2d. Non-metallic elements present in a metallic mass may change their relation to the metallic atoms; and

3d. The *atoms* in the *molecule* of a solid metal or alloy may be redistributed or rearranged, and this is called *polymerization.*

These molecular changes are almost always accompanied by the evolution or absorption of heat, and can, therefore, be studied by the aid of thermal measurement.

The photographic records have thrown much light on all these cases of molecular change, but for the purpose of minute investigation, another mode of experimenting may be adopted.

Suppose that the spot of light from the galvanometer (Figs. 6 or 7), with which the thermo-couple is connected, does not fall through a slit on to a sensitized plate, but on to a screen placed at some distance from the galvanometer. This screen may be forty feet long, and may be suitably divided into degrees. The room must, of course, be darkened, so that the spot of light may be readily visible. The screen is fixed, and, therefore, the spot of light will traverse it horizontally, and the freezing of a metallic mass would simply be indicated by a more or less prolonged arrest of the spot of light during the solidification of the metal. Suppose, however, that it is not a question of studying the behavior of a freezing metal, but of one which, though it may be strongly heated, is still solid. Take, for instance, the case of a piece of steel of somewhat low carburization which is being slowly cooled. Here the molecular behavior is very complicated. M. Osmond and myself, and, recently, other experimenters, have studied this behavior minutely. There will be at least two arrest points, and probably three, as the pieces of steel cool from bright redness. One of these will occur at a temperature which varies slightly, but is somewhere close to 650° C., and is caused by a change in the relations between the carbon and the iron. An ordinary photographic record obtained on a plate about ten by six inches would simply show a bend in the curve of about the form and amplitude shown in the sketch (Fig. 12). If, however, it is wished to

FIG. 12.

study this particular change more fully, the following plan may be adopted: Assume that, in indicating temperatures up to a white heat, the path of the spot of light along the screen is some forty feet, then it is easy so to arrange the experiment that the spot of light may be received (at the critical part of its path which it is desired to study) on a second but smaller screen, say four feet square, which may be moved upward at a slow but uniform rate of, say, an inch a second. The spot of light from the galvanometer may be divided by the images of cross wires, and, as the point of intersection of these wires is clearly visible on the moving screen, its position at any given moment may be recorded, by hand, with a pencil mark. The result is, that the portion of the cooling curve which represents the "recalescence" of iron, instead of being a small sinuous line, shown in Fig. 12, becomes a loop four feet across, of the form shown in Fig. 13. The

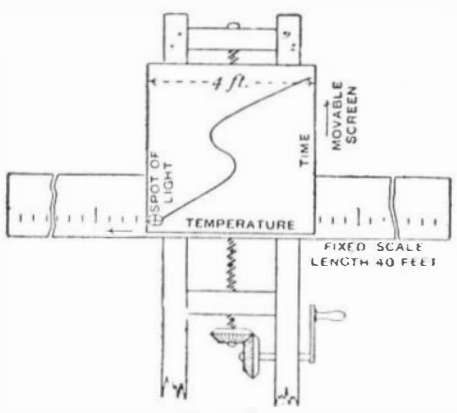

FIG. 13.

same degree of magnification may be applied at any period during the cooling of the steel, and it enables the molecular change in the iron which occurs at 855°, that is at a higher temperature than recalescence, to be submitted to a very rigorous investigation. For the purposes of lecture demonstration, it is only necessary to fix a screen of paper on a light frame, and place it like a canvas on an artist's easel, which is provided with a vertical screw for elevating the screen, but it will be evident that for purposes of delicate research some method of uniformly moving the screen could readily be devised.

It is now possible to study the behavior of alloys at high temperatures and to obtain photographic records of the molecular changes by the aid of a simple and trustworthy appliance, which is considered to afford "incontestable" results by so distinguished a pioneer in molecular research as M. Raoult.

THE PURIFICATION OF WATER BY PRECIPITATION AND SEDIMENTATION.

By Dr. PERCY FRANKLAND, F.R.S.

IN an interesting article on "Recent Improvements in the Manufacture of Aerated Waters," published in *Industries and Iron* on the 27th October last, reference is made to some experiments which I made some years ago* on the remarkable bacterial purification which may be procured by agitating a water with certain substances in a fine state of division, and allowing subsidence to take place. In this manner I found for the first time that bacteria are carried down together with the coarser suspended particles in the water. The substances I used were spongy iron, chalk, animal charcoal, vegetable charcoal, coke and other materials, the coke being especially effective, for after agitating the water for fifteen minutes with one-fiftieth of its weight of this material in a finely divided condition and allowing it to subside for forty-eight hours, the supernatant water was on one occasion absolutely sterile or did not contain a single organism.

