Previously it had been known as the Senate House Examination, and this name continued long afterwards and for more than thirty years was still printed as a heading to the papers set. It was only as a means of distinguishing it from the Classical and other newer Triposes that the name Mathematical Tripos gradually came into use. By the regulations which took effect in 1828 a totally distinct series of papers were set to the poll-men, who then formed the fifth and sixth classes. The fiction of regarding the poll-list as a continuation of the list of mathematical honours still lingered till 1858, the names being arranged in order of merit in four classes called the fourth, fifth, sixth, and seventh; the fourth class being in theory supposed to be the next class to that of the junior optimes.

(To be continued.)

THE COLOURS OF METALS AND ALLOYS[1]

THIS lecture is published by request, but the author fears that, dealing as it does with the colours of metals, such interest as it may have possessed when delivered will be greatly diminished in the absence of the experiments and diagrams by which it was illustrated.

I begin with no ordinary pleasure the work which has been intrusted to me by the Council of the British Association. It is nearly twenty years since this series of lectures was established. The first, on "Matter and Force," was delivered at Dundee by a brilliant experimenter and one of the most eloquent living exponents of science; it was followed, at Norwich, by a lecture by Prof. Huxley, to whom the nation owes a deep debt of gratitude for his intense sympathy with all who are seeking to widen the bounds of scientific knowledge—to be whose colleague in one of the most important scientific schools of the country is my great good fortune. These lecturers were succeeded by other eminent men, among whom may be mentioned Spottiswoode, Bramwell, and Lubbock. The object of the lectures is to diffuse a knowledge of the operations of Nature, and to add to the number of those who rejoice in her works. Many, therefore, who have spoken to audiences similar to this, have appealed to natural phenomena; and instead of talking to you about the colour of metals, I also should have liked to dwell on the colour of the sea and sky, but Ruskin's works are, I know, often in your hands, and he has told you once for all of the colour of clouds that "there is not a moment of any day of our lives when Nature is not producing scene after scene, picture after picture, glory after glory, and working still upon such exquisite and constant principles of the most perfect beauty that it is quite certain it is all done for us, and intended for our perpetual pleasure."[1] The metallurgist, however, cannot speak with authority on themes such as these; and I have therefore selected a subject which will, I believe, enable me to bring before you important truths affecting a wide range of industrial operations, and at the same time to sustain the true function of art by pointing to the direction in which we may have increased pleasure in things that constitute our most ordinary possessions, and which we use in daily life. First permit me to explain that I intend to include under the title of the lecture any facts which are, in my opinion, connected with the colours of metals and alloys, whether natural to them or produced by artifice, as well as a brief examination of the influence which the colours of metals appear to have exerted on the history of science.

I propose to begin at what will appear to be a somewhat remote starting-point. We say that copper is red, gold yellow, and silver white, but it is by no means certain that the early races of the world had any very clear perception of the difference between these several metallic colours. With regard to early Hebrew and Greek civilisation, Mr. Gladstone has expressed his belief that the colour-sense—that is the power of recognising colour and distinguishing it from mere brightness or darkness—was imperfectly developed, and he considers that "the starting-point is absolute blindness to colour in the primitive man," and he urges that the sense of colour has been gradually developed "until it has now become a familiar and unquestioned part of our inheritance." He adds: "Perhaps one of the most significant relics of the older state of things is to be found in the preference (known to the manufacturing world) of the uncivilised nations for strong and, what is called in the spontaneous poetry of trading phrases, loud colour."[2]

Dr. Magnus holds the view that the colour-sense in man has undergone a great improvement within the last 2000 years, and Prof. Haeckel supports this speculation, but it is opposed by Romanes, who has favoured me with some observations on the subject, in view of this lecture; and it seems to me strange, if savage nations are really deficient in the sense of colour, that the use of such colours as they can get in metals and fabrics, blended, for instance, in a war-club or a pipe-stem, should be so thoroughly "understood" and so discriminatingly employed as we sometimes find them to be. It may further be observed that primitive man may even have derived from his more remote ancestry some power of being influenced by colour, and we are told that the attraction which gorgeous colouring in flowers has for birds and insects, and which colour generally possesses for our nearer ancestors, has been of great importance in the origin of species, and in the maintenance of organic life.

