law), we deduce a differential equation for the work obtained or required in isothermal changes. The change under consideration may involve external work, as when a vapour or gas is generated against atmospheric pressure; or it may be internal work of different kinds, as when the molecules are endowed with increased kinetic energy in volatilising, or when a compound is decomposed into its constituents, with increased potential energy.

A somewhat difficult but important paper by J. Willard Gibbs[1] treats of the equilibrium of heterogeneous substances, giving deductions from the two laws of thermo-dynamics, which in turn become major premises for a host of further deductions; so broad, indeed, are the propositions of Gibbs, that the distinctions between chemistry and physics do not appear; there may be two "heterogeneous substances" of like chemical nature, as water and its vapour; there may be three chemical bodies, as limestone with the lime and the carbon dioxide obtained by ignition; or there may be several physical mixtures, as solution of water in ether, solution of ether in water, and the mixed vapour resting upon both liquids. Now, a little consideration will show the importance of knowing when equilibrium is established, for this is equivalent to saying that no further action can take place; the solution is saturated, no longer acting upon the salt; or the gas which has been generated under pressure is no longer evolved. When a change takes place spontaneously, as when I drop a stone, or mix sulphuric acid with water, heat is developed from some other form of energy. To reverse the process, work must be done. The conversion of heat into work is limited by natural law; when a given change implies the doing of work, and that work is forbidden by the terms of our major premise, the change is impossible, equilibrium prevails.

"Osmotic pressure" in dilute solutions is analogous to the pressure of gases; the Gay-Lussac-Marriotte law, with slight modification of terms, applies to molecules in the liquid state. If work is required to diminish the volume of a gas by means of pressure, work is likewise required to diminish the volume of a body in dilute solution, whether the solvent be removed by evaporation or by freezing. Boiling point and freezing point of the solvent are changed by the presence of the dissolved body. The agreement of observed facts with theoretical deductions has led to important methods of determining molecular weights, while the apparent discrepancies in the case of electrolytes have proved an important argument for the doctrine that these compounds are dissociated into their ions.

The mutual indebtedness of technology and pure science has already been pointed out. Manufacturing processes afford many examples of change which are not carried to completion; it is important to know how far the operation can be improved to afford a larger yield, a purer product or less waste. Combustible gases issue from the blast furnaces. There is still a great reducing power in this mixture of carbon monoxide with carbon dioxide. Can it be utilised by enlarging the furnace? Immense furnaces were built in order to secure a larger yield of iron, but the results were disappointing. The law of mass action shows that the equation

$$Fe_2O_3 + 3CO = 2Fe + 3CO_2$$

is limited by certain conditions of equilibrium, and that the ratio of the two oxides of carbon could not be greatly improved over that already secured in practice. The expense of a technological experiment might have been saved, had the indications of mathematical chemistry been heeded.

What hopeless confusion seems to prevail in our present knowledge of solubilities; yet how important in the separations required for chemical analysis. Here, again, we deal with questions of equilibrium. Will work be done at the expense of heat or not?

There are two special difficulties in the general application of thermo-dynamical principles: first, the minor premise is often wanting; and, second, the mathematical form of reasoning is often difficult for the best laboratory workers. Among the published data of thermo-chemistry, some have been determined directly, some indirectly; it is often difficult to find the data desired, or to judge of their accuracy. A critical compilation of all available thermal data, conveniently arranged for reference, with at least some indication of the probable errors, would be very desirable. Many such data might be computed indirectly from experimental determinations of equilibrium. Many empirical equations have been computed, showing solubility as a function of temperature. Who will trace the correlation among such, and thus add a large chapter to thermo-chemistry? What genius shall discover that form of mathematical function that shall substitute rational for empirical equations with a clear interpretation for each constant required? "But this work is mathematical rather than chemical," you will say. Yes, it is applied mathematics; and mathematicans (not being chemists) are not likely to undertake such a task for us, unless we ask their counsel and aid. Specialisation is inevitable; yet by too arbitrary a specialisation, we may inadvertently lose the very help we need. Again would I emphasise the fruitfulness which follows a "cross-fertilisation of the sciences" (*Journ. Amer. Chem. Soc.*, 15, 601 (1893). Judging from the advances recorded in late years, especially in the *Zeitschrift für physikalische Chemie*, it is safe to predict great developments for the rising generation. I heartily echo the sentiment that we need more data; yet great stores of observations upon record have not yet been coordinated and put to use. Ostwald, desiring to know the influence of free iodine upon a reduction process, made three series of determinations (twenty-four in all) from which he concludes that the influence is *not* proportional to the mass. It was no part of his purpose to discover what the law of retardation is; but others might well follow out this clue, using also the data supplied by Meyerhoffer, and supplementing these with further experiments if needed. A glance at the literature of solubilities, and the lack of rational formulæ to express broad generalisations, may convince us that a great mine, with abundant ore "in sight," is awaiting development; or, rather, that ore has been run through a stamp-mill to extract half the gold, while fully half still remains in the tailings, awaiting more perfect methods of treatment.

