The gases expelled by heat from the dried garbage on the inclined plane ignite with the free oxygen of the surplus air admitted through the grates. The hot fire gases then mingle with the aqueous vapors rising from the fresh charges, and on their way through a secondary fire room above the furnace chamber decompose the organic gases that may be contained in those vapors. Should the heat produced by the combustion of garbage alone not be sufficient, it becomes necessary to spread fine coal (screenings) over the fire through the two doors in the rear of the furnace. Ashes and clinkers found on the grate are pushed directly into suitable wagons placed underneath it.

Back of the fire room and above the furnace chamber is a dust chamber, accessible through two doors, and above this chamber is the chimney flue, provided with a damper for each furnace. The chimney is a brick-lined iron tube, set on top of the furnaces, and stayed sideways.

Assuming that the garbage is deposited in the bin by the scavengers who collected it, and that the ashes and clinkers are hauled off by the same men, it takes but one man to attend to two furnaces, causing an expense of 21 cents per ton of garbage destroyed if no coal is used, and of 36 cents per ton of garbage if 1 ton of screenings is used in each furnace for 24 hours. Since garbage as a rule does not require additional fuel for its destruction, the average cost of the process will not exceed 25 cents per ton. Among the special advantages afforded by a garbage furnace is the possibility of effectively destroying matter that cannot otherwise be well disposed of, such as infected articles, dead animals, etc. For the destruction of large quantities of garbage the necessary furnace capacity may be provided for either at several separate stations to save haulage, or at one central station to facilitate management and attendance; in the latter case all the furnaces may be connected to one common chimney of large dimensions.—*Trans. Asso. Engineering Societies.*

ON CERTAIN PROPERTIES COMMON TO FLUIDS AND SOLID METALS.*

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IN one of the beautiful discourses, delivered in the early part of the last century, which grace the annals of the French Academy of Sciences,† Reaumur observes that industrial art, like nature, has its marvels, which we often fail to notice because they are constantly before us.

The extraordinary ductility of metals appeared to him to involve one of the deepest secrets of nature, and although he held that in his time science was hardly in a position to explain more fully than the old philosophers did the cause of this property of bodies, it was nevertheless possible to see better than they what advantage art has gathered from the power of leading and guiding metals by hammering or by traction, and from this point of view, both art and nature seem, he says, to rival each other in furnishing us with remarkable facts. Reaumur, then, with singular clearness, defines the conditions under which metals prove to be ductile.

The relation between the behavior of solid metals and fluids has long been recognized, not merely in the sense that atomic motion is common to solids and fluids, and that therefore "everything moves and nothing remains;" but apart from theory there is much experimental evidence as to the properties that are common to fluids and solid metals, the characteristics of which, at first sight, seem widely separated. Let me remind you of the elementary definition of the two states, *solid* and *liquid*. A solid has a definite external form which either does not change, or only changes with extreme slowness when left to itself, and in order to change this form rapidly, it is necessary to exert a more or less energetic effort. A liquid, on the other hand, can be said to have no form of its own, as it always assumes that of the containing vessel; the mobility of its particles is extreme, its resistance to rupture is very small, and its free surface is always a plane when the mass is left at rest.

Then there is the colloid condition, which intervenes between the liquid and crystalline solid state, extending into both and probably affecting all kinds of solid and liquid matter to a greater or less degree. The colloid or jelly-like body does present a certain amount of resistance to change of shape. Such a substance is well imitated by a skin of thin India-rubber filled with water. Another illustration is probably afforded by iron and other substances which soften under heat, and may be supposed to assume, at the same time, a colloid condition. Lastly, there is the gaseous condition of matter, with which we have but little to do at present.

We are in the habit of regarding metals as typical solids. I hope to trace this evening the analogies of their behavior under certain conditions with that of fluids, and the following list shows the order in which I propose to group the properties common to fluid and solid metals:

1. Rejection of impurities on solidification.
2. Surface tension.
3. Flow under pressure.
4. Changes due to compression.
5. Absorption of gases.
6. Absorption of liquids.
7. Diffusion.
8. Vaporization.
9. Surface tension.

The transition from the liquid to the solid state is marked by the same phenomena, in the case of many metals, as is observed in certain fluids, and I must dwell on this very briefly as leading up to the relations between solid metals and fluids, which come more definitely within the title of the lecture.

Water on passing from the liquid to the solid state undergoes a partial purification, the ice first formed being sensibly more free from coloring matter or suspended particles than the water from which it separates.

Many metals on freezing similarly eject impurities. In the case of alloys, saturated solutions of one metal in another appear to be formed, and excess of

metal ejected, a fact which is being studied with much care by my colleague, Dr. Guthrie. The prominent facts are perhaps best illustrated by reference to a frozen mixture of copper, antimony, and lead. The results of some experiments conducted in my laboratory by my assistant, Dr. E. J. Ball, show that when a molten mixture of these metals is solidified, a definite atomic alloy of copper and antimony, which possesses a beautiful violet tint, first forms, and after saturating itself with lead, up to a certain point, it ejects the rest of the lead, driving it to the center of the mass so as to form a sharp line of demarcation, as is shown in the engravings, Fig. 1, the outer circle of which represents violet and the inner gray, presenting a direct analogy to the ice, which is comparatively colorless, first forming from colored water.

