any time it is required to extend our methods to localised vectors the methods of Grassmann's "Ausdehnungslehre" are available. The algebras which have been proposed for dealing with the simpler case agree in making addition follow the parallelogram law for compounding two forces, but they differ in the meanings they attach to multiplication. In Prof. Henrici's algebra the products of two vectors α, β are :—$(\alpha\beta)$ a non-directional or "scalar," in magnitude equal to the product of one vector into the component of the other along the first, and $[\alpha\beta]$ a vector perpendicular to the plane drawn through α and β, and in magnitude equal to the area of the parallelogram of which α and β are concurrent sides. This algebra is evidently identical with those of Heaviside and Gibbs, and, like them, open to the objection that it does not discriminate between "polar" vectors, *e.g.* forces and "axial" vectors, *e.g.* couples. Its relation to that of quaternions is expressed by the equation $\alpha\beta = -(\alpha\beta)+[\alpha\beta]$, where $\alpha\beta$ is the quaternion product of α and β. If, now, u be a scalar function of the vector ρ of a point P, and P be displaced through a distance $d\rho$, the change du in the value of u will be proportional to $d\rho$, and may be denoted by $d\rho \,.\, \nabla u$, where ∇u is a vector such that for a given magnitude of $d\rho$, du is a maximum when $d\rho$ is parallel to ∇u. Hence the direction of ∇u is that of the greatest rate of change of u, and its magnitude that rate of change. Similarly for a vector function η of ρ $d_\rho \eta = (d\rho\nabla.)\eta$, and ∇ follows quite generally the laws of combination of vectors. Thus we have $(\nabla\eta)$ the "divergence" of η and $[\nabla\eta]$ the "curl" of η, with their numerous applications. By the use of this operator ∇, theorems like those of Green and Stokes can be proved in a generalised form with great ease and elegance, and the equations for the electromagnetic field follow in a couple of lines of work.

With so powerful a calculus as this at command, Prof. Henrici considers it the height of folly, after using vectorial methods in those elementary parts of physics which deal with addition of forces or velocities, to drop them for Cartesian coordinates and direction cosines at the next step forward. He advocates the use of vectors throughout, and, like Heaviside, would make trigonometry follow and depend on vectors by the definitions $x=r \cos \theta$, $y=r \sin \theta$. Vectors would thus be introduced into school curricula previous to or along with the use of squared paper and the idea of coordinates.

In the discussion which followed, Sir Oliver Lodge, Dr. Sumpner and others spoke as to the usefulness of vectorial methods in physical work. Prof. Larmor said there could be no doubt as to the extreme elegance of vectorial methods, and attributed the slow progress they had made to the want of uniformity in definitions and notation, which rendered it necessary for each writer who used vectors to describe his notation and methods before his work could be understood by his readers. Mr. Swinburne also referred to this difficulty. Prof. Boltzmann pointed out that this confusion would have been avoided if Hamilton had accepted Grassmann's methods and notation. The writer suggested that the question of the possibility of introducing greater uniformity into the notation and methods of vector algebra was a suitable one to be considered by a committee of the British Association. Prof. Henrici thought there would be little difficulty in coming to some agreement between the advocates of the various systems now in existence. His communication was ordered to be printed *in extenso* in the reports, so that those interested in the subject might be able to consider the suggestions made in detail.

Mr. Swinburne opened the discussion on the treatment of irreversible processes in thermodynamics by pointing out that so much attention was devoted in books on thermodynamics to the consideration of the changes involved in reversible processes, and so little to irreversible ones, that there was a danger of the latter being overlooked, although they are the only ones which really occur in nature. His object was to bring them more prominently forward, and to suggest a method of introducing the subject which would not involve alteration or extension of fundamental ideas on passing from reversible to irreversible changes. The sketch of the method he proposed was necessarily brief, and it was not easy at the time to see to what the proposals made would eventually lead. This probably accounts for the unsatisfactory nature of the discussion, which consisted to a great extent of statements by the speakers that they had been unable to understand what was proposed, or of condemnation of any attempt to alter the definition of entropy. Fortunately, copies of Mr. Swinburne's communication were available, and a quiet perusal of his suggestions shows that they are by no means so drastic as was supposed.

He points out that, while the first law of thermodynamics asserts that heat is a form of energy, the second states that only a portion of a given supply of heat is available for conversion into work, although energy of other forms is wholly convertible. That part of a supply of heat which cannot be converted into work during a cyclic change of state of the body containing the heat he proposes to call the "waste heat." It depends on the temperature of the coldest available reservoir of heat of large capacity, say that of the sea. Any process which goes on in an isolated system involves in general an increase of this "waste," and the quotient of this increase by the temperature of the coldest available reservoir of heat Mr. Swinburne defines as the increase of entropy of the system during the process.

