but in the later hours it produced an increase of from 4·3 to 11·0 per cent. The reaction of the organism to a constant environmental condition was thus a variable one. This is probably explicable by the fact that the temperatures necessary to kill the organisms, and presumably also those which cause an unfavourable effect on growth, rise steadily during development. Thus the death temperature is about 28·5° for unsegmented ova, 34° for blastulæ, and 40° for plutei.

The impregnated ova were also found to be much more sensitive to changes in the salinity of the water during the early stages of development than during the later ones.

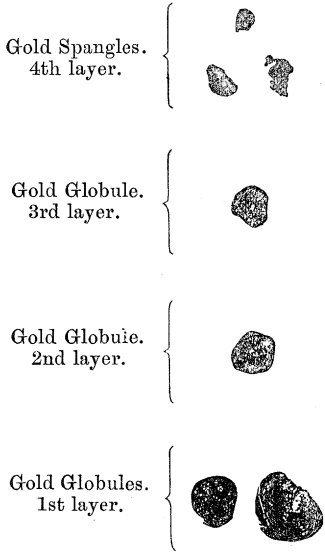
"On the Diffusion of Gold in Solid Lead at the Ordinary Temperature." By Sir W. Roberts-Austen, K.C.B., F.R.S., Professor of Metallurgy, Royal College of Science. Received April 5,—Read May 10, 1900.

In the Bakerian Lecture, "On the Diffusion of Metals,"* delivered in 1896, evidence was given to show that gold placed at the base of a column of fluid lead 16 cm. high, maintained at a mean temperature of 492°, or 166° above the melting point of lead, diffuses to the top of the column in an appreciable amount in a single day, the diffusivity expressed in centimetre-day units being 3·0. If the lead be heated, say to 251°, or 75° below the melting point of the metal, diffusion takes place at a much slower rate; it may still be readily measured, though the diffusivity is only 0·023 in centimetre-day units. In the experiments on diffusion in solid lead, the latter metal was prepared with great care, and possessed a high degree of purity. The method of preparation consisted in the reduction of carefully purified carbonate of lead by cyanide of potassium, the reduced metal being cast in carbon moulds.

It became evident that at the ordinary temperature the rate of diffusion of solid gold in solid lead must be very slow, and I stated in the Bakerian Lecture that cylinders of lead had been set aside with discs of gold affixed to their bases, in order that, after a sufficient lapse of time, the diffusion occurring at the ordinary temperature might be measured. By the month of March in the present year, four years had elapsed since the experiment began, and the time appeared to be sufficiently long to justify the attempt to ascertain how far the gold had diffused. In starting the experiments the bases of the lead cylinders were carefully brought to a smooth surface, and the discs of pure gold were specially cleaned, the discs of gold being held against

* Delivered February 20, 1896. 'Phil. Trans.,' A, vol. 187 (1896) pp. 383—415.

the bases of the cylinders by means of clamps. The laboratory in which the cylinders were placed consists of a vaulted chamber situated in the basement of the Mint, and its temperature varied but little from a mean of 18° C. The diameters of the cylinders were in all cases 0·88 c.m., their lengths varied somewhat, the longest being 25 cm. At the end of the four years the discs of gold were found to be adherent to the lead. The cylinders were divided into thin slices at right angles to the axes of the cylinders, the first slice was approximately 0·75 mm. thick, but the succeeding layers were about 2·3 mm. thick. By the ordinary methods adopted by assayers, which were conducted with extraordinary precautions, gold was found in each of the four lower slices, while only the minutest traces of gold could be found in any slice beyond the fourth from the base. The amount of gold that had diffused in the different cylinders of lead was, however, not uniform. The variation is probably due to difference in contact



between the cylinders of lead and the discs of gold. The results in all four experiments were, however, of the same order, and it will be sufficient to give the actual amounts of gold found in a single cylinder. The richest layer was, of course, the one in direct contact with the gold, and from it a globule of gold was extracted which weighed 0·00005 gramme. There is in the Mint a balance that will readily weigh such globules. The gold extracted from the 2nd and 3rd layers was too small to be weighed, but the amounts could be approximately determined by measurement under a microscope. Actual

photographs of the gold extracted from the successive layers of a cylinder are, moreover, appended; the magnification being in all cases the same (56 diameters).

It may be thought that the amounts are but small, but from the point of view of the assayer, who is accustomed to determine minute quantities of precious metal in large masses of material, the results assume very substantial proportions. Thus the amount of gold found in the richest layer of lead represents no less than 1 oz. 6 dwts. of gold per ton, which could be profitably extracted, while the amount in even the poorest layer is $1\frac{1}{2}$ dwt. per ton.

The significance of these results may perhaps be made clearer if it is stated that the amount of gold which would diffuse in solid lead at the ordinary temperature in 1000 years is almost the same as that which would diffuse in molten lead in a single day, provided no more gold is supplied in either case than can be held in solution. This will serve to show how important temperature is in relation to diffusion. As an example of the relative effects of temperature on this purely physical change and on a chemical change, it may be interesting to refer to the case of the dissociation of auric chloride. At the ordinary temperature, the tri-chloride of gold is very stable though it decomposed rapidly at 180°, and my colleague, Dr. Rose,* has shown that though the decomposition of auric chloride may be perceptible at a temperature of 70°, it would nevertheless require, at that temperature, about twenty-five years for its nearly complete change into mono-chloride.