Then there is another remarkable analogy between the freezing of certain fluids and the solidification of some metals. Water may, as is well known, be cooled down to -8° Cent. without solidification, but agitation immediately determines the formation of ice, and at the same time a thermometer plunged in the water rises to zero. Faraday stated, in 1858, that fused acetic acid, sulphur, phosphorus, many metals, and many solutions* would exhibit the same effect. Tin also may be cooled to several degrees below its solidifying point without actually freezing, and Dr. Van Riemsdijk, † of Utrecht, has observed that a globule of gold or silver, in a fused state, will pass below its solidifying point without actually solidifying, but the slightest touch with a metallic point will cause the metal to solidify, and the consequent release of its latent heat of fusion is sufficient to raise the globule to the melting point again, as is indicated by a brilliant glow which the button emits, a beautiful effect which I hope to show you.

It may be well also to remind you incidentally that a minute variation in composition is sometimes sufficient to lower the melting point of a metal or alloy, as is instanced by the addition of $\frac{1}{10}$ per cent. of silicon to standard gold, which, as you will observe in the case of this strip of the alloy, softens in the flame of a candle, or at about the melting point of zinc, 412 deg. Cent. although the melting point of standard gold, free from silicon, would be over 1,000 deg. Cent.

Now to pass to solid metals. It is the common experience of us all, that a counterfeit shilling, consisting principally of lead, does not "ring" when thrown on a wooden surface. In 1726, Louis Lemery observed that lead is under certain conditions almost as sonorous

shape of the grains, and to the "way in which they touch each other;" further, the blows of the hammer not only change the arrangement of the fibers, but they alter the shape of the grains; "the round grains are rendered flat, they are compelled to elongate and fill the interstitial spaces which previously existed between them. The particles are no longer free to vibrate, hence the lead is dull." These remarks derive additional interest, if we compare them with the observations in Professor Osborne Reynolds' most important lecture on "Dilatancy in Granular Matter," recently delivered here. We shall also, I think, see that this description of Reaumur's shows that he fully appreciated the theoretical importance of the kind of facts depending on the transfer of metallic matter from one position to another, which we now consider to be characteristic of the "flow" of metals; at any rate, I have thought it well to make Lemery's experiment the starting point of the rest of the remarks I have to offer you.

A solid may be very brittle, and may yet, if time be given to it, flow from one point to another. This stick of sealing wax was supported at its ends, and it has in a few weeks bent at the ordinary atmospheric temperature, although at any given point of its flow it would have been easy to snap it with a slight application of force. This much thinner strip of pure lead, of the same breadth as the sealing wax, also bends at the ordinary temperature with its own weight, the ends being supported. Sir William Thomson has pointed out that a gold wire sustaining half the weight which would actually break it, would probably not rupture in a thousand or even a million years, that is to say, there would be no "flow" ending in disruption; if, however, force be suitably applied, metals will flow readily. First let us examine the case of a metal under force applied, so as to compel it to flow through a hole; and I would point to the analogy of an ordinary viscous fluid. This vessel, containing treacle, is provided with a cylindrical hole in its base, and on the removal of the plug which now closes it, the treacle will flow out, the end of the stream being rounded. If a similar vessel be filled with lead, it will, at the ordinary pressure, remain there; but if the pressure be applied, the lead will prove by its behavior that it is really a viscous solid, as it flows readily through the orifice; the end of the jet is rounded, and, as has been shown by the beautiful researches of the late M. Tresca, of Paris,* all the molecules which compose the original block place themselves in the jet absolutely as the molecules of a flowing jet of a viscous

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as bell metal.‡ He communicated the fact to Reaumur, who, being much struck by it, investigated the conditions under which lead becomes sonorous, and submitted the results to the French Academy.§ He pointed out that in describing a body which is not sonorous, it is usual to say that it is as "dull as lead," an expression which has become proverbial. "Nevertheless," he adds, "under certain conditions lead has a property both novel and remarkable, for it emits surprisingly sharp notes when struck with another piece of lead." He showed that it was necessary that the lead should be formed by casting into a segment of a sphere, that is, mushroom shaped, as in the specimens of lead exhibited. The lead must be free from prominences and must be neatly trimmed. The effect is less marked if the lead be very pure than if ordinary commercial lead be used, but it is only a question of degree.

[A mass of pure lead cast into the shape shown in the sketch, Fig. 2, was struck with a piece of lead, and it emitted a sharp, clear note.]