A part of the system may decrease in entropy, but the rest must increase by at least an equal amount. If the increase is equal to the decrease the increase is said to be "compensated," if it exceeds the decrease the excess is the "uncompensated" increase of entropy. A reversible change in an isolated system involves no increase of entropy of the system, and any change in the entropy of any part of the system must therefore be "compensated." When irreversible changes occur there is an increase of entropy of the system, and an uncompensated increase of entropy of some part of it. So far as reversible changes are concerned, it is evident that Mr. Swinburne's definition of entropy leads to the same result as the one commonly used, *i.e.* $\int \frac{dH}{\theta} = d\phi$. For if in a Carnot cycle heat H_1 is taken in by the working substance at a temperature θ_1, the increase of entropy of the substance $=H_1/\theta_1$, and if at the temperature of the coldest available reservoir θ_0, H_0 is given up by the substance, H_0 is Mr. Swinburne's waste heat, and H_0/θ_0, according to his definition, the increase of entropy of the substance when it took in H_1 from the reservoir θ_1. As temperatures are measured on the absolute scale, the two quantities are identical.

From this point onwards Mr. Swinburne's treatment of the equilibrium of isolated systems is much like those in use at present, except that he objects to the use of some of the names, *e.g.* "thermodynamic potential," now commonly used.

Prof. Perry, in the discussion which followed, stated that engineers, while using the definition of entropy which connected it with reversible changes, were quite aware that most of the processes with which they had to deal were irreversible, and that their theory was an approximation only.

Prof. Larmor thought Mr. Swinburne's method was a praiseworthy attempt to introduce simplification and precision into a part of the subject which had received little attention, and was still somewhat obscure, and Mr. Boys added that the ideas brought forward were well worthy of careful consideration.

Before stating his views as to the nature of the emanations from radio-active substances, Prof. Rutherford gave a short *résumé* of the known facts about radio-activity. Substances which possess the property throw off material which carries with it a positive electric charge. This charged material can penetrate to some extent through solids, is deviated in electric and magnetic fields, and appears to consist of particles of matter of about twice the weight of a hydrogen atom, moving with a velocity about one-tenth that of light. This is known as the α radiation, and accounts for about 99 per cent. of the energy sent out by a radio-active substance. Another kind of radiation, known as the β or kathode ray, is also emitted. It is negatively charged, more penetrative and more easily deviated than the α radiation, and appears to consist of particles of about one-thousandth the mass of the hydrogen atom. A third kind of radiation, known as the γ, is more penetrative still, but up to the present has not been sufficiently studied to enable its properties to be definitely stated. The matter which remains after the α radiation has been thrown off behaves in the case of thorium and radium like a gas of large molecular weight, diffuses, condenses at low temperatures, may deposit itself on bodies with which it comes into contact, and may again divide into a positively charged α radiation and a second emanation, and so on until he changes cease to produce the usual effect on an electrometer. Whatever the nature of the radio-active material, the amount of radiation it emits in unit time is equal to λ times the amount of radio-active element present, where λ is a constant for each type of matter, and is unaffected by chemical and physical agencies.

Prof. Rutherford regards the process which goes on in radio-active substances as a gradual breaking up of the atoms of the substance, and this gradual disintegration as the cause of the radio-active properties. The electrically neutral atom of a radio-active substance throws off a positively charged body which constitutes the α radiation; what remains of the atom constitutes the emanation. This again throws off a positively charged body, and the process repeats itself until the positively charged bodies are exhausted, and the substance no longer possesses radio-active properties.

This disintegration theory fits all the known facts, but it involves the existence in the atom of a radio-active substance of a store of energy hitherto unsuspected, amounting in the case of radium to at least 10^{16} ergs per gram. This energy exists, according to Prof. Rutherford, as kinetic energy of motion of the atoms in closed paths with velocities comparable with that of light, and disintegration is the moving off at a tangent of one or more of the particles of an atom. If this is the case it seems probable that the atomic energy of elements not yet found to be non-radio-active is of the same order of magnitude, and may be set free by methods of which we are not yet cognisant.

In the discussion which followed Sir Oliver Lodge said the theory put forward by Rutherford seemed to him to be a valuable working hypothesis, very near, if not absolutely, the truth. It was supported by Larmor's electrical theory, according to which the atoms of matter should be unstable.

Lord Kelvin, in a letter communicated to the section, put forward another theory as to the nature of the processes going on in radio-active materials. According to it each atom of matter has positive electricity distributed uniformly through its mass, and concentrated at one or more points, in general within it, atomic quantities of negative electricity, to which Lord Kelvin gives the name "electrions." A normal atom has the necessary number of electrions to neutralise the positive electricity associated with its matter. The α radiation consists of atoms of matter which have less than the normal number of electrions. When they move into matter they quickly pick up the negative charges necessary to render them neutral, and cease to be detected. The β radiation consists of electrions thrown off during violent oscillations of the atoms of matter, and are readily absorbed by matter. The γ radiation consists of vapour of the radio-active matter, *e.g.* radium, which would possess the penetrative power it is found to have if the Boscovichian forces between the atoms of radio-active matter and ordinary matter were small. The large amount of energy radiated is, according to this view, derived from without the atoms, where it exists in a form which we have not yet found a means of detecting.