I believe, with Robert Boyle, that though solid gold may have its "little atmosphere," "no man has yet tried whether gold may not in time lose its weight," but the rate at which gold can possibly evaporate into the air at the ordinary temperature must be far less than that at which it diffuses into lead. This shows that the action of a solvent for the gold is necessary, and this solvent is provided by bringing gold into contact with *solid* metallic lead.

I would express my warm acknowledgment to Dr. A. Stansfield, who aids me in conducting the Metallurgical Laboratory at the Royal College of Science, for the care he has devoted to the tedious manipulation involved in these experiments. His help has given me great confidence in the accuracy of the results. It may be well to add that I propose to prepare suitable cylinders of lead and gold on the lines indicated in this paper, and to offer them to the National Physical Laboratory with a view to their being examined after such a lapse of time as may be deemed fully adequate.

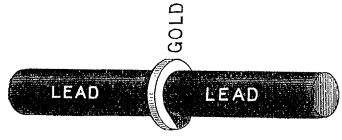
[*Note, May* 28.—In the Graham Lecture, delivered at Glasgow on the 18th of April last, after speaking of the diffusion of gold in solid lead,

* 'Journ. Chem. Soc.,' vol. 67 (1895), p. 904.

I stated that I was "trying to ascertain whether diffusion in the solid metal is, or is not, accelerated by the simultaneous passage of a strong electric current." I again referred to the subject in answer to Lord Kelvin during the discussion which followed the reading of the present paper, and stated that the experiments were incomplete. Such experiments take a long time, and it may be well to add that the arrangement was just as is described above, except that the lead ordinarily used for assaying was employed. Two cylinders, each 0·88 cm. in diameter, with gold clamped to their respective bases, were maintained at a temperature of 150° for 544 hours, beginning on the 31st of January of the present year. A current of 1·5 ampères was passed through one of the cylinders only during the whole time, the current passing from the gold to the lead. The amount of gold which had diffused into each of the lead cylinders was then ascertained by the method which has already been described. Gold was detected at a height of 7·5 mm. in the case of the cylinder through which the current had passed, while in the other case with no current it had reached a height of 10 mm., the amount of gold in each section being also greater. Subsequent experiments showed that a part at least of this difference was due to imperfection in the contact between the lead and the gold. Other experiments are now in progress in which far greater current densities are employed.

If these experiments confirm the previous one, they will show that a solution of gold in lead does act, to a small extent, as an electrolyte. The following method was adopted for ensuring contact between the gold and the lead:—

My assistant, Mr. W. H. Merrett, succeeded in joining by fusion discs of gold between two cylinders of lead, as is shown in the accompanying figure. Contact between the metals is, therefore, above re-



proach, but it will be many weeks before the results can be recorded.

Thirteen years ago I was unsuccessful in the attempt to electrolyse a solution of gold in metallic lead by the passage of a current of 300 ampères through the molten mass.* The failure may have been due to the fact that at the high temperature produced diffusion must have been very rapid. If, therefore, separation of gold from the lead did take place, uniformity of the solution may have been restored by diffu-

* British Association Report, 1887, p. 341.

sion. I succeeded in 1895 in obtaining some evidence as to the separation of gold from its solution in metallic lead by electrolysis through a glass septum.* This is, however, only indirectly connected with the electrolysis of alloys.]

"On Certain Properties of the Alloys of the Gold-Copper Series."

By Professor Sir W. Roberts-Austen, K.C.B., F.R.S., and T. Kirke Rose, D.Sc. Received and read May 10, 1900.

[Plate 1.]

Notwithstanding the extraordinary importance from a technical point of view of the members of this series, which constitute the gold coinages of the world, singularly little is known respecting either their molecular constitution or even their physical constants. Both the authors of this paper possess unusual facilities for studying them, and they felt that time should not be lost in beginning a systematic examination of the series. The other alloys used for coinage have, on the other hand, not been so neglected. Many years ago one of us,† in submitting his first paper to this Society, gave a curve representing the freezing points of the members of the silver-copper series. This curve, corrected in accordance with more recent work and interpreted in a modern way, proved to be one with two branches meeting at a point where the eutectic alloy of the two metals occurs. The presence of the eutectic has also been since readily detected in standard silver and in several other members of the series, and possesses a melting point of 778°. As is well known, different portions of a mass of any of the solidified alloys of the silver-copper series, except the eutectic alloy, exhibit divergences in composition which usually amount to about two or three parts in a thousand.

The gold-copper series, on the other hand, has long enjoyed a reputation for homogeneity, and it was supposed that the variations in the composition either of the alloy which contains 916·66 parts of gold in 1000, and is used for the coinage of the Empire, or of the alloy which contains 900 parts of gold in 1000, and is one adopted by the Latin Union and in the United States of America, need not exhibit greater divergences than 0·1 part in 1000. It was, moreover, believed that such a divergence was not the result of any systematic molecular grouping. This view was shaken by one of us‡ in 1895, when evidence was obtained by chemical analysis that in the case of a gold-

* Third Report to the Alloys Research Committee, 'Proc. Inst. Mech. Engineers, 1895, p. 240.

† Roberts-Austen, 'Roy. Soc. Proc.,' vol. 23 (1874), p. 481.

‡ Rose, 'Chem. Soc. Journ.,' vol. 67, 1895, p. 552.

Gold Spangles.
4th layer.

Gold Globule.
3rd layer.

Gold Globule.
2nd layer.

Gold Globules.
1st layer.


GOLD
LEAD
LEAD