No doubt, in ancient times, there was much confusion between mere brightness and colour, such as is evident in the beautiful sentence in which St. Augustine[3] says: "For this *queen of colours, the light*, bathing all which we behold, wherever I am through the day, gliding by me in varied forms, soothes me when engaged on other things and not observing her." If, however, it were proved that the power of distinguishing the colour of metals was not widely diffused among the Egyptians, Hebrews, and Greeks, it is at least certain that there were individuals of these nations to whom, in very early times, the colour of metals was all-important; and although they may have confused different precious stones under generic names, they certainly appreciated their various colours, and knew, moreover, that by fusing sand with the addition of a small quantity of certain minerals, they could produce artificial gems of varied tints.

a stoole before Mr. Proctours" and to dispute with the "eldest son" (the foremost of the questionists), and afterwards with "the father" (a graduate of the College to which the "eldest son" belonged, representing the paternal character of the College). At this time the only "Tripos" was the three-legged stool on which the Bachelor sat. A century later this Bachelor seems to have become a sort of licensed buffoon, and to have been called "Mr. Tripos," just as a president is sometimes referred to as "the Chair," or a judge as "the Bench." During the 120 years in which the name Tripos or Tripus indicated a personage there are frequent allusions to the humorous orations delivered in the schools by those who filled this office. These were known as Tripos speeches. It is probable that Mr. Tripos ceased to take part in the arguments in the schools between 1730 and 1750, just about the time when the Senate House examination was originating. The Tripos speeches were then replaced by copies of Latin verses, which were circulated on the admission days. These were called Tripos verses. About 1747 the Moderators began the custom of printing Honour lists on the back of the Tripos verses. Thus the list of Honours in the Senate House examination came to be called the Tripos list, so that a man's name was said to stand in such a place in the Tripos of his year, *i.e.* upon the back of the Tripos verses. And, lastly, the name was transferred from the list to the examination, the results of which were published in the list. This account is abridged from Wordsworth's *Scholæ Academicæ*, chap. ii. Wordsworth concludes: "Thus, step by step, we have traced the word *Tripos*, passing in signification, Proteus-like, from a thing of wood (*olim truncus*) to a man, from a man to a speech, from a speech to two sets of verses, from verses to a sheet of coarse foolscap paper, from a paper to a list of names, and from a list of names to a system of examination."

[1] A Lecture delivered on September 3 by Prof. W. Chandler Roberts-Austen, F.R.S., to the Operative Classes in the Town Hall of Birmingham, in connection with the meeting of the British Association.

[1] "Modern Painters," vol. i. part 2, p. 201, 1851.

[2] *Nineteenth Century*, p. 367, 1877.

[3] "Confessions of St. Augustine." Edition edited by E. B Pusey, D.D. (p. 211).

My object in leading you so far back—in discussing what appears to be a very matter-of-fact subject—is to point to the close connection between the early recognition and appreciation of colour in metals or minerals, and the foundation of the science of chemistry.

In early scientific history the seven metals known to the ancients were supposed to be specially connected with the seven principal planets whose names they originally bore, and whose colours were reflected in the metals; thus gold resembled the sun, silver the moon, while copper borrowed its red tint from the ruddy planet Mars. The belief in the intimate relation between colours and metals, the occult nature of which they shared, was very persistent, and we find a seventeenth-century writer, Sir John Pettus, saying[1] that "painters" derive "their best and most proper colours from metals whereof seven are accounted the chief, produced from the seven chief metals, which are influenced by the seven planets." A survival of this feeling is suggested by a modern writer, Leslie, who supposed that "when Newton attempted to reckon up the rays of light decomposed by the prism, and ventured to assign to them the famous number seven, he was apparently influenced by some lurking disposition towards mysticism."[2]

It would be impossible for me to overrate the importance of the colour of metals in relation to scientific history, for the attempt to produce a metal with the colour and properties of gold involved the most intense devotion to arduous research sustained by feverish, hope, attended by self-deception and elaborate fraud, such as hardly any other object of human desire has developed. It led to despair, to madness, and to death; but finally, through all, alchemy prepared the way for the birth of chemistry, and for the true advancement of science.