Much may be learned from the systematic habits of the astronomer, dividing his work among the several observatories in a spirit of helpful co-operation, and assigning the labour of computation to those who are fitted thus to follow the lead of others. What better service can we do for the University student than to set before him some of the problems in mathematical or physical chemistry that require patient toil, and give him the pleasure of assisting in their solution by the use of logarithms and squares? What is more practical than to utilise any service he can render?

In conclusion, I beg leave to suggest the appointment of a joint Committee (representing Sections A, B and C of the American Association) to consider the feasibility of striving towards the following ends:

(1) The compilation of all reliable data of physical chemistry in convenient form for reference, distinguishing those determined directly from those calculated indirectly.

(2) The calculation of empirical formulæ, to combine any series of data, when some better form of generalisation is not already at hand.

(3) The preparation and use of rational formulæ, wherever possible, to deduce the natural constants from series of observations, and to express the conditions that may be expected to hold between observations of different kinds.

(4) The organisation of a band of volunteer compilers and computers from among advanced students, who (with the counsel and aid of their instructors) may assist in the work of compiling data and computing formulæ.

While the time did not seem ripe for the appointment of such Committee at the late meeting of the A. A. A. S., the writer would be pleased to receive any further suggestions from those interested, regarding the points noted above.

ROBT. B. WARDER.

[1] *Trans.* Conn. Acad., 3, 108, 343 (1874-78). See also, *Amer. Jour. Sci.* [3] 16, 441 (1877); 18, 277 (1878).

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—At the 160th meeting of the Junior Scientific Club, held on Wednesday, November 17, the following officers for next Term were elected:—President, E. C. Atkinson; permanent treasurer, D. H. Nagel; treasurer, N. V. Sidgwick; biological secretary, R. Warren; chemical secretary, H. P. Stevens; editor, A. W. Brown; committee, R. A. Baddicom, M. Hesketh, T. J. Garstang. It was announced that Prof. W. Ramsay had consented to deliver the fifth Robert Boyle Lecture in the Summer Term, 1896.

CAMBRIDGE.—The late Mr. James Carter has bequeathed his collection of fossil Crustacea, on which he was a recognised authority, to the Woodwardian Museum. A portrait of the late

T. Sterry Hunt, Hon. LL.D. of the University, has been presented to the same Museum by Mr. Douglas, of New York.

The Walsingham Medal, given annually by the Lord High Steward for an essay on a biological subject, has been awarded to Mr. I. L. Tuckett, Fellow of Trinity College. Essays for the next award are to be sent in to Prof. Newton, by October 10, 1896.

Dr. Joseph Griffiths has been appointed an Examiner in Surgery.

The Special Board for Medicine propose a new scheme for the degree of Master in Surgery, whereby the degree will be open to M.A.s and B.C.s who have made contributions of sufficient merit to the advancement of the science or art of surgery.

Prof. J. G. McKendrick, F.R.S., has been appointed an Elector to the Chair of Physiology, in the place of the late Prof. Huxley.

A grant of £50 has been made by the State Medicine Syndicate to the Department of Pathology, in aid of the course of bacteriology there given.

The Agricultural Science Syndicate report an increase in the number of candidates for the University's diploma in agriculture. All of the candidates at the recent examination were trained in Cambridge, and one of them obtained the silver medal of the Royal Agricultural Society. Seventeen students, all of them members of the University, are now attending the courses provided in the sciences bearing on agriculture. The fees for the examination are not yet sufficient to meet the expenses.

THE Calendar (1894-95) of the Imperial University of Japan, which has come to hand from Tokyo, should be seen by all who desire to know something about the history of that University, and the work that is being done. The number of professorial chairs in the several Colleges appears surprisingly large to those who are not familiar with the character of the University. There are twenty-three chairs attached to the College of Medicine, twenty-one to the College of Engineering, seventeen to the College of Science, and twenty to the College of Agriculture, not to mention those in the Colleges of Law and Literature. From each of the Colleges valuable memoirs on special researches have been issued, and the University seems to be carrying out the objects of its founders, viz., "the teaching of such arts and sciences as are required for the purposes of the State, and the prosecution of original investigations in such arts and sciences."

MR. WILLIAM TATE, of the Royal College of Science, South Kensington, has been appointed Professor of Chemistry at the Civil Engineering College, Sibpur, Calcutta.

PROF. R. A. SAMPSON has been appointed to the chair of Mathematics in Durham University, vacated by the resignation of the Rev. R. J. Pearce.

THE parts of the University of Virginia destroyed by fire are being rebuilt. *Science* states that reconstruction of the Rotunda, the central building of the group recently destroyed, has already been begun. The necessary money to do this, about £16,000, has been practically subscribed. It is proposed to build a general academical building costing £18,000, a physical laboratory costing £6000, a building for mechanics and engineering costing £6000, and a building for the law school costing £4000. Governor O'Ferrall has promised to recommend in his message to the State Legislature a prompt and liberal appropriation to repair the losses of the school, and it is hoped that £40,000 will be received from this source. Appeals are being made to friends of the University and of education to contribute to the rebuilding and enlargement of the University.