It may interest your readers to know that I have quite recently been examining the processes and value of sedimentation, as it takes place on the large scale in waterworks reservoirs, used for the storage of more or less turbid water before submitting it to sand filtration. As these are so far the only experiments which have been made on the large or practical scale, they are of especial interest in bearing out the results which I obtained previously on a small scale in the laboratory.

The object of these reservoirs is, as every one knows, to enable some of the coarser particles in suspension to subside before running the water onto the several filter beds, so that the latter may be taxed with the minimum amount of suspended matter. Although such reservoirs have been constructed without any view to the bacterial purification of the water, this actually takes place to a very remarkable extent, as the following investigations carried out at the works of the London Water Companies show very clearly. Thus, in the first instance, the water in a large cemented reservoir belonging to the Grand Junction Company was examined. The water in this reservoir had been obtained from the Thames at Hampton, and the greater part of it had been stored for six months. Now, I have repeatedly shown in the course of the periodical examinations which I made of the London water supply for the Local Government Board, that this raw, untreated water contains sometimes as many as 92,000 bacteria in one c. c. of water, while the smallest number I have ever found is over 1,000. This reservoir water taken from two different ends of the basin contained, however, only 464 and 368 micro-organisms per c. c., showing that a most remarkable bacterial purification had taken place during the storage of this water.

The value of this process of sedimentation was even more strikingly brought out by the following investigations made at the West Middlesex and New River Companies' works respectively. The Thames water is run successively into two reservoirs at the West Middlesex works, where it remains for some time before being run onto the filter beds. The raw river water running into the reservoir on this occasion contained 1,437 bacteria per c. c.; in the water running out of this reservoir only 318 were found, while after passing through the second reservoir only 177 were present. In the case of the New River Company's water I obtained equally striking results, for, while this water (a mixture of river with spring and deep well water) contained 677 as running into the first reservoir, in that flowing out of this reservoir 560 were present, while after remaining in the second reservoir only 183 micro-organisms were found per c. c.

The hygienic importance of these results is obvious, for, should pathogenic bacteria be present at any time in the raw, untreated water, while some diminution in their numbers will take place already in the course of a river's flow, on collecting the water in these reservoirs there is additional opportunity afforded for their removal by the natural processes of sedimentation which I have shown take place to such a remarkable extent.

It is, therefore, of great importance that in the purification of all water for hygienic purposes the maximum amount of sedimentation should be allowed to take place before the processes of sand filtration or other methods of purification are resorted to.—*Industries.*

PLANT CHEMISTRY AND BACTERIOLOGY.

By HENRY WURTZ, Ph.D.

AMONG the many wondrous chemical laboratories in which Dame Nature employs herself without ceasing, those which occupy the cells of plants are in a high degree the most mysterious, inscrutable and astonishing in the results they present to us. Although some few animals secrete or excrete materials of peculiar and exceptional characters and qualities, yet the great majority of their products are very closely similar, in the main, in composition and character, when from animals under normal conditions. Their principal plastic constituents also are usually much the same. But in the vegetable kingdom we find that almost every family has its peculiar and characteristic product or products, found often in no other. Moreover, ordinary plants deal with the simplest compounds of the chemical elements of matter, and are constantly occupied in building up from these more elaborate compounds of the greatest variety and complexity, endowed with potential chemical energies great in amount and variety. These the animal, under normal conditions, is continually occupied in consuming and destroying, and reducing back again to the simplest compounds, which the plant immediately proceeds again to build up into complexity, and endow with energy, for the animal again to use up. The plant is always building beauteous structures, temples and palaces of molecules, merely that the animal may destroy and tumble them into ruins again. The plant process is one of deoxidation or decombustion, while the animal process is always one of oxidation or combustion. The plant, however, does not accomplish this decombustion and accumulation of potential energy in the products thereof, by virtue of any inherent power of its own. Plant life, in some wondrous way, directs, controls, and condenses the energies brought by the heat rays and chemical rays from the sun. With some strange exceptions, of which further on, the plant races are children of the sun.

The present writer wrote as follows on this subject in 1877: "Within the leaf of the plant resides the inscrutable vital influence which is able, with the assistance of the heat of the solar ray, to set up the most mysterious of chemical laboratories, wherein such substances as cellulose and starch (and though these sugars), with still more complex proteid bodies, are elaborated from the simple compounds, carbonic acid and water. Generations may pass away at the present rate of progress of chemical investigation before any real insight will be gained into the chemistry of the plant leaf."*

Nevertheless, the writer was not optimistic enough here. But a few years subsequent to this date, an important insight was actually gained into the way in which these plastic constituents of plants are chemically built up in the leaf cells. A German chemist, Baeyer, discovered that the process consists of two successive steps: *First*, and essentially, in the formation in the leaf, from the moisture and carbon dioxide of the air, of the compound *oxymethylene*, CH_2O, also called *formic aldehyde.* This is accomplished by the operation above referred to, simply by the deoxidation (or dissociation by the energy of the solar rays of the carbon and oxygen) of the carbon dioxide, commonly, but inaccurately, called "carbonic acid," of the atmosphere, under the influence of this mysterious vital influence of the plant.

