

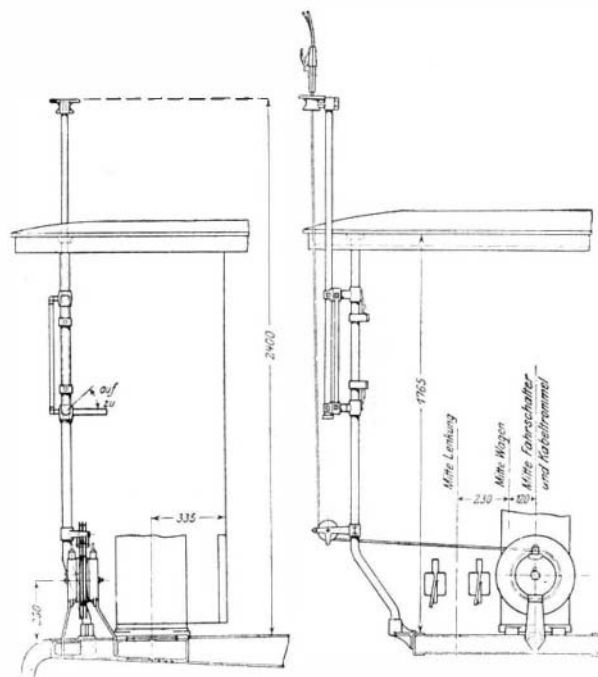
selves automatically to the overhead conductor, irrespective of the car's movements. The pole itself forms one of the current conductors, the other conductor pressing within the pole. In the Drammen road the distance between the overhead wires is only 150 millimeters instead of 350 as in Figs. 11 to 14. This current collector is described in German patent 220,174, and has for its chief object to enable simple automatic overhead switches to be built into the overhead line, without using any links or crossings. Furthermore, this construction insures the proper supply of current even if the car has to travel as much as 3 meters to one side of the overhead wires.

Trackless electric roads are intended only for moderate traffic, and for this reason the overhead wires form generally a single track. If two cars traveling in opposite directions on the same wires should meet, one of them will proceed undisturbed, the other must turn out and pull down its current collector while passing. The pole can be drawn down by the motorman from his stand. It is not necessary to stop the car while it is disconnected from the overhead wire, but it may be allowed to roll on by its momentum.

The total length of the eleven lines constructed and now in operation according to this system, for the conveyance of passengers and freight, is 45½ kilometers (about 28¼ miles), and the total number of motor cars and locomotives is 28.

The Stoll type of trackless electric roads owes its recent development, as stated above, to the use of wheel hub motors for heavy automobiles, particularly motor omnibuses, the cars of such roads (Fig. 15) being almost identical with such omnibuses. Even the trucks and lower frame are similar to those of motor omnibuses, being made of pressed sheet metal; with the motors, controllers and other electrical appliances (but without the superstructure) this frame

weighs but 1.7 tons. The motors are of the well-known Mercedes Electric construction. Figs. 19 and 20 illustrate in cross-section and in side elevation respect-



FIGS. 26 AND 27.—CONNECTION OF CABLE WITH CAR.

ively, a 20 horse-power motor for the rear axle, this motor being built into a wheel having a solid rubber tire, current being supplied through the hollow axle.

The motors, however, may also be built into the steering wheels, in which case the steering knuckle will be approximately in the plane of the wheel. For very steep mountain roads cars have been constructed with four driving wheels, Fig. 21. When traveling down hill, such cars may be braked electrically at each of the four wheels, thus avoiding a jamming of the wheels.

The car bodies are made with side entrances as a rule, the motorman acting as conductor also, and will hold 22 passengers. The total weight of the empty car is 2.5 tons.

The current collector, Figs. 22 to 25, consists of a four-wheel carriage (with ball-bearings) traveling on the bipolar overhead conductor and connected with the motor car by a flexible double cable from 10 to 12 meters long. The stability of this carriage is increased by suspending from it, by means of a long rod, a spring reel, the wire or rope of which draws the cable into a loop and takes up the pull exerted by the car so that this pull will not come on the portion of the cable which is secured to the carriage.