I have shown you the experiment mainly for the sake of being able to quote Reaumur's observations upon it. He showed that the sonorous lead might be rendered dull by hammering it. Here is lead from the same sample of metal as that from which the sonorous mass was cast, but it has been flattened out, and you will observe that it is "dull." I think his remarks have been overlooked in late years. He was led to the belief that in cast lead there must be an arrangement of the interior of the mass which the hammer cannot impart, because lead fashioned by hammering into the same form as the sonorous cast mass is dull; and, more important still, he held that the fibrous and granular structure of the lead is modified in a manner which makes it probable that the sound is due to the

fluid would. If the metal has a constant "head," as it would be termed in the case of water, that is, if the vessel be kept filled with solid lead up to a certain level, then you have a continuous stream, the length depending on the constancy with which the "head" and the pressure are maintained. If, on the other hand, the head is diminished so that nearly all the solid lead has been allowed to flow away, you have a folding of the jet, and vertical corrugations, exactly such as would characterize the end of the flow of certain other viscous fluids, and finally the jet forms a distinct funnel-shaped tube, concentric with the jet. It is also seen that when the formation of these cavities takes place, the jet is no longer equal to the full diameter of the orifice, as is shown in Fig. 3, the formation of the contracted vein is manifest, and a new analogy is thus obtained between the flow of solids and liquids.

The application of this fact, that solid metals flow like viscous fluids, is of great importance in industry, and the production of complicated forms by forging or by rolling iron and steel and other metals entirely depends on the flow of the metal when suitably guided by the artificer. The lines of flow in iron may be well shown by polishing a surface of the metal, and by submitting it to the action of a solution of bichloride of mercury, which etches the surface, or, better to the slow action of chromic acid solution, as suggested by Sir Frederick Abel, the result in either case being that any difference in the hardness of the metal, or in the chemical composition, or want of continuity, caused by the presence of traces of entangled slag, reveals the manner in which the metal has flowed. The engravings illustrate the direction of flow in the following cases.

Fig. 4 is a section of a forged crosshead, kindly sent me by Mr. Webb, of Crewe. Fig. 5 represents the top,

* Faraday, Experimental Researches in Chemistry and Physics, p. 379.

† Dr. Van Riemsdijk, Ann. de Chim. et de Phys., t. xx., 1850, p. 66.

‡ Hoefler, Histoire de la Chimie, t. ii., p. 374.

§ Histoire de l'Académie Royale des Sciences, Année 1726, p. 243.

* The substance of a lecture delivered at the Royal Institution of Great Britain, on March 26.

† Histoire de l'Académie Royale des Sciences, 1713, p. 193.

* These researches extend through a long series of memoirs; those relating to the flow of metals are well summarized in the Proc. Inst. Mech. Engineers, 1867, page 114, and in the report of the Science Conferences held in connection with the Loan Collection of Scientific Apparatus (Physics and Mechanics), London, 1876, page 252.

planed and etched, of a hemisphere of mild steel, of the form and dimensions shown in the sectional view, Fig. 6, $\frac{5}{8}$ in. thick, "dished" cold by forcing a plate through a circular orifice. The convolutions of the etched portions afford evidence of the struggle sustained by the flowing particles of the metal. The experiments of M. Tresca were not made on "cinder-free" metal; it is therefore interesting to compare the etched section of the old rail, Fig. 7, the result of the complicated welding of puddled iron, with a basic-Bessemer rail, rolled from steel which has been cast, and which is therefore free from entangled slag. Fig. 8 represents a section of such a rail presented to me by Mr. P. C. Gilchrist.

A very striking illustration of the importance of the flow of metals, when used in construction, is afforded by some observations of Mr. B. Baker, in a recent paper on the Forth Bridge.*

He says: "If the thing were practicable, what I should choose as the material for the compression members of a bridge would be 34 to 37 ton steel which had been previously squeezed endwise, in the direction of the stress, to a pressure of about 45 tons per square inch, the steel plates being held in suitable frames to prevent distortion." He adds: "My experiments have proved that 37 ton steel so treated will carry as a column as much load as 70 ton steel in the state in which it leaves the rolls, that is to say, not previously pressed endwise. . . . At least one-half of the 42,000 tons of steel in the Forth Bridge is in compression, and the same proportion holds good in most bridges, so the importance of gaining an increased resistance of 60 per cent. without any sacrifice in the facility of working, and safety, belonging to a highly ductile material can hardly be exaggerated." I need not point to the extreme interest of these remarks in connection with my subject.

The very ancient mechanical art of striking coin is wholly dependent on the flow of metals. There is a popular belief that the impression imparted to disks of

[A disk of pewter was spun, on a lathe, into a vase, the shadow being projected on the screen during the operation.]

The production of complicated forms, like a jelly mould, from a single sheet of copper under the combined drawing and compressing action of the hammer, is a still more remarkable case.

The flow of metals is illustrated very curiously in one phase of Japanese art metal work, of which, however, it is now so difficult to obtain native examples that I have been obliged to prepare, with the aid of skillful artificers in the Mint, the few specimens I have to submit to you. I allude to the metal work in banded alloys to which the Japanese give the name of Moku-me, or "wood-grain." In its preparation thin layers of copper, precious metals, and various alloys are soldered in superposition like the leaves of a book; through these layers, as is shown in Fig. 9, holes are drilled to varying depths in the thickness of the metal, or trenches are cut in it. The mass is then hammered flat until the holes or trenches disappear, and the result is contorted bands, of some complexity, and often possessing much beauty, especially when the color of the metal is developed by suitable chemical treatment and polishing. A similar effect may be produced by beating up the metal from one side and filing the other flat, as is shown in Fig. 10. The structure depends on the flow of the respective metals of which the mass is composed and the behavior of the components of the system, and suggests one of the most marked facts in experimental hydrodynamics, namely, the difference in the way in which water flows along contracting and expanding channels. The sinuous lines the metal assumes in the preparation of Moku-me resemble the beautiful illustrations devised by Professor Osborne Reynolds to show the flow of water.