In early times, as now, gold was an extremely desirable form of portable property, and its colour was, perhaps, held to be the most distinctive and remarkable fact about it. I may incidentally observe that the dominant idea of colour in connection with the metallic currency survives in the familiar phrase, "I should like to see the *colour* of his money," which curiously expresses a desire, tempered by doubt as to its fulfilment. On looking back, we find that, at least from the third to the seventeenth century, the colour of gold haunted the early experimenters, and induced them to make the strangest sacrifices, even of life itself, in the attempt to imitate, and even actually to produce, the precious metal. Let us see what kind of facts were known within the period I have indicated. In barbaric times, hammered pieces of gold, or gold beaten into thin sheets and plates, were used with coloured stones and coral for personal adornment. The next step was to make gold go further by gilding base metals with it, and, in order to do this, the colour was for the moment sacrificed by combining the gold with quicksilver. This was done at least in the time of Vitruvius, B.C. 80, heat being used to drive away, as vapour, the quicksilver which had been united to the gold, leaving a thin film of precious metal on the surface to be gilded. But this was possibly not the first method of gilding, for we now know, from a papyrus of about the third century[3] of our era, that lead was used for this purpose. Gold, when fused with lead, entirely loses its golden colour, and yet, by the application of heat in air, the lead may be made to flow away as a fusible oxide, leaving the precious metal on the metallic object to be gilt, the base metal being as it were transmuted, superficially at least, into gold. The point I want to insist upon is that the metallic colour of the gold vanished during the process as carried on by the craftsman, only to re-appear at the end of the operation; and I am satisfied that it was from such simple technical work as this that the early chemists were led to think that the actual production of gold—the transformation of base metals into gold—was possible. The more observant of them, from Geber, the great Arabian chemist of the seventh century, to our own countryman, Roger Bacon, in the thirteenth, saw how minute a quantity of certain substances would destroy the red colour of copper, or the yellow colour of gold. A trace of arsenic will cause the red colour of copper to disappear; therefore, the alchemists very generally argued, some small quantity of the right agent, if only they could find it, will turn a base metal to the colour of gold. Look, they said, how small a quantity of quicksilver will change the appearance of metallic tin. Here is a bar of tin 2 feet long and 1 inch thick, which it would be most difficult to break, though it will readily bend double. If only I rub a little quicksilver on its surface a remarkable effect will be produced, the fluid metal will penetrate the solid one,[1] and in a few seconds the bar will, as you see, break readily, the fractured surface being white, like silver. It was by such facts as this that men were led to believe that the white metal, silver, could be made.

Successive workers at different periods held divergent views as to the efficacy of the transmuting agent. Roger Bacon, in the thirteenth century, held that one part of the precious substance would suffice to turn a million parts of base metal into gold. Basil Valentine, in the fourteenth century, would have been content with the transmutation of seventy parts of base metal by one part of the agent. While, coming to the end of the eighteenth century, Dr. J. Price, F.R.S., of Guildford, only claimed that the substance he possessed would transmute from thirty to sixty parts of base metal.[2]

It is a curious fact that no one seems to have actually prepared the transmuting agent for himself, but to have received it in a mysterious way from "a stranger"; but I must not dwell on this. I will merely point out how persistent was the view as to the singular efficacy of the transmuting agent, and I will content myself with a reference to Robert Boyle, our great countryman, an accurate chemist of the seventeenth century, who did more than any one else to refute the errors of alchemy. He nevertheless characteristically records[3] the following experiment, in which, instead of ennobling a base metal, he apparently degraded gold to a base one. He first purified a small quantity of gold, about "two drachms," with great care, and, he states, "I put to it a small quantity of powder communicated to me by a stranger,"—it is singular that even he should have received the transmuting agent in the usual way,—"and," he adds, "continuing the metal a quarter of an hour on the fire, that the powder might diffuse itself through it, . . . the metal when cold appeared to be a lump of *dirty colour;* . . . 'twas brittle, and, being worked with a hammer, it flew into several pieces. From hence," he adds, "it appears that an operation almost as strange as that called 'projection'" (or transmutation) "may safely be admitted, since this experiment shows that gold, . . . the least mutable of metals, may in a short time be exceedingly changed . . . by so small a portion of matter that the powder transmuted a thousand times its weight of gold." He elsewhere observes of a similar experiment, "transmutation is nevertheless real for not being gainful, and it is no small matter to remove the bounds which Nature seems very industriously to have set to the alterations of bodies."[4] The change in the