On the car the cable is connected by means of a removable plug switch, with a cable about 10 to 12 meters long, Figs. 26 and 27, which is kept taut by a special spring drum. The motorman is thus enabled to use practically the full width of the road irrespective of the position of the overhead wires. Furthermore, this detachable connection enables cars traveling in opposite directions, to pass each other readily, the motormen simply exchanging the plugs and current collectors, and then proceeding on their way.

Trackless roads of this type have been put in operation during the last two years upon eight lines having a total length of 23 kilometers (about 14.3 miles) and an equipment of 26 motor cars.—*Zeitschrift des Vereins Deutscher Ingenieure*.

# THE STUDY OF SOLUTIONS.\*

## PAST THEORIES AND FUTURE RESEARCH.

BY DR. LOUIS KAHLBERG.

SOLUTIONS have been known since earliest times, and the problems which they represent have been studied by a long line of very able investigators. All of the early work on solutions has been inseparably linked with the study of chemical phenomena. Indeed, up to the year 1887 chemical views of solutions have predominated. So for example, in his lectures delivered at Yale College in 1837, Benjamin Silliman, Sr., considered solutions as chemical compounds; and in his memorable work on theoretical chemistry which appeared in 1863, Hermann Kopp treated solutions as chemical compounds that exhibit variable proportions, which mode of treatment was retained by A. Horstmann when in 1883 he wrote the second volume of the new edition of Kopp's work, now known as *Graham-Otto's "Lehrbuch der physikalischen und theoretischen Chemie."* Ever since the days of Lavoisier, when the so-called law of definite proportions was first recognized, a distinction has been drawn between compounds which follow that law and combinations that do not. Chemical combinations which exhibit definite qualitative and quantitative composition that cannot be varied gradually by small increments arbitrarily chosen were soon termed definite chemical compounds, whereas solutions, whose composition may be varied gradually, quite arbitrarily—at least within certain limits—were regarded as indefinite chemical compounds, or compounds according to variable proportions. So Robert Bunsen used to teach that we may have compounds according to definite proportions and also compounds according to variable proportions, the latter compounds being the group known as solutions.

The careful quantitative investigation of solutions really dates from the time of Lavoisier, who, as is well known, introduced the balance into the chemical laboratory. Before this the observations made were generally only qualitative in character; at any rate they were often crude and faulty. The very fact that solutions were regarded as chemical compounds led to their study by much the same methods adopted for the investigation of definite chemical compounds, i. e., chemical compounds in the narrower sense in which the term is at present commonly used. So the qualitative composition and the quantitative composition of solutions were carefully studied. The density, the color, the boiling point, the specific heat, the optical activity, the thermal accompaniment of the formation of solutions and of their reactions with other substances, as well as their other physical, chemical and physiological properties, were studied in much the

same way that these various properties were determined for definite chemical compounds. And yet, the fact that the composition of solutions may be varied gradually and arbitrarily within certain limits and that this cannot be done in the case of definite chemical compounds, has for nearly a whole century been considered to be the vital difference between a solution and a definite chemical compound, and this is quite proper.

To obtain a definite chemical compound in the pure state usually requires a considerable amount of work. The usual operations of purification as in vogue at present are crystallization, solution and precipitation, sublimation and distillation. By means of the so-called purification process a product is finally obtained whose composition does not change further, though the substance be subjected to further similar treatment. As F. Wald states it, a chemical compound is a phase whose composition remains constant though temperature, pressure and contact with other phases be varied within certain limits inside of which the substance in question is stable. In a sense then the so-called definite chemical compounds are really obtained in certain cases as the more resistant cleavage pieces resulting when the purification processes are applied. That the latter processes after all frequently represent rather violent treatment will probably not be gainsaid by any one.

The law of definite proportions was considered by Ostwald in his Faraday lecture, which in turn was discussed by others, among whom Benedicks voiced the sentiment that after all when closely scrutinized it becomes evident that there is an arbitrary element in judging as to when we really have a pure, definite compound before us, and that the matter of definite proportions is to some extent one of definition. As to the law of multiple proportions, this has been directly challenged by P. Duhem as a tenet that can neither be proved nor disproved, though I must frankly confess my inability to agree completely with him in his argument.