We have hitherto only considered the flow of metals when submitted to compression. Let us now examine the effect of traction. When a viscous metal, such as

tion, under conditions in which the escape of the compressed metal is, as far as possible, restrained. I must, therefore, turn to what I believe to be the most important work relative to the molecular constitution of metals which has been done for many years, namely, the researches of Professor Walther Spring, of the University of Liege, whose labors have since 1878 been devoted to the study of the effect of compression on various bodies.* The particles of a metallic powder left to itself at the ordinary atmospheric pressure will not unite; by "augmenting the number of points of contact in a powder," the result may be very different. The powders of metals may weld into coherent blocks. Let us appeal to his own experiments. The section, Fig. 13, shows the general form of the compression apparatus employed by Spring.

Under a pressure of 2,000 atmospheres on the piston, or 13 tons to the square inch, lead in the form of filings becomes compressed into a solid block, in which it is impossible to detect the slightest vestige of the original grains, so that lead filings weld into a block identical with that obtained by fusion. Under a pressure of 5,000 atmospheres the lead no longer resists the pressure, but flows as if it were liquid through the cracks of the apparatus, and the piston of the compressor descends to the base of the cylindrical hole, driving the "flowing" lead before it.

This result in the case of lead is hardly unexpected.† Bolley showed, in 1849, that lead prepared in a particular way, so as to be in a state of fine division, may be converted under a powerful press into a flexible plate, or may be made to receive a sharp impression. The more interesting results were obtained by Spring with crystalline metals. Bismuth is, as is well known, very brittle and crystalline, yet fine powder of bismuth unites under a pressure of 6,000 atmospheres into a block very similar to that obtained by fusion, having a crystalline fracture. The density of compressed bismuth is 9.89, identical with that of metal which has been fused. The table shows the amount of pressure required to unite the powders of the respective metals:

	Tons per Square inch.
Lead unites at.....	13
Tin ".....	19
Zinc ".....	38
Antimony unites at.....	38
Aluminum ".....	38
Bismuth ".....	38
Copper ".....	33
Lead flows at.....	33
Tin ".....	47

We will endeavor to repeat M. Spring's results in the case of bismuth. It is necessary that the powder be perfectly clean and dry; if it be then submitted *in vacuo* to a pressure of 6,000 atmospheres, it will weld into a crystalline mass.

We know that combinations are produced when certain bodies in solution are submitted to each other's action. But do solids combine? Is the alchemical aphorism, that bodies do not react unless they are in solution, true? Experiment proves that such solution is not necessary. I have here two anhydrous salts, iodide of potassium and corrosive sublimate, and they are at the same time dry; when they are mixed in this mortar, they unite, as is shown by the vermilion color which is produced.

My colleague, Professor Thorpe, called attention to the importance of this fact at the meeting of the British Association at York, 1881. But do solid metals combine in the sense, that is, in which chemical combination is possible between metals, when submitted to each other's action? We know that metals do combine if they be fluid, and the extraction of gold and silver from their ores by amalgamation is moreover easy.

It occurred to M. Spring that if there be a true union between the particles of a metallic powder, when submitted to great pressure, it ought to be possible to build up alloys by compressing the powders of their constituent metals, and he urged that the formation of alloys by pressure would afford the most conclusive proof that there is a true union between the particles of metals in the cold, when they are brought into intimate contact. Experiment proved that this reasoning was correct, for by compressing, in a finely divided state, fifteen parts of bismuth, eight parts of lead, four parts of tin, and three parts of cadmium, an alloy is produced which fuses at 100 deg. Cent. It is necessary, however, to compress the mixed powders twice, crushing or filling up the block obtained in the first compression, because the mechanical mixture of the constituent metals is not sufficiently intimate to enable a uniform alloy to be obtained by a single compression. The alloy we have thus produced fuses, you will observe, in boiling water actually at 98 deg. Cent., although the melting point of the most fusible of its constituents, the tin, is 228 deg. Cent. I agree with Professor Spring in thinking that the formation of alloys by pressure affords the most complete proof which can be given of the accuracy of the views he has adduced.