Prof. Armstrong pointed out that, as the experiments of Rutherford and Soddy had been made on what was supposed to be radium bromide, the dissociation which they believed to be taking place might be of the compound and not of the element. He was disposed to regard Lord Kelvin's theory with favour.

Mr. Soddy thought ordinary chemical changes were excluded by the fact that the rate of production of the radiations was unaffected by chemical and physical conditions which greatly affected the former. The view Prof. Rutherford and he put forward was that at each stage of the process a new element was formed.

Prof. Dewar gave an account of the experiments on the effects of low temperature on the properties and spectrum of radium carried out partly in conjunction with Sir W. Crookes and recently communicated to the Royal Society.

Prof. Schuster thought the internal energy more probable than the absorption theory, and questioned whether the instability of the atoms predicted by electrical theory would account for the high velocities of the emanations. He was disposed to regard these high velocities as probably due to some cause not yet known.

Prof. Larmor agreed with Prof. Rutherford's theory, and pointed out that, just as atoms of matter must have size, or a half-size atom would still be an atom, so it may be that the atoms of electricity have size and configuration, and thus account for the complicated structure of the radium atom.

Mr. Whetham directed attention to the still unexplained fact that the negatively charged emanation seemed to deposit more readily on negatively than on positively charged bodies, and Dr. Lowry, after recounting some experiments on the flash of light seen when certain substances are crushed, suggested that the emanation might be a modification of a constituent of the atmosphere, *e.g.* helium.

C. H. LEES.

CHEMISTRY AT THE BRITISH ASSOCIATION

THE Southport meeting of Section B proved to be one of the most successful held during recent years; the meetings were largely attended, and a keen interest was exhibited in the proceedings of the section. After the reading of the presidential address (NATURE, p. 472), Prof. J. Campbell Brown described an apparatus for determining latent heats of evaporation, in which a known quantity of heat, generated electrically in a platinum wire, is absorbed in converting a liquid at its boiling point into vapour at the same temperature; very concordant results are obtained.

In a paper on some derivatives of fluorene, Miss Ida Smedley showed that whilst fluorenone $\begin{matrix} C_6H \\ | \\ C_6H_4 \end{matrix}\!\!>\!C{=}O$, is orange-red in colour, the corresponding sulphur derivative, thiofluorenone, is intensely red; the radicle $>$CS has thus a greater tendency to produce colour than the carbonyl group. In a paper on the action of diastase on the starch granules of raw and malted barley, Mr. A. R. Ling showed that the starch derived from both raw and malted barley is dissolved and hydrolysed by diastase at a temperature below its gelatinising point, and that the optical and reduction constants differ according to the sample of grain from which the starch is derived. Evidence was adduced in two other papers on the action of malt diastase on potato starch paste, one by Mr. A. R. Ling and the other by Mr. A. R. Ling and Mr. B. F. Davis, that when diastase is heated in aqueous solution at 60°–70° for a short time, the molecule of the enzyme becomes so changed that it no longer yields the same products when it acts on potato starch paste.

Dr. H. C. White described the chemical and physical characteristics of the so-called mad-stone, which, in accordance with a superstition current in the southern States of America, is used to detect and cure the bites of venomous snakes or rabid animals; the mad-stone is found to be a concretionary calculus from the gullet of the male deer, and is devoid of discriminative or curative powers.

Prof. E. A. Letts, Mr. R. F. Blake, and Mr. J. S. Totton read a paper on the reduction of nitrates by sewage, in which it was shown that, when potassium nitrate is added to the effluent from a septic tank, practically all the nitrogen is evolved in the free state or as nitric oxide; the oxygen of the nitrate is evolved as carbon dioxide.

A method for the separation of cobalt from nickel and for the volumetric determination of cobalt was described by Mr. R. L. Taylor; it is based on the fact that cobalt is precipitated quantitatively as a black oxide from neutral solutions by barium or calcium carbonate in presence of bromine water. The black oxide has the composition Co_8O_{14} or Co_7O_{11}.

Prof. J. Dewar, F.R.S., contributed a description of the more recent results obtained from his investigations at low temperatures; he described the methods by which he has succeeded in determining the densities of solid hydrogen, nitrogen, and oxygen, the methods of producing solid hydrogen and nitrogen, and the methods by which he has been able to determine the latent heats, specific heats, and the coefficient of expansion of liquid hydrogen.

A paper on the application of low temperatures to the study of biological problems, by Dr. Allan Macfadyen, is printed in another part of the present issue (p. 608).

Mr. J. Hübner and Prof. W. J. Pope, F.R.S., gave a paper on the cause of the lustre produced on mercerising