The year 1887 is noteworthy, for it brought both the van't Hoff theory of dilute solutions and the theory of electrolytic dissociation of Arrhenius. These theories really supplement each other, as is well known. They may well be called physical theories of solutions as distinct from the chemical views of solutions already mentioned. It is quite unnecessary to rehearse here the great activity that has resulted in the study of dilute solutions during the last two decades as a direct consequence of the theories of van't Hoff and Arrhenius. The pages of the history of chem-

istry that record this experimental work on dilute solutions will ever maintain their brilliant luster, for they reflect the enthusiastic efforts of scores of active young hands and minds that were urged on by a most inspiring leader, an able teacher and experimenter, and a most lovable man—Wilhelm Ostwald. Without him the theories of van't Hoff and Arrhenius would scarcely have gained a foothold.

But excellent as were many of the experimental acquisitions that were thus obtained as a result of these working hypotheses, time has shown that the latter have long since served their purpose, and that mere physical conceptions of solutions are untenable as an explanation of the phenomena actually observed. Furthermore, a theory which applies merely to very dilute solutions, and then only in an imperfect way, is quite untenable in the long run, even as a working hypothesis. It is not my purpose to enter upon a discussion of the numerous experimental researches which have made the theories of van't Hoff and Arrhenius untenable. These investigations have been published at various times during the last decade, and I have dwelt upon them in detail on previous occasions. It is quite safe to assume that they are sufficiently well known to all. Moreover, I frankly confess that I am glad to escape the task of recounting again the weaknesses of these views of solutions as exhibited by experimental facts, for in my younger days I was quite enthused with these hypotheses, and it was to me a great disappointment to find later that they were contradicted by so many experimental truths. It is rather my purpose to point out the direction in which experimental investigations made thus far have led us, and to attempt to indicate the line of attack which must be followed to insure success in the future, so far as this can at present be foreseen.

The data collected since 1887 in studying the various properties of solutions, though frequently gathered with the aid of the physical hypotheses already named, have nevertheless gradually and unerringly demonstrated that the chemical view of solutions is far nearer to the truth, than is the idea that a solution is a mere physical mixture. In this connection permit me to call attention to a few experimental illustrations.

When antimony trichloride and camphor are brought together the two solids liquefy each other, forming a thick syrupy solution, the proportions of the two ingredients of which may be varied within certain limits. Antimony trichloride and chloral hydrate similarly liquefy each other, though less readily. Again, camphor and chloral hydrate when in intimate contact with each other form a liquid. If now cane sugar or

\* Address of the vice-president and chairman of Section C—Chemistry—American Association for the Advancement of Science.

paraffine be treated with antimony trichloride or with camphor or chloral hydrate no change will be observed. The question arises, why do antimony trichloride and camphor liquefy each other and cane sugar and camphor not? It is perfectly clear that all that we can say is that this is because of the specific nature of the substances themselves. In other words, antimony trichloride and camphor liquefy each other and sugar and camphor do not for reasons that are similar to those which we give as to why charcoal will burn and platinum will not. We may say that the mutual attraction, i. e., the affinity of antimony trichloride for camphor, is sufficient to overcome their cohesions, and so they unite and form the solutions. Now as to whether the antimony trichloride dissolves the camphor or the camphor the antimony trichloride is clearly an idle question. We may regard either the one or the other as the solvent, for this is obviously a purely arbitrary matter. Let us now raise the following question: In the syrupy liquid that has been formed by the action of antimony trichloride and camphor on each other, how much of the camphor present is combined with the antimony trichloride that has been employed? The answer is perfectly obvious, for clearly all of the antimony trichloride is combined with all of the camphor in the syrupy liquid that has been formed. One might as well ask the question: When mercury and oxygen unite to form mercuric oxide, how much of the oxygen present is united with the mercury that the oxide contains? Clearly here, too, all of the oxygen is united with all of the mercury present. When the solution of antimony trichloride and camphor is heated, the vapor obtained contains both of the ingredients. Similarly when we heat mercuric oxide the vapor contains mercury and oxygen. We see thus that the cases are essentially similar in character, the only difference being that in the case of the solution in question we have a compound according to variable proportions, whereas in the mercuric oxide we have a compound according to definite proportions.