The formation of fusible metal by compression leads me to deal with an objection which may, no doubt, have suggested itself to many of us. It may be urged that by compressing these metallic powders heat is evolved, and that this heat may be sufficient to produce incipient fusion in the metallic powders, or, at all events, may exert a material influence on the result obtained. This objection has been experimentally anticipated by Professor Spring. First, the compression is effected with extreme slowness, and therefore there can be no question as to the sudden evolution of heat, as would be the case if the powders were compressed by impact instead of by a slow squeeze; and to sum the matter up briefly, Spring calculates, taking an extreme case, that if it be granted that all the work done in compressing the powders were actually translated into heat, it would only serve to heat a cylinder of iron 10 mm. in height and 8 mm. in diameter (the dimensions of cylinder produced in his apparatus) 40.64 deg. Cent. In order that direct experimental evidence might not be wanting, Spring took the organic body phorone, a

* Bull. de l'Acad. Royale de Belgique [2] t. xlv., No. 6, 1878. [2] t. xlix., No. 5, 1880. See also subsequent papers in the same publication, in the Bull. Soc. Chim., Paris, and in the Deutschen Chemischen Gesellschaft (Bildung von Legirungen durch Druck), b. xv., p. 595.

† Leibig u. Kopp. Jahresbuch, 1849, p. 278, quoted by Dr. Percy, Metallurgy of Lead, 1870, p. 9.

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metal during coinage is merely the result of a permanent compression of the metal of which the disk is made. Striking a coin, however, presents a case of moulding a plastic metal, and of the true flow of metal under pressure, into the sunk portions of the die. I once heard Mr. Ruskin say: "You stamp the figure of the cow on a pat of butter; why do you not impress the bee on honey?" Simply because honey is not plastic and is too viscous, and it flows at the ordinary atmospheric pressure. This medal, struck from a series of disks, will serve to show, when the disks are separated, the way the metal flows into the deepest portion of the die.

If the alloy used be too hard, or if the thickness of the metal required to flow be insufficient, the impression will always be defective, no matter how many blows may be given by the press. In Mr. Browning's well-known poem, "The Ring and the Book," there is a subtle recognition of the viscous nature of very pure gold, which he characterizes as "the oozing of the mine;" while, with regard to the manufacture of the ring, he shows:

"Since hammer needs must widen out the round
And file emboss it fine with lily flowers,"

that this is only possible because gold behaves like the honey to which he compares it. I have chosen this reference to Browning because I happen to have a coin of "the great Twelfth Innocent," the Pope of the poem I have cited, and this coin has scars on its surface which prove that there was not quite enough metal to flow into the depths of the die.

If one side of a coin be ground away so as to leave a flat surface, and if the disk be then struck between plain polished dies surrounded by a steel collar so as to prevent the escape of the metal, the impression on the disk will be driven through the thickness of the metal, and will then appear on both sides. In industrial art the property of flow of metals is very important. The "spinning" of articles in pewter is a familiar instance, and one which I propose to illustrate.

* Jour. Iron and Steel Inst., vol. ii., 1885, p. 497.

iron or soft steel, is submitted to stress by pulling its ends in opposite directions, it stretches uniformly throughout its length; there is in such a solid, a limit in the application of the stress up to which the metal, if released, will return to its normal length; this point is the limit of elasticity. Directly, however, this limit is reached, the metal begins to stretch, and at first it stretches in a very singular way, without an increase of load, as is shown by the curve, Fig. 11; when the limit of elasticity has been passed, the metal continues to stretch with increased load until it gives up resisting and breaks.

The limit of elasticity of a solid body marks the moment at which the body begins to "flow" under the influence of the force to which it is submitted. There are many materials which do not stretch when their limit of elasticity is reached; in very hard steel, for instance, the breaking point and the limit of elasticity practically coincide. Further, it must be observed that very minute variation in composition is sufficient to change the property of a body, and to cause what was a viscous body to break close to the limit of elasticity. A most remarkable instance is presented by certain alloys of gold and copper.

Standard gold, such as is employed for British gold coin, which contains 9,167 parts of gold in 10,000 parts, breaks with a load of 18 tons to the square inch. Its limit of elasticity is reached at $1\frac{3}{4}$ tons per square inch, but it elongates 34 per cent. before it breaks. If this standard gold has only the $\frac{1}{100}$ part of lead added to it, it becomes very brittle, and breaks, as is shown by the diagram, Fig. 12, with a stress of about $5\frac{1}{2}$ tons to the square inch, instead of 18 tons borne by the original pure standard gold, and as it does not elongate sensibly it cannot be said to flow at all. A remarkable difference in the property of the alloy, standard gold, is therefore caused by the addition of only the $\frac{1}{100}$ part of lead.

In order to understand this, it will be necessary to trace the analogy between fluids and solid metals still further, and to ascertain what takes place when metals, in a roughly granular state, are submitted to compression,

hard, crystalline substance, which melts at 28 deg. Cent., and compressed it exactly as in the case of the metallic powders.*

He took the precaution to place a shot of lead on the top of the powder before submitting it to compression; only imperfect union of the particles of the phorone resulted.

The conclusion of the experiment proved that the shot remained where it had been placed at the top of the column, and therefore the 28 deg. necessary to melt the substance had not been evolved, for if it had, the shot must have fallen through the fluid mass. I think, then, it is absolutely safe to conclude that, in the compression of bismuth, for instance, there can be no question of the evolution of the heat necessary for the fusion of the metal. There is, however, other evidence to which I may incidentally appeal.