The latter is thus able to transfer the energy of the sun rays to the carbon of the oxymethylene—which comes from the decomposed carbon dioxide—in the form of chemical potential energy, which would be given out again if the oxymethylene were set on fire and burned. The chemical equation of this primary transformation is thus:

$$H_2O + CO_2 = CH_2O + O_2;$$

free oxygen passing into the atmosphere, as we know is constantly the case, from the growing leaf. It will be seen that the other product besides the free oxygen, that is, oxymethylene, may be looked upon as virtually a compound of carbon and water, H_2O. As it is a gaseous body, which is largely soluble in water, such a solution may be looked upon as in effect a solution of carbon in water. This body, oxymethylene, considered to be formic aldehyde, thus continually being formed in the plant leaf by a natural process, may be produced artificially by passing a mixture of vapor of wood alcohol and air over a red hot helix of copper or platinum wire contained in a glass tube. Such helix may be heated by an electric current.

Second.—Like other aldehydes (with many other organic bodies) this formic aldehyde has a fashion of forming *polymeres*, so called. In this case, just as with common or acetic aldehyde, three molecules combine together into one, thus:

$$3(CH_2O) = C_3H_6O_3.$$

This triplicated molecule constituting now a *solid* body instead of a gas. Such solidification of the gaseous compound takes place spontaneously in a concentrated watery solution. Now it happens (or rather results, for nothing can be rightly said to *happen* in chemical transformations, all being subject to fixed laws) that by carrying this polymerization twice as far as above, which the leaf knows how to do, though we cannot yet do it, there results $C_6H_{12}O_6$, which is *glucose*, or fruit sugar. Then by separating from this a molecule of water, H_2O we get $C_6H_{10}O_5$, which is *starch.* By a second doubling up of glucose, and taking out a molecule of water, we get $C_{12}H_{22}O_{11}$, which is *cane sugar.* By taking out another molecule of water, we get $C_{12}H_{20}O_{10}$, which is *cellulose*, the main component of wood and of all plants. It may be observed that in all these cases the resulting polymere may still be regarded as a compound of carbon and water, and the energy that has come from the sun is locked up solely in the carbon atoms, which all come from the carbon dioxide gas of the air. There is no more beautiful development of chemical science than the one we have here been following up.

It is desirable here to emphasize the fact that these are developments mainly of *chemical* science. The botanists, biologists, and microscopists have, until of late, had the great fields of investigation of plant structure, with the transformations and metamorphoses that proceed in plant cells, almost wholly to themselves. The time has fully come, however, when chemistry must step in, and do what man has been endowed with the power to do, namely, to subdue this kingdom of nature. The laboratory and the microscope have indeed already begun to co-operate in earnest, and will jointly achieve discoveries which neither alone could hope to approach. At last summer's meeting of the British Association for the Advancement of Science, several papers were read by chemists of distinction relative to this subject. So many facts of interest and importance demonstrative of the necessity of applying chemical knowledge and laboratory methods to the study of microscopic and microbic vegetation, and their relations to health and disease, to life and death, that a strong impression was produced. The project was started and urged of the immediate "establishment of an institute for research where chemists, biologists and pathologists could mutually assist one another."

The work of the microscope, which has laid the foundation for the great structure of plant chemistry that is now soon to arise, has not been confined merely to the morphology, or study of the forms and minute structure, of such plants as we see around us, without microscopic aid—or rather only with that conferred on us by the Creator—the microscope and telescope combined, which gives us our limited *natural* insight into his illimitable creation. The microscope has further developed to us the existence of generations of plants, whose number baffles human speech to convey and the human mind to conceive, and whose importance to the present welfare and future destiny of the human race is greater than that of any other agency in the scheme of nature. These are the so-called bacteria.

At this last meeting referred to of the British Association, the eminent chemist, Frankland, stated that microscopic manipulations and methods had largely failed in the fundamental matter of recognition and identification, with the needed certainty, of some of the more important forms of bacterian life. This, even when aided by the chemical method, now in universal use, of staining the internal structure of these organisms by soaking them with brilliant dyes. Even in the case of the cholera bacillus or spirillum he said that as much difference had been found "between different specimens as between this spirillum and totally different species."

* "The Removal of Micro-organisms from Water." *Proc.* Roy. Soc., 1885. *Transactions* Institution Civil Engineers, 1886.

* "Johnson's Universal Cyclopedia," vol. 4, p. 1117. Under "Chemistry of the Vegetative Process."

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