Now when ice acts on sodium chloride is not the case quite similar to that of camphor and antimony trichloride? Suppose we knew of no temperature above 0 deg. C., would any one argue that the solid ice dissolved the solid salt in the process of forming the brine? Certainly not, we should say that the brine has been formed by the union of the ice with the salt. And here similarly the question as to how much of the salt in the brine is united with how much of the water in the latter is quite idle, for obviously all of the salt used has united with all of the ice. The case would clearly not be altered if we started with liquid water and solid salt and formed the brine by the interaction of the two substances. This view, that in a solution all of the substances present are united with one another just as all of the elements in a definite compound are combined with one another, is to my mind the only rational view we can take of the matter. It is not new; on the contrary, it is quite old. It has been held quite generally by scientists prior to 1887, when the physical theories came upon the stage and diverted attention into other channels, as already stated, with the result that the true nature of solutions has been thoroughly obscured. If now we dilute the brine with more water, does the water added combine further with the salt present? Most assuredly, for is not the vapor tension of a brine, however dilute, lower than that of pure water, and does not this show that the water in the brine experiences greater difficulty in evaporating because of the mutual attraction between the salt and the water? Were any of the latter uncombined with the salt of the brine, this uncombined water would show the same vapor tension as pure water; but a brine of the same vapor tension as pure water of the same temperature does not exist.

The phase rule of Willard Gibbs marks a great advance in the study of heterogeneous equilibrium. Through the practical work of Bancroft, Roozeboom, and numerous other able chemists, the phase rule has borne rich fruits. In all of this work the composition of the phases that are in equilibrium with one another under given conditions of temperature and pressure was carefully determined. This work has revolutionized solubility determinations, placing them upon an accurate scientific footing. Nowadays when the solubility of a compound is to be thoroughly investigated nothing less than the complete equilibrium curves of the compounds in question will suffice; but once the work is carefully done, it is final for all time. This is not the place to dwell upon all the various questions that have been cleared up by the application of the phase rule. It should here be emphasized, however, that the latter deals with the equilibrium of the various phases whose qualitative and quantitative composition is of course ascertained. As to the inner structure of any one of the phases the phase rule is able to tell us nothing. Indeed, in the study of single-phase chemistry, the phase rule is no help whatever. We may consider the investigation of the constitution of definite chemical compounds a part of single-phase chemistry, and we may similarly consider the question as to the inner nature of a solution (i. e., of a com-

pound according to variable proportions) as a problem of single-phase chemistry. In the investigation of the constitution of single phases it is quite impossible to get along without hypotheses. While the phase rule does not involve even the atomic and molecular theories, these are at present indispensable tools in prying into the inner nature of any one phase. But in the study of solutions, interest centers not so much in the equilibrium between phases as in the inner structure of the latter themselves.

Our methods of ascertaining the structure of chemical compounds are quite numerous, but they readily fall into a few categories. So we argue as to the structure of a compound from its synthesis, from its analysis, from its behavior toward various other chemical agents, from alteration by the application of pressure, heat, electricity, light, and kindred agencies, and also from its various physical and physiological properties. Thus, for example, it has always been considered as sound reasoning that because red precipitate can be formed from mercury and oxygen, these substances are in red precipitate, which conclusion is verified by the fact that the latter compound may be decomposed into oxygen and mercury. There has never been any objection to the argument that if one of the elements actually enters into a compound during the latter's formation, or can be obtained from the compound either in the free state or in combination with other elements, that element is actually in the compound. So since calcium carbonate may be made from calcium, carbon, and oxygen, we argue that these elements and these only are contained in calcium carbonate. Again, when calcium carbonate is heated, calcium oxide and carbon dioxide, and these only, are obtained; and conversely calcium carbonate may be formed by the union of calcium oxide and carbon dioxide. These facts were duly expressed by the old dualistic formula for calcium carbonate  $\text{CaO.CO}_2$ , which consequently had much to commend it. Yet while we thus hold that the elements calcium, carbon and oxygen are in calcium carbonate, we do not argue that this compound contains calcium oxide and carbon dioxide, even though the last two substances will unite and thus form calcium carbonate, or though they may be obtained as decomposition products of the latter compound. We write our formula for calcium carbonate  $\text{CaCO}_3$ , because of the precipitation methods by which the compound may be prepared, and because of the formulae that we assign to soluble carbonates on the basis of the products that they yield by electrolysis. We consequently hold that the carbon dioxide and lime that form when calcium carbonate is heated result from the rearrangement of the atoms and splitting of the compound on account of the violence to which it has been subjected by heating it very highly. Similarly, while we recognize that carbon, hydrogen, and oxygen, are contained in cane sugar, we do not argue that the latter consists of water and carbon, though these products may among others be obtained by heating sugar. Likewise we are loath to conclude that proteins contain amino acids, simply because these result as cleavage products when the proteins are subjected to certain rather drastic treatment.