The annual meeting of the National Association for the Promotion of Technical and Secondary Education was held on Tuesday, the Duke of Devonshire being in the chair. After the eighth annual report of the Association, presented by Sir Henry Roscoe, had been adopted, the Duke of Devonshire opened a conference of representatives of technical education committees of county and borough Councils. The subjects discussed were evening continuation schools, the award and tenure of scholarships, and trade and technical classes.

SOCIETIES AND ACADEMIES.

LONDON.

Institution of Civil Engineers, December 3.—Sir Benjamin Baker, K.C.M.G., President, in the chair.—The Influence of Carbon on Iron, by Mr. John Oliver Arnold. This paper embodied the results of researches undertaken by the author primarily to determine whether, at high temperatures, the carbon still remained in combination with the iron. A series of eight 3-inch square crucible-steel ingots, ranging in carbon between 0·08 per cent. and 1·47 per cent., the total impurities other than carbon averaging 0·2 per cent., were hammered and rolled to $1\frac{1}{16}$ inch diameter. They were then submitted to chemical, mechanical, microscopical, thermal, and magnetic tests, in three standard physical conditions, namely: normal, or cooled in air; annealed, or very slowly cooled; and hardened, or very rapidly cooled. The differential analyses for carbon confirmed the conclusion arrrived at by the author in a previous research, that the hard plates of Sorby's laminæ consisted of pure crystallised Fe_3C; and under certain conditions contained practically the whole of the carbon present in the steel. The mechanical tests showed that in normal steels the tenacity increased with carbon up to 1·2 per cent., a further addition of carbon causing a diminution in the stress. The ductility of normal steel diminished with the carbon; the elongation with 0·1 per cent. of carbon being 47 per cent., and at 1·5 per cent. 3 per cent. on 2 inches. Under compression the softness of normal steel decreased with the carbon until 0·9 per cent. of that element was present. Annealed steels under compression indicated a maximum hardness at 0·9 per cent., and were distinct softer than the normal metals. Steel with 1·5 per cent. of carbon was softer than iron containing 0·1 per cent. In hardened steels the rigidity of the metals increased enormously as the carbon rose. The microscopical investigation showed that pure iron consisted of cubic and octahedral crystals. The general results of the microscopical examination sustained the theory that the hardness of quenched steel was due not to a hard allotropic modification of iron, but to a definite sub-carbide corresponding to the formula $Fe_{24}C$. The magnetic observations on hardened steels had led the author to the conclusions that (1) the magnetic permeability varied inversely as the carbon present; (2) the permanent magnetism was directly proportional to the carbides of iron present; and (3) in iron containing between 0·1 per cent. and 0·9 per cent. of carbon the permanent magnetism was directly proportional to the sub-carbide of iron present. The author based the existence of a sub-carbide of iron, possessing the formula $Fe_{24}C$, to which the phenomena of hardening and tempering were due, on the following experimental facts: (1) the well-marked saturation points in the micro-structure of normal, annealed, and hardened steels; (2) a sharp maximum in a curve, the co-ordinates of which were heat evolved or absorbed at the carbon change point, Ar. 1, and the carbon percentage; (3) a point in the compression curve of hardened steels at which molecular flow ceased; and (4) a sharp maximum in a curve, the co-ordinates of which were the carbon percentage and permanent magnetism in hardened steels.—The Dilatation, Annealing, and Welding of Iron and Steel, by Mr. Thomas Wrightson. This paper dealt with investigations of some of the physical changes which occurred in iron during its passage from the homogeneous molten state to the solid and more permanent condition. With regard to the alleged floating of solid iron upon molten iron of the same kind, the author had found that if the piece of solid iron was lowered into the liquid metal by means of an iron fork, it always descended with the fork, but in a few seconds left the prongs and floated to the surface. For some time the sphere continued to rise above the surface until, at such a temperature that it melted, it quickly joined the molten metal. On first sinking the ball proved itself to be denser than the liquid iron. It then expanded and became considerably less dense than the liquid; and lastly, a reversal took place and the ball in melting became of the same density as the liquid. The assumption that dilatation was continuous and uniform during the passage from the liquid to the solid state was therefore erroneous. In order to eliminate the errors due to the emergence of the floating body above the surface of the molten metal, the author used for subsequent experiments an instrument by which the specific gravity of a 4-inch cast-iron ball, completely submerged in the metal, could be observed and continuously recorded. A specimen of the record obtained from the apparatus was given. Experiments upon grey Cleveland iron showed that the specific gravities of the cold solid iron, molten iron, and of plastic iron, were 6·95, 6·88, and 6·50 respectively; and that in passing from the solid to the plastic condition, the iron underwent an increase of volume of 6·92 per cent., followed by a quick contraction as it became liquid. The order of experiment was afterwards reversed, and the change of volume was measured as the molten iron solidified. Into two spherical moulds of dried