[1] "Fleta Minor," 1686, Appendix, "Essay on Metallic Words.—Colour."
[2] "Treatises on Various Subjects of Natural and Chemical Philosophy."
[3] "Les Origines de l'Alchimie," par M. Berthelot, 1885, pp. 82, 89. It is interesting to compare the account of this method of gilding by lead with the expression used by Homer, who says: "As when gold is *fused* around the silver by an experienced man."—"Odyssey," vi. 232-35, quoted by Schliemann, "Ilios," p. 258, in relation to a gilded knife of copper which he permitted me to analyse in 1878.

[1] Homberg, *Mém. de l'Acad. Royale des Sciences*, 1713 (vol. published 1739), p. 306.
[2] "An Account of some Experiments on Mercury, Silver, and Gold made at Guildford, in the Laboratory of James Price, M.D., F.R.S.," Oxford, 1782.
[3] "The Philosophical Works of the Hon. Robert Boyle" (Shaw's second edition), 1738, vol. i. p. 78.
[4] *Ibid.* p. 262.

colour of the gold was remarkable, but Boyle had only produced one of the series of alloys most dreaded by every jeweller—"brittle gold"—for the way in which an alloy of gold and copper is affected by a small quantity of impurity presents one of the most serious difficulties in working gold. It has been known since the seventh century, that minute quantities of certain metals render gold brittle, and it may be well to demonstrate the fact.

Here are two hundred sovereigns: I will melt them and will add in the form of a tiny shot a minute portion of lead amounting to only the 2000th part of the mass, first, however, pouring a little of the gold into a small ingot, which we can bend and flatten, thus proving to you that it is perfectly soft, ductile, and workable. The rest of the mass we will pour into a bar, and now that it is sufficiently cold to handle, you see that I am able to break it with my fingers, or at least with a light tap of a hammer. The *colour* of the gold is quite altered, and has become orange-brown, and experiments have shown that the tenacity of the metal, that is, the resistance of the gold to being pulled asunder, has been reduced from 18 tons per square inch to only 5 tons. These essential changes in the property of the metal have been produced by the addition of a minute quantity of lead. I have cited these facts mainly to show that the changes produced in the colour and properties of metals by small variations of composition were such as to lead the alchemists on in their belief that it was possible to change lead or tin into gold, and the hope in which they worked enabled them to gather facts out of which chemical science was gradually constructed. We shall see presently that changes in the colour of metals and alloys produced by the addition of small quantities of foreign matter, are of great importance in the application of metals to artistic purposes, but we must first try to examine more closely some of the prominent facts connected with the colour of metals, that is, the effect metals have on light so as to produce the effect of colour in our eyes. We are apt to think of gold as being essentially and distinctively golden-yellow; it may, however, possess a wide range of colours without in any way losing the condition of absolute metallic purity, its relations to light depending entirely on the nature of its surface, and especially on whether the metal is in mass or in a more or less fine state of division. Interesting as gold is to us in mass (and I may incidentally mention that during my official connection with the Mint I have been responsible for the quality of 462 tons of it) it is perhaps still more interesting to us when beaten so fine that a single grain, of the value of 2*d.*, would cover a space of 48 square inches, or when it is so finely divided that the dimensions of a single particle may closely approximate to those of the ultimate atom.