Turning now, for example, to a compound like blue vitriol whose composition we are wont to express by the formula  $\text{CuSO}_4.5\text{H}_2\text{O}$ , to indicate that it consists of copper sulphate plus water, we find that the water may be driven off by heat properly applied and that the dehydrated copper sulphate remains behind. On heating the copper sulphate further it is decomposed into copper oxide and sulphur trioxide. If it were intended to express these changes by means of a formula, surely the old dualistic formula  $\text{CuO.SO}_3.5\text{H}_2\text{O}$  would best indicate what has been observed. But here again we have departed from the idea that copper sulphate contains copper oxide and sulphur trioxide because upon electrolysis of an aqueous solution of copper sulphate, metallic copper, sulphuric acid and oxygen are obtained; while upon adding zinc or iron to a copper sulphate solution metallic copper is thrown out, and the sulphate of the more basic metal results. So far as the water content of blue vitriol crystals is concerned, we only know its relative amount and that it can be driven off by heat, higher temperatures being required to secure complete dehydration, while relatively lower temperatures will suffice to remove a large portion of the water. As to how this so-called water of crystallization is held, whether it is united with the copper sulphate simply as water molecules adhering to the copper sulphate molecule, or whether, like the oxygen and hydrogen content of the cane-sugar molecules, the oxygen and hydrogen in blue vitriol are united with the sulphur and copper in some more complicated way, is an open question. So far as the facts known are concerned, they are expressed by the formula  $\text{CuSO}_4.5\text{H}_2\text{O}$ , just as at one time the formula  $\text{CaO.CO}_2$  expressed what was known about calcium carbonate. To me it would seem very probable that the hydrogen and oxygen content in blue vitriol is not present as water molecules clinging to the copper sulphate molecule, but some subtle experimental

method, as yet quite unknown, is required to elucidate this matter, and until such a method is found we shall continue to write our formula for blue vitriol as we are wont to do. It is perhaps well in this connection to allude to the well-known fact that many salts containing water of crystallization can not be dehydrated by heating them, for when this is attempted not only water, but other ingredients as well, are driven off, in other words, further deep-seated decomposition occurs.

If crystals of blue vitriol be placed in water, a blue liquid is formed as a result of the action of the crystals and water on each other. This liquid we call a solution. The amount of water and blue vitriol used in its preparation may be varied arbitrarily within certain limits. For reasons already stated, this blue liquid contains no water that is not in combination with the salt present, and also no salt that is uncombined with the water. The fact is that this blue liquid is found to be perfectly homogeneous by all tests that we are able to apply. If we add more water to it, this additional water also combines with all of the salt present and the liquid is again homogeneous; and this dilution may be carried on indefinitely. If, on the other hand, we permit the blue liquid to evaporate, we thus decompose it by abstracting water from it. We say that the solution is becoming more concentrated. This change is a perfectly reversible one, and like all chemical changes, it follows the law of mass action. The abstraction of water from a solution of copper sulphate by means of heat is just as truly an act of decomposing that liquid as is the abstraction of carbon dioxide from lime stone when the latter is heated.