M. Spring has shown that by compressing powders together, chemical combination may be induced, and he has, in this way, produced arsenide and sulphide of zinc, sulphide of lead and of bismuth, and arsenide of lead. These are not merely intimate mechanical mixtures. Take, for instance, the sulphide of magnesium produced by compression; it is soluble in hot water; treatment with dilute hydrochloric acid evolves sulphureted hydrogen, which is not the case with mere mixtures of magnesium and sulphur. Further, Spring has shown that by pressure a body may be made to pass from one allotropic state to another. Plastic sulphur is, under a pressure of 6,000 atmospheres, compelled to pass into the condition of octahedral sulphur, an allotropic state which possesses a greater density. And he points out that a solid metal (not powders of metals) may have cavities obliterated by pressure, but that matter cannot be permanently compressed by pressure, unless it can assume an allotropic state of greater density than the one it possesses at the moment of compression.†

Now let me point to the evidence these experiments afford as to the relation between solid metals and fluids. Members of the Royal Institution will know that Faraday discovered, in 1850, that two fragments of ice pressed against each other will unite, tendency to their union being considerable when the fragments are near their melting point. We also know what splendid service the regelation of ice has afforded in the hands of Dr. Tyndall, in explaining the formation of glaciers.

Ice owes its movement, not to viscosity, but to regelation, and the union of fragments of ice under compression is due to regelation. The facts which have been appealed to, and the theories which have been formed, respecting the regelation of ice, are too well known to you to demand lengthy notice from me. I will only observe that bismuth, like ice, expands on solidifying; and although Faraday failed to establish the existence of a property similar to regelation in bismuth, an eminent engineer, Mr. Thomas Wrightson, to whom we owe a series of experiments on the fluid density of metals, has satisfied himself by experimental evidence that regelation exists in bismuth. Now, in explaining Spring's results, we are met by this difficulty: the union of the particles of the metals cannot, in all cases, be due to viscosity, because viscous bodies are always capable of being stretched, and we find the welding taking place between the compressed powders of bodies such as zinc and bismuth, which, when submitted to traction, will not stretch. Spring therefore asks, "Is it possible that regelation may have something to do with the union of the powders?" and he urges, "Is it safe to conclude that regelation is peculiar to water alone?" "It is difficult to believe," he adds, "that in the large number of substances which nature presents to us, but one exists possessing a property of which we can find only minute traces in other bodies. The sum of our chemical and physical knowledge is against such a belief, and therefore the phenomenon of regelation may be pronounced in ice without being absolutely wanting in other bodies. To ascertain whether this is so, it is necessary to submit various bodies to the conditions under which the phenomena can be produced." "What," he asks, "are these conditions?" and he answers, "The pressure supported by the body, a certain degree of temperature, and time."

Helmholtz and Tyndall have shown that when the pressure is weak, the regelation of ice is effected slowly. Spring points out that nitrate of sodium and phosphate of sodium, in powder, left to themselves in bottles become coherent, and if the coherence in these and other chemical compounds is but weak, it is simply because the points of contact between the particles of powder are but few.

If, on the other hand, metallic or other powder be submitted to strong compression, the spaces between the fragments become filled with the debris of the crushed particles, and a solid block is the result. Finally, it may be urged that this union of powders of solid metals under the influence of pressure, that is to say, the close approximation of the particles, can be compared to the liquefaction of gases by pressure.

At the first view this comparison may appear rash or strained, but it is nothing if we accept the views of Clausius on the nature of gases and liquids. In a gas the molecules are free, but if by pressure at a suitable temperature the molecules are brought within the limits of their mutual attraction, the gas may be liquefied, and under suitable thermal conditions solidified. The mechanical pulverization of a metal merely detaches groups of molecules from other groups, because the mechanical treatment is imperfect, but the analogy between the solid and a gas has, in a sense, been established; filing has coarsely gasified the mass, but pressure will solidify it, as you have already seen.

It is possible that in some of these metallic blocks, the particles are not actually united by the pressure, which may, nevertheless, develop the kind of "mutual attraction" contemplated by Sir W. Thomson as existing between two pieces of matter at distances of less than ten micro-millimeters.

There are two other properties which solid metals possess, in common with certain fluids, to which I must briefly allude. The first is the power of dissolving gas, which metals in the solid colloid condition possess. I will not offer any experimental illustration on this point, because the work of Graham has been fully

dealt with in this theater by Dr. Odling; and I have, in a course of lectures recently delivered here, shown that just as solid palladium occludes hydrogen, so the alloy of rhodium and lead occludes oxide of nitrogen, which it gives up with explosive violence on heating *in vacuo*, suggesting an analogy with fluid nitro-glycerine. The last property I have to submit to you is the power which certain solid metals possess of taking up fluids, sometimes with a rapidity which suggests the miscibility of ordinary fluid substances.