This aspect of the question was investigated by Faraday, and the experimental part of the subject remains practically unadded to since his time. It is well known that a leaf of gold when seen by transmitted light is either green or blue, according to its thickness. Here is such a leaf of green gold, as seen when light is actually sent through it (Fig. 1), so as to project a green disk on the screen. A portion of the light will be *reflected* from its surface, and this reflected ray may be caught in a mirror and thrown on the screen so that you have, shown side by side, the green disk of transmitted light and the golden one of reflected light from the same leaf of gold.

Gold may readily be converted into a soluble chloride which produces a beautiful golden solution. If such a solution contains very little gold, not more than 2 grains in a gallon, and if certain chemical methods be adopted to precipitate the gold, that is, to throw it out of solution in a *solid*, though in a very fine state of division, the metal may exhibit a wide range of tint, from ruby to black.

[A few drops of phosphorus dissolved in bisulphide of carbon had been added to about a gallon of a very dilute solution of chloride of gold contained in a tall glass cylinder, as shown in the sketch (Fig. 2). The beam from an electric light, thrown through the vessel, revealed in the lower part the presence of finely-divided metal of the natural golden colour, while the more finely-divided gold in suspension imparted a brilliant ruby colour to the liquid, and a glowing ruby disk was projected on a white screen.]

When gold is in the "ruby" state, it is so finely divided that each particle probably approximates to the dimensions of the gold atom.

[The solar spectrum was then thrown upon the screen, and the audience was invited to compare it with a diagram which, while closely resembling the solar spectrum,

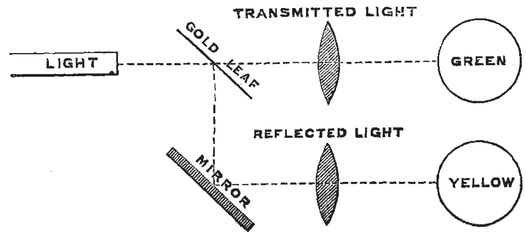

FIG. 1.

really represented the way in which pure metallic gold, prepared by various methods, is capable of behaving in relation to light so as to produce the sensation of a wide range of colours.]

It would be easy to show that light is similarly affected by other metals; but I have selected gold for the purpose of illustration because it is easy to maintain it in a state of purity, however finely divided it may be. We must therefore modify any views we may have formed as to a metal having exclusively a special colour of its own, because it

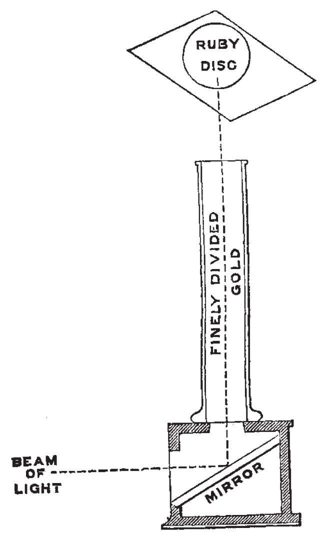

FIG. 2.

will be evident that a particular colour is only due to a definite state of arrangement of its particles. The intimate relation between the state of the surface of a metal and its colour is well shown by the beautiful buttons devised by Sir John Barton. He proved that if very fine lines be drawn close together, so that about 2000 would be ruled in the space of an inch, a beautiful iridescent effect is produced, the tints being quite independent of the metal itself due to an optical effect of the lines.

[The image of such a button was then thrown upon the screen.]

Let us now examine some effects of uniting metals by fusing them together into what are called alloys; and, second, the direct influence of a minute quantity of one metal in changing the mass of another in which it is hidden, and causing it to behave in a different way in relation to light, and consequently to possess a colour different from that which is natural to it; or the added metal may so change the chemical nature of the metallic mass that varied effects of colour may be produced by the chemical combinations which result from the action of certain "pickling" solutions. This portion of the subject is so large that I can only hope to set before you certain prominent facts.[1]