Blue vitriol is formed by the addition of water to anhydrous copper sulphate. The compound thus produced is quite stable at room temperature. If now we add anhydrous copper sulphate to crystals of blue vitriol, the latter lose part of their water content, which is taken up by the anhydrous salt till equilibrium is established. If, on the other hand, we treat the blue vitriol crystals with water, it is clear that we can not thus dehydrate the crystals. On the contrary, this added water will, because of mass action, tend to increase the stability of the complex which we represent by the formula  $\text{CuSO}_4.5\text{H}_2\text{O}$ , and to this complex all of the additional water present in the solution adds itself. What then is the formula of the hydrate contained in an aqueous copper sulphate solution at known temperature? This question is really an idle one, for since all of the copper sulphate present is combined with all of the water of the solution, the composition of the hydrate is clearly expressed by  $\text{CuSO}_4.x\text{H}_2\text{O}$ , where  $x$  represents the number of water molecules which the entire solution contains per each copper sulphate molecule; and so  $x$  increases as we dilute the solution and diminishes as we concentrate it. But this must not be taken as meaning that all of the water in a copper sulphate solution is equally strongly bound to the salt molecules. Indeed, in the case under consideration it is extremely probable that at least five molecules of water are more strongly bound to each copper sulphate molecule in the solution, for as the salt separates out, these five molecules remain in combination as a part of the compound. But while in the solution the copper sulphate molecule plus five molecules of water may be present as a nucleus to which the additional water molecules are attached, the force of attraction with which the outlying water molecules are held by the nucleus shades off so gradually as the radius of the sphere of influence increases that there is at no point any very sharp demarkation, and so it would be folly to attempt to ascribe any definite formula whatever to the hydrate existing in the solution. Attempts to deduce the formulae of hydrates in solutions from the boiling points or freezing points of the latter are very far from the mark, though to be sure boiling-point and freezing-point curves do frequently show maxima and minima which are doubtless due to changes of intensity with which the water and salt molecules are held together as their relative number is changed. Furthermore, it is very significant that such maxima and minima in the boiling-point and freezing-point curves are found in the case of those substances, which, when they crystallize from the solution, do so with one or more molecules of the solvent attached as so-called crystal water. It is well known that at higher temperatures salts separate from solutions with less crystal water than at lower temperatures. Indeed at high temperatures the anhydrous salt is frequently in equilibrium with the saturated solution. So while at ordinary temperatures copper sulphate forms crystals with five molecules of water, at lower temperatures it may be obtained with seven molecules of crystal water. Now would it then be right to conclude from this that at room temperature the hydrate in the solution is  $\text{CuSO}_4.5\text{H}_2\text{O}$  and at lower temperatures  $\text{CuSO}_4.7\text{H}_2\text{O}$ ? Obviously not, but we may say that it is at least that indicated by the composition of the compound that separates. In the solution itself many additional

water molecules are combined with the salt molecules, and the force of attraction gradually shades off as the radius of the sphere of attraction from the nucleus outward increases so that it is quite impossible to ascribe any definite formula to the hydrate in the solution. (I should like to add parenthetically here that the recent attempts made to draw conclusions as to how many water molecules are attached to a portion of certain salts, from observations of changes of concentration that occur at the electrodes during electrolysis, are also based upon misapprehensions, but these details can not be taken up here.) It is, moreover, well known that when any physical property of a solution is studied at different temperatures the curve representing the alteration of that property with change of temperature does not show sharp points of inflection, indicating that whatever the internal alterations may be within the solution, they occur gradually rather than suddenly.

SCIENCE NOTES.

Messrs. Lacomte and Lainville presented samples of a milk powder at a recent meeting of the French agricultural society which is obtained by a new process. Instead of evaporating the milk by hot air or *in vacuo*, the authors use the method of freezing in order to separate the water from the milk so that it can be afterward dried. The milk is placed in freezing tanks and is cooled to -2 deg. C. (28.4 deg. F.), when the water separates in the form of snowy crystals. These last are removed from the remainder of the mass by the centrifugal process, and we thus obtain a soft and unctuous paste which contains the essential elements of the milk, with some water still remaining. By drying the mass at a slight heat and *in vacuo*, the water is removed and the mass becomes solid. The present method of concentrating the milk has an advantage over others in that the resulting milk powder has not the taste of boiled milk which is an objectionable feature. Seeing that butter establishments already possess freezing plants, the new process will be a very practical one, as we can use the skimmed milk and can readily carry out the freezing, so that no special difficulty is found. The milk powder will thus be in a position to compete advantageously with condensed milk, which contains from 12 to 50 per cent of water. Milk tablets can also be made, and these can be combined with chocolate. Another use of the dried milk is for food for animals.