In reference to this I have found an interesting paper published so long ago as 1713, by the Dutch chemist Homberg,* "On substances which penetrate and which pass through metals without melting them." He enumerates several substances which will pass through the pores of metals without disturbing the particles, and he points out that mercury penetrates metals without destroying them. Few of us are, I think, familiar with the rapidity with which mercury will pass through tin. Here is a bar, 1 in. wide and $\frac{1}{2}$ in. thick; if a little mercury be rubbed lightly on it, the mercury will in thirty seconds penetrate the mass, so that it breaks readily, although before the addition of the mercury, the bar would bend double without any sign of fracture.

With regard to the vaporization of solid metals, time will only permit me to remind you that Demarcay† has shown that *in vacuo* metals evaporate at much lower temperatures than they do at the ordinary atmospheric pressure, and he suggests that even metals of the platinum group will be found to be volatile at comparatively low temperatures. Merget‡ has shown that the solidification of mercury by extreme cold does not prevent the solid metal evaporating into the atmosphere surrounding it.

With regard to the remaining properties on my list, you will say, Surely, solid metals do not show any tendency to diffusion? I have shown§ that in the case of molten metals the interdiffusion may be extremely rapid, but, with regard to solid metals, some experiments conducted by Sir Frederick Abel prove that carbon can pass from a plate of richly carburized iron to one of iron free from carbon, against which it is tightly pressed. This passage of carbon takes place at the ordinary temperature, and it is difficult to explain the transference of matter without admitting the presence of some action closely allied to the diffusion of liquids.

Finally, can we offer any evidence of surface tension in solid metals? There is only one experiment to submit to you illustrating a point I am still investigating. Some months since, Mr. F. W. Fletcher, manager of the works of Messrs. C. Ash & Sons, the well-known dealers in the precious metals, pointed out to me an interesting property of a hard-drawn rod or thick wire of 13 carat gold; the gold being alloyed with silver or copper in the following proportions:

Gold.....	54.17
Copper.....	33.33
Silver.....	12.50
	100.00

If such a rod be touched with a solution of chloride of iron or certain other soluble chlorides, it will, in a short time, varying from a few seconds to some minutes, break away, as is shown in the diagram, Fig. 14, the fracture rapidly extending for a distance of some inches.

[The image of the rod was projected on the screen, and in a few seconds after the rod was touched with chloride of iron, it split close to the point of contact with the solution.]

This result may be attended with the absorption of gas, but, in any case, it would appear that in the hard-drawn rod the surface is in a state of tension, which is released by the action of the chloride.

The facts we have considered afford additional evidence as to continuity in the properties of all kinds of matter, and serve as a connecting link with the work of the past, the importance of which is too often overlooked. I trust it will be evident that the analogy of solid metals to fluids has an important bearing on the labors of those who are striving to advance science, to develop art, or to promote the industrial well-being of this country.

GOSSYPIN.

THE COLORING PRINCIPLE OF COTTON SEED.

THE quantity of cotton seed annually crushed and pressed for oil in the United States probably equals two and three-quarter millions of tons, and if we add to this the half million tons similarly treated in Europe, the proportions of this giant infant industry begin to appear. As expressed, the oil is of an intense ruby color, sometimes verging to black, owing to its containing in solution a powerful vegetable coloring principle, properly termed gossypin. This peculiarity distinguishes it from all other oils. The oil cells appear in the seeds as brown specks dispersed through the albuminous matter. According to Mr. James Longmore, of the Liverpool section of the Society of Chemical Industry, who has given great attention to the subject, the quantity of coloring matter in a ton of crude oil is fifteen pounds, although this proportion must vary considerably. The woody husk of the seed also contains a large quantity apparently of the same nature. Its properties are insolubility in acids, slight solubility in water, free solubility in alcohol or alkalies. In its dry state it is a light powder of a pungent odor, of a brown color, and strongly tinctorial.

For expression, the seeds are first crushed by passing through rollers, and then ground to a fine state of division under edge wheels. When sufficiently reduced, the powder is transferred to steam-jacketed kettles, and heated for about ten minutes to a temperature sufficient to render the oil more easily expressible, and to coagulate the albumen of the seed. From the kettles the hot and finely ground seed is put in coarse bags, each making a cake weighing about ten pounds, and subjected to powerful hydraulic pressure. The crude, nearly black oil, containing the coloring matter in solution, is by this means expressed, and runs into a tank from which it is transferred to the refinery. The next

step is the removal of the coloring matter, the process bringing the oil to a light straw or yellow tint.

The tank used is of iron; it is provided with a mechanical agitator, and its capacity sufficiently exceeds that of the charge of 10 tons weight of crude oil and 30 cwt. caustic soda lye of 10° to 12° Twaddell. The lye, at the temperature of 60° F., is fed slowly by perforated pipes extending over the surface of the oil and distributing uniformly. As the agitation proceeds, the lye and oil, which are both cool, mix, and the latter gradually becomes full of black flocculent particles of soap caused by the partial saponification of a portion of the oil by the caustic soda lye. The agitation is continued for about half an hour, and at the end of that time a portion is taken out and allowed to stand. If the soapy particles precipitate, and the oil is found nearly deprived of color, the operation is then terminated. If not, the agitation is continued, more lye being added until the desired decoloration is obtained. The charge of oil is then allowed to stand for twelve or fifteen hours, until the "mucilage" or partially saponified portion of the oil, with the liquid excess of lye used, has settled away. The clear oil is then run off, and the refining completed by washing and bleaching.