First, with reference to the colour produced by the union of metals. Here is a mass of red copper, and here one of gray antimony: the union of the two by fusion produces a beautiful violet alloy when the proportions are so arranged that there is 51 per cent. of copper and 49 per cent. of antimony in the mixture. This alloy was well known to the early chemists, but unfortunately it is brittle and difficult to work, so that its beautiful colour can hardly be utilised in art. The addition of a small quantity of tin to copper hardens it, and converts it, from a physical and mechanical point of view, into a different metal. The addition of zinc and a certain amount of lead to tin and copper confers upon the mettal copper the property of receiving, when exposed to the atmosphere, varying shades of deep velvety brown, characteristic of the bronze which has from remote antiquity been used for artistic purposes. But by far the most interesting copper alloys, from the point of view of colour, are those produced by its union with zinc, namely brass. Their preparation demands much care in the selection of the materials, and I might have borrowed from the manufacture of brass instance after instance of the influence of traces of impurity in affecting the properties of the alloy, but it is unnecessary to dwell upon this alloy in Birmingham, for in all that relates to the mechanical manipulation of the alloys of copper with tin and with zinc, you are masters. I have many inducements in this place to speak about this beautiful alloy. I am proud to be a namesake of the craftsman, William Austen, who, in 1460, made that magnificent monument in brass which covers the remains and commemorates the greatness of Richard Beauchamp, Earl of Warwick, and I am glad to remember that Queen Elizabeth granted the first patent for the manufacture of brass in England to William Humfrey, Assay Master of the Mint, a predecessor in the office it is my privilege to hold.

I want, however, to direct your attention to-night to some alloys of copper with which you are probably less familiar than with brass. In this direction Japanese art affords a richer source of information than any other. Of the very varied series of alloys the Japanese employ for art metal-work, the following may be considered to be the most important and typical. The first is called "shaku-dō"; it contains, as you will observe from Analyses I. and II.,[2] in

Shaku-dō.

I.		II.	
Copper	94·50	Copper	95·77
Silver	1·55	Silver	0·08
Gold	3·73	Gold	4·16
Lead	·11		
Iron and Arsenic	traces		
	99·89		100·01

addition to about 95 per cent. of copper, as much as 4 per cent. of gold. It has been used for very large works. Colossal statues are made of it; one cast at Nara in the seventh century being specially remarkable. The quantity of gold is, however, very variable; specimens I have analysed contained only 1·5 per cent of the precious metal. The next alloy to which I would direct your attention is called "shibu-ichi." There are numerous

Shibu-ichi.

III.		IV.	
Copper	67·31	Copper	51·10
Silver	32·07	Silver	48·93
Gold	traces	Gold	·12
Iron	·52		
	99·90		100·15

varieties of it, but in both these alloys, shaku-dō and shibu-ichi, the point of interest is that the precious metals are, as it were, sacrificed in order to produce definite results; gold and silver, when used pure, being employed very sparingly to heighten the general effect. In the case of the shaku-dō, we shall see presently the gold appears to enable the metal to receive a beautiful rich purple coat or *patina*, as it is called, when treated with certain pickling solutions; while shibu-ichi possesses a peculiar silver-gray tint of its own, which, under ordinary atmospheric influences, becomes very beautiful, and to which the Japanese artists are very partial. These are the principal alloys, but there are several varieties of them, as well as combinations of shaku-dō and shibu-ichi in various proportions, as, for instance, in the case of kiu-shibu-ichi, the composition of which would correspond to one part of shaku dō rich in gold, and two parts of shibu-ichi rich in silver. Interesting effects are produced by pouring two alloys of different tints together just at the solidifying point of the less fusible of the two, so that the alloys unite but do not blend, and a mottled surface is the result. These alloys are introduced into almost every good piece of metal-work.

Now as to the action of pickling solutions. Many of you will be familiar with the mysteries of the treatment of brass by "dipping" and "dead dipping," so as to produce certain definite surfaces, but the Japanese art metal-workers are far ahead of their European brothers in the use of such solutions.

The South Kensington Museum contains a very valuable series of fifty-seven oblong plates, some plain and others richly ornamented, which were specially prepared as samples of the various metals and alloys used by the Japanese. The Geological Museum in Jermyn Street has a smaller, but very instructive, series, of twenty-four plates presented by an eminent metallurgist, the late M. Hochstätter-Godfrey. From descriptions accompanying the latter, and from information I have gathered from certain Japanese artificers now in London, it would appear that there are three solutions generally in use. They are made up respectively in the following proportions, and are used boiling.