G. Charpy has observed certain phenomena in the case of steel resembling those described in the SCIENTIFIC AMERICAN by Prof. Cohen as the effect of strain disease or forcing disease. Stead has shown that the growth of the grains of ferrite in soft steel proceeds

most rapidly between 650 deg. and 800 deg. C. Charpy has found that previous mechanical working of the metal causes a considerable increase in the rate of growth of the ferrite grains on subsequent annealing. For example in the case of two test pieces of a bar of soft steel of which one had been worked by means of a screw-plate, the difference in the growth of the ferrite grains on annealing for a certain time between 650 deg. and 800 deg. C. was so marked as to be visible to the naked eye on breaking the pieces of metal. In a given bar in which the mechanical working had been only superficial, the grains at the periphery were larger than those at the center. It is stated that if the annealing be prolonged sufficiently, the growth proceeds until in a piece of metal there is only a single large crystal of ferrite. This growth of the grains of ferrite does not notably affect the tensile strength of the steel, but renders the metal brittle. In some cases observed by Charpy, bars of steel which had been worked in a screw-plate gave good results in the bending test, but after annealing at about 650 deg. C., became so brittle that they broke on falling to the ground. Similar results are obtained with steel that has been worked in other ways, e. g., by drawing, cold-rolled plates, cold-forged or stamped steel, etc., and it is probable that many so-called abnormal failures of metallurgical products are due to effects such as those described.

ELECTRICAL NOTES.

A telephone line provided with phonographic transmitting and receiving apparatus has been installed in London. The object of this innovation is to make it possible to send a telephone message to a person who is not, at the moment, within reach of his telephone. The person called finds, on returning to his home or office, a phonographic record of the telephone message which was sent during his absence, and his phonograph reproduces the message from the record. This result was sought and obtained, in principle, by Poulsen, the Danish physicist, who has perfected the method of producing sustained electric waves by means of the singing arc. Poulsen's telegraphone, which was exhibited in Paris in 1900, is an electromagnetic phonograph which can readily be applied to the registration of telephone messages. The record is made on a ribbon of steel, which moves between the poles of an electromagnet and receives and preserves a magnetic impression of the words spoken into a microphone connected with the electromagnet.

Messrs. W. M. Thornton and E. Bowden have made a study of the ignition of coal dust by single electric flashes. The results of experiments on the ignition of

a mixture of three typical coal-dusts from different seams of the Birtley Collieries are given in a series of tables and curves. The values of the smallest current, in amperes, capable of igniting a mixture of coal-dust and air, when interrupted by a quick-break switch, are summarized in the following table:

Volts.	Amperes.				Alternating Current Power- Factor.
	Direct Current.		Alternating Current.		
	Inductive.	Non- inductive.	Inductive.	Non- inductive.	
77				150	0.75
100	16.0	70.3	140.0	.....	0.80
240	5.7	11.0		.....	
250			30.0	.....	0.80
480	2.3	5.8	14.2	.....	0.81
635		.....	5.2	.....	0.83

The author discusses, on the basis of his results, the most suitable conditions for the safe use of electricity in collieries.

TRADE NOTES AND FORMULÆ.

Bottle Wax (Gray).—	I.	II.	III.
Thick turpentine .....	2.	2.5	2.75
American rosin .....	2.	2.5	2.75
Shellac .....	1.	1.	1.
Oil of turpentine .....	0.75	0.75	0.75
Infusorial earth .....	1.	1.5	1.75
Chalk .....	1.5	2.	2.5
White lead .....	1.5	1.5	1.5
Lamp-black .....	0.25	0.25	0.25

Green Bottle Wax.—	I.	II.	III.
Thick turpentine ...	2.5 2.5	2.5 2.5	2.5 2.5
American rosin ....	2.5 2.5	2.5 2.5	2.5 2.5
Shellac .....	1. 1.	0.75 0.75	0.75 0.75
Oil of turpentine....	1. 1.	1. 1.	1. 1.
Infusorial earth....	1.5 1.5	2. 2.5	2.5 2.5
Berlin blue .....	1.5 ..	1.5 ..	1.5 ..
Chrome yellow.....	2.5 ..	2.5 ..	2.5 ..
Ocher .....	.. ..	0.5 ..	0.5 ..
Chrome green .....	.. 2.	.. 2.	.. 2.
Heavy spar .....	3. 3.	4. 4.	4.5 4.5

Orange Bottle Wax.—	I.	II.	III.
Thick turpentine .....	2.75	2.75	2.75
American rosin .....	2.75	2.75	2.75
Shellac .....	1.	0.75	0.75
Oil of turpentine .....	1.	1.	1.
Infusorial earth .....	1.	1.5	2.
Chalk .....	2.	2.5	3.
Orange chrome yellow .....	1.	1.	0.5
Orange ocher .....	1.	1.5	2.