The success of this process evidently depends on the property the coloring matter possesses of solubility in alkalies. The particles of soap seem to be sufficiently alkaline at the moment of forming to inclose within them the coloring matter, which is thus precipitated from the rest of the oil. After separation the precipitate is treated with strong soda lye, say 70° Twaddell, and heated. The coloring matter is thus dissolved out, the solution carefully filtered from the saponaceous mass, and dilute sulphuric acid gradually added to the filtrate until the alkali is completely neutralized. The gossypin then separates as a flocculent precipitate. This is collected on a filter, carefully washed to remove any trace of acid, and dried slowly at a low temperature. It is then ready for use as a dye, and gives fast colors on both wool and silk. The saponaceous mass, partially decolorized by the caustic soda lye, may either be converted into hard soap, or, by addition of milk of lime, be deprived of any albuminous matter, be bleached with chlorinated lime (chloride of lime), and by treatment with a mineral acid, the refined oil mingled with fatty acids obtained.

To dye wool with gossypin, take for every ten pounds of yarn seven ounces of the dye dissolved with seven ounces of soda crystals in sufficient water, and boil for three hours. Another method is to prepare the bath by dissolving the gossypin with the requisite amount of soda crystals, and then precipitate it with just the quantity of sulphuric, hydrochloric, or acetic acid necessary to render the solution neutral. The coloring matter remains in suspension in a very fine state of division. In this state it is taken up by the wool immediately. The operation is shortened, but the wool is liable to be surface-dyed only, and in the operation of scouring the shade will be much lightened. No more sodium carbonate should be used than is absolutely necessary to dissolve the dye, as the attraction of the alkali neutralizes the attraction of the wool for the coloring matter. A richer shade is obtained by using wool previously mordanted in the usual manner by working in a bath of potassium bichromate; this deepens the shade, giving a warm brownish-red.

The shades and colors can be varied to any extent by combinations with other coloring matters, especially the anilins, with which gossypin seems to possess the property of forming definite compounds, the nature of which has not been fully investigated. These are formed by dissolving equal weights of gossypin and soda crystals in water. To the strained solutions thus obtained add a previously prepared solution of the anilin dye, the strength and quantity of the latter being governed by the shade required. The whole is then thoroughly mixed, and dilute sulphuric acid is slowly poured in until the neutralization is effected. The coloring matters precipitate, and are separated, washed and dried. They are not decomposed by boiling water; they possess much of the brilliancy of the anilin, and of the quality of fastness of vegetable dyes. The proportion of the former required is therefore much reduced.

The methods of dyeing silk are analogous to those described for wool.

If the coloring matter is heated to the boiling point with its own weight of soda crystals and six times its weight of water, the whole being stirred until dissolved, it will on cooling set to a paste, and in this form it is very readily soluble. For some purposes this may be more convenient than the dry powder.

Unless the dyeing be very carefully conducted, a faint feeling of harshness is imparted to the wool. This may be a natural property of the dye; but it is more likely to be due to the alkaline treatment through which it passes in the process of preparation, and will probably yield to further experiment.

CENTENARY OF PARMENTIER.

THE city of Montdidier, where the philosopher Parmentier was born, on the 17th day of August, 1737, has recently celebrated the centenary of one of the most memorable events in the history of useful discovery, that is, the culture of the potato, which has so often been called the "poor man's bread." We, in our turn, also wish to do reverence to a man who signalized himself by the most important services.

It has been said that the potato reached Europe much before Parmentier's time, in the 17th century, and even in the 16th, according to some historians. Mr. Virey has demonstrated that the right of priority belongs to the Spaniards, who, in the first half of the 16th century, were propagating this valuable product of the American soil in their European possessions. This appears to be indisputable. Much has been written upon this subject, but it is nevertheless true that the potato was nearly ignored when Parmentier resolved to cultivate it, and that it is to him at least that our country is indebted for the benefits of it. Parmentier's life was a glorious one, and he consecrated it with rare devotion to the interests of his fellow man. He was an orphan at an early age, and entered a pharmacy as a student before he had finished his studies. In 1757 he went as a hospital steward into the army of Hanover, where he conducted himself with great energy. He was five times made prisoner during the war, and remained a prisoner in Prussia until the end of the campaign.

On returning to Paris, in 1768, he resumed his studies,

* Bull. Soc. Chim., Paris, 1884, t. xli., page 488.

† "Sur l'élasticité parfaite des corps solides chimiquement définis," Bull. Acad. Roy. Belgique [3], t. vi., 1883.

* Mem. de l'Acad. Royale des Sciences, 1713, p. 306.

† Comptes Rendus, xcv., p. 183 [1882].

‡ Ann. de Chim. et de Phys. [4], xxv., 121.

§ Report British Association, 1883, p. 402.