By comparison with the first equation we see that RT/F is equal to D, the diffusion constant. This constant can be measured experimentally, and for such a substance as sugar or water comes out about 0∙3 at 20° C., the unit of time being the day. Hence the force required to drive one gramme-molecule of sugar through water with a velocity of one centimetre per second may be calculated as some thousands of millions of kilogrammes weight.

In the case of electrolytes we can go further, and calculate the diffusion constant itself from the theory of electrolytic dissociation (see Conduction, Electric, § *In Liquids).* On that theory’ the ions of a dilute solution migrate independently of each other. Since some ions are more mobile than others, a separation will ensue when water is placed in contact with a solution, the faster moving ion penetrating quicker into the water under the driving force of the osmotic pressure gradient. This separation causes a difference of potential, which can be calculated and is found to agree with the values obtained experimentally. The separation also sets up electro­static forces, which increase until they are strong enough to drag the slower moving ions along faster, and to retard the naturally faster ions till they travel at the same rate. The resistance offered by the liquid, and therefore the force F, required to drive one gramme­molecule through the liquid with unit velocity is the sum of the corresponding quantities for the individual ions. Now the veloci­ties *u* and *v* of the opposite ions under unit potential gradient, and therefore U and V under unit force, are known from electrical data. Thus F, which is equal to ι∕U÷ι∕V, is known. The osmotic pressure of an electrolyte consisting of two ions is double that of a non-electrolyte. Hence for a binary electrolyte the diffusion constant is measured by 2RT∕F or 2UVRT∕(U+V). This result gives a value of D for dilute hydrochloric acid equal to 2∙49 to compare with the observed value of 2∙30. Other substances give equally good agreements; thus sodium chloride has a calculated constant of 1∙12 and an observed one of 1∙11. Such concordance gives strong support to the theory of diffusion outlined above.

*Colloidal Solutions.—*Besides a large number of animal and vegetable substances, many precipitates formed in the course of inorganic chemical reactions are non-crystalline and appear in the colloidal state, instances are the sulphides of antimony and arsenic and the hydroxides of iron and alumina. Some of these colloids dissolve in water or other liquids to form solutions called by Graham *hydrosols;* Graham named the solids formed by the setting or coagulation of these liquids *hydrogels.* Solutions of colloids in solvents such as water and alcohol seem to be divisible into two classes. Both mix with warm water in all proportions, and will solidify in certain conditions. One class, represented by gelatin, will redissolve on warming or diluting, while the other class, containing such substances as silica, albumen, and metallic, hydrosulphides, will solidify on heating or on the addition of electrolytes to form a solid “ gel ” which cannot be redissolved. Solidification of the first kind may be termed “ setting,” that of the second “ coagulation."

The power of coagulation of colloids shown by electrolytes depends in a curious manner on the chemical valency of the effective ion. The average of the coagulative powers of salts of univalent, divalent and trivalent metals have been found by experiment to be proportional to the numbers 1:35:1023. If we assume that a certain minimum electric charge must be brought into contact with a group of colloid particles to produce coagu­lation, twice as many univalent ions must collect to produce the same effect as a number of divalent ions, and three times as many as an effective number of trivalent ions. We can calculate, by the help of the kinetic theory and the theory of chances, the fre­quency with which the necessary conjunctions of ions will occur, and show that the general law will be that the coagulative powers should be in the ratios of 1 : x : x2. Putting x=32, we get I : 32 : 1024 to compare with the experimental numbers. The ordinary surface energy of a two-phase system tends to diminish the area of contact, and thus to help the growth of the larger aggregates required for coagulation. A natural electric charge on the particles would oppose this tendency, and tend to increase the free surface and thus promote disintegration and solution. The function of the electrolyte may be to annul such a natural charge and thus allow the non-electric surface energy to produce coagulation. This explanation is supported by some experiments by W. B. Hardy, who found that certain colloids did possess electric charges, the sign of which depended on whether the sur­rounding liquid was slightly acid or slightly alkaline. At the neutral point, when the particles possessed no charge, their stability was destroyed, and they were precipitated. But recent experiments have shown that the simple theory of coagulation here outlined needs amplification in certain directions. The phenomena seem to be dependent on variables such as time, and are more complicated than seemed likely at first.