Red Bottle Wax.—	I.	II.	III.
Thick turpentine .....	2.	2.25	2.5
American rosin .....	0.5	2.75	2.5
Shellac .....	0.5	0.75	0.5
Oil of turpentine .....	0.5	0.75	0.75
Infusorial earth.....	0.5	1.	1.5
Heavy spar .....	2.	2.5	3.
Red lead .....	0.5	0.5	0.5
English red .....	1.	1.	1.
Bole .....	0.5	0.5	0.5

Production of Gold Bronze.—Melt 2 parts of pure tin in a crucible and add 1 part of quicksilver, heated so that it is just beginning to fume. After cooling, the amalgam is reduced to a fine powder and intimately mixed with 1 part chloride of ammonia and 1 part flowers of sulphur; hereupon place the mixture in a glass flask, or a retort, which must be closed and set in the sand bath. Heating must be carried so far as to cause the escape of vapors, which collect in the upper part of the vessel. As soon as sublimation ceases, the vessel is removed from the sand bath and allowed to cool. The upper part will be found to form a bronze of the brightest gold shade, the lower portion consists of sal ammoniac and cinnabar.

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Alcohol

Its Manufacture  
Its Denaturization  
Its Industrial Use

The Cost of Manufacturing Denatured Alcohol in Germany and German Methods of Denaturation are discussed by Consul-General Frank H. Mason in SCIENTIFIC AMERICAN SUPPLEMENT 1550.

The Use, Cost and Efficiency of Alcohol as a Fuel for Gas Engines are ably explained by H. Diederichs in SCIENTIFIC AMERICAN SUPPLEMENT 1596. Many clear diagrams accompany the ext. The article considers the fuel value and physical properties of alcohol, and gives details of the alcohol engine, wherever they may be different from those of a gasoline or crude oil motor.

In SCIENTIFIC AMERICAN SUPPLEMENT 1581 the Production of Industrial Alcohol and Its Use in Explosive Motors are treated at length, valuable statistics being given of the cost of manufacturing alcohol from farm products and using it in engines.

French Methods of Denaturation constitute the subject of a good article published in SCIENTIFIC AMERICAN SUPPLEMENT 1599.

How Industrial Alcohol Is Made and Used is told very fully and clearly in No. 3, Vol. 95, of SCIENTIFIC AMERICAN.

The Most Complete Treatise on the Modern Manufacture of Alcohol, explaining thoroughly the chemical principles which underlie the process without too many wearisome technical phrases, and describing and illustrating all the apparatus required in an alcohol plant, is published in SCIENTIFIC AMERICAN SUPPLEMENTS 1603, 1604 and 1605. The article is by L. Baudry de Saunier, the well-known French authority.

In SUPPLEMENTS 1607, 1608, 1609 we publish a digest of the rules and regulations under which the U. S. Internal Revenue will permit the manufacture and denaturation of tax free alcohol.

A Comparison of the Use of Alcohol and Gasoline in Farm Engines is given in SCIENTIFIC AMERICAN SUPPLEMENTS 1634 and 1635 by Prof. Charles E. Lucke and S. M. Woodward.

The Manufacture, Denaturing and the Technical and Chemical Utilization of Alcohol is ably discussed in the SCIENTIFIC AMERICAN SUPPLEMENTS 1613 and 1636 by M. Klar and F. H. Meyer, both experts in the chemistry and distillation of alcohol. Illustrations of stills and plants accompany the text.

The Source of Industrial Alcohol, that is the Farm Products from which alcohol is distilled, are enumerated by Dr. H. W. Wiley in SCIENTIFIC AMERICAN SUPPLEMENTS 1611 and 1612 and their relative alcohol content compared.

The Distillation and Rectification of Alcohol is the title of a splendid article by the late Max Maercker (the greatest authority on alcohol), published in SCIENTIFIC AMERICAN SUPPLEMENTS 1627 and 1628. Diagrams of the various types of stills in common use are used as illustrations.

In SCIENTIFIC AMERICAN SUPPLEMENT 1613 the Uses of Industrial Alcohol in the Arts and in the Home are discussed.

Any Single Number of the SCIENTIFIC AMERICAN or SUPPLEMENT will be sent for 10 cents by mail. The entire set of papers above listed will be mailed on receipt of \$2.00.

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