The size of the suspended particles in colloidal solutions varies greatly. In some solutions they are visible under a good microscope. In other cases, while too small to be directly visible, they are large enough to scatter and polarize a beam of light. In yet other solutions, the particles are smaller again, and seem to approach in size the larger molecules of crystalloid substances. It is not yet agreed whether colloid solution is the same in kind though different in degree from crystalloid solution or is a phenomenon of an entirely different order.

References.—The properties and theory of solutions are treated in all works on general physical chemistry; Ostwald’s discussion in his *Lehrbuch* was translated into English in 1891 by Μ. Μ. P. Muir entitled *Solution.* Special works are W. C. D. Whetham, *Theory of Solution* (1902); W. Rothmund, *Löslichkeit* (1907). Solubility tables are given in Landolt, Börnstein and Meyerhoffers, *Tabellen* (1905); A. Μ. Comey, *Dictionary of Solubilities (Inorganic)* (1896); A. Seidell, *Dictionary of the Solubilities of Inorganic and Organic Substances* (1907). (W. C. D. W.)

**SOLUTRIAN EPOCH,** in archaeology, the name given by G. deMortillet to the second stage of his system of cave-chronology, and that synchronous with the third division of the Quaternary period. It is so called from the Solutré Cave, Maçon district, Sâone-et-Loire. The period is characterized by two series of chipped flints, one modelled on the laurel-leaf, the other on that of the willow. Those of the first series are artistically chipped upon the two faces and the end, and are readily distinguishable from the flints of the preceding Mousterian epoch. Large thin spear-heads; scrapers with edge not on the side but on the end; flint knives and saws, but all still chipped, not ground or polished; long spear-points, with tang and shoulder on one side only, are also characteristic implements of this epoch. Bone or horn, too, was used. The Solutrian work exhibits a transitory stage of art between the flint implements of the Mousterian and the bone implements of the Madelenian epochs. The fauna includes the horse, reindeer, mammoth, cave lion, rhinoceros, bear and urus. Solutrian “ finds ” have been also made in the caves of Les Eyzies and Laugerie Haute, and in the Lower Beds of Cresswell Cave (Derbyshire).

**SOLWAY FIRTH,** an estuarine inlet of the Irish Sea, between England and Scotland. If its mouth be taken as between St Bee’s Head on the English and Burrow Head on the Scottish coast, its length is 50 m. The breadth at the mouth is 32 m.; near the head, where the Solway viaduct of the Caledonian rail­way crosses the firth, it is nearly 1½ m. The general direction is north-easterly from the mouth. The Scottish counties bordering the firth are Wigtownshire, Kirkcudbright and Dumfriesshire; the English coast belongs to Cumberland. On the English side the low Solway Plain borders the firth, except for a short distance above St Bees Head. The Scottish shore, however, is not continuously flat, and such elevations as Criffell (1866 ft.), Bengairn (1250) and Cairnharrow (1497), above Wigtown Bay, rise close to it. The shore line is broken on both sides by the estuaries of several rivers. Thus in Scotland the Cree and other streams enter Wigtown Bay; the Dee, Kirk­cudbright Bay; Auchencairn Bay and Rough Firth receive numerous small streams, and the Ñith discharges through a long estuary. The Annan has its mouth near the town of that name; and the Esk and Eden at the head of the firth, in Cumberland. On this shore Morecambe Bay receives the Wampool and Waver from the plain, the Ellen has its mouth at Maryport, and the Derwent from the Lake District at Workington. The waters of the firth are shallow, and a tidal bore occurs periodically. The fisheries are extensive, and though there are no ports of the first magnitude on the firth, a considerable shipping trade is carried on at Whitehaven, Harrington, Workington, Maryport and Silloth in Cumberland, and at Annan, Kirkcudbright, Creetown and Wigtown on the Scottish side.