	I.	II.	III.
Verdigris	438 grains	87 grains	220 grains
Sulphate of copper	292 ,,	437 ,,	540 ,,
Nitre	—	87 ,,	—
Common salt	—	146 ,,	—
Sulphur	—	233 ,,	—
Water	1 gallon	—	1 gallon
Vinegar	—	1 gallon	5 fluid drachms

That most widely employed is No. I. When boiled in No. III. solution, pure copper will turn a brownish red; and shaku-do, which, you will remember, contains a little gold, becomes purple; and now you will be able to appreciate the effect of small quantities of metallic impurity as affecting the colour resulting from the action of the pickle. Copper containing a small quantity of antimony gives a shade very different from that resulting from the pickling of pure copper. But the copper produced in Japan is the result of smelting complex ores, and the

[1] A list of books and papers dealing with the colours of metals and alloys, and with the production of coloured patina, is given by Prof. Ledebur in his work "Die Metallverarbeitung," p. 285, 1882, published in Bolley's "Technologie."

[2] Analyses Nos. I. and III. are by Mr. Gowland, of the Imperial Japanese Mint at Osaka; Nos. II. and IV. by Prof. Kalischer, *Dingl. Polyt. Journ.*, ccxv. 93.

methods of purification are not so perfectly understood as in the West. The result is that the so-called "antimony" of the Japanese art metal-workers, which is present in the variety of copper called "kuromi," is really a complex mixture containing tin, cobalt, and many other metals, so that a metal-worker has an infinite series of materials at command with which to secure any particular shade; and these are used with much judgment, although the scientific reasons for the adoption of any particular sample may be hidden from him. It is strictly accurate to say that each particular shade of colour is the result of minute quantities of metallic impurity, and these specimens and diagrams will, I trust, make this clear, and will prove that the Japanese arrange true pictures in coloured metals and alloys.

[This portion of the subject was illustrated with much care by coloured diagrams representing specimens of Japanese art metal-work, by photographs projected on the screen, as well as by the reflected images of small ornaments made of the alloys which had been specially referred to. There was also a trophy of leaves of copper of varying degrees of purity coloured brilliantly by one or other of the "pickles" above described.]

There is one other art material to the production of which I hope art workmen in Birmingham will soon direct their attention, as its applications are endless. It is called in Japanese "mokume," which signifies "wood-grain." It is now very rare even in Japan, but formerly the best specimens appear to have been made in Nagoya by retainers of the Daimio of Owari. I have only seen six examples, and only possess a single specimen of native work, and have therefore had to prepare a few illustrations for you in soldered layers of gold, silver, shibu-ichi, shaku-dō, and kuromi.

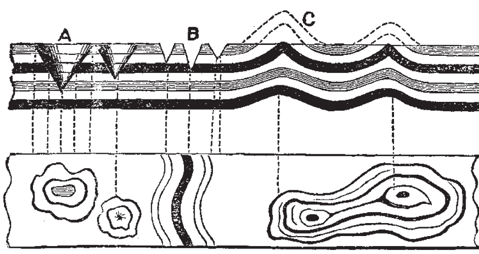

FIG. 3.

This diagram (Fig. 3) shows the method of manufacture. Take thin sheets of almost any of the alloys I have mentioned, and solder[1] them together layer upon layer, care being taken that the metals which will present diversity of colour come together. Then drill conical holes of varying depth, A, in the mass, or devices in trench-like cuts of V section, B, and hammer the mass until the holes disappear; the holes will thus be replaced by banded circles and the trenches by banded lines. A Japanese artificer taught me to produce similar effects by taking the soldered layers of the alloy, and by the aid of blunted tools making depressions on the back of the mass so as to produce prominences on the front, C. These prominences are filed down until the sheet is again flat; the banded alloys will then appear on the surface in complicated sections, and a very remarkable effect is produced, especially when the colours of the alloys are developed by suitable "pickles." In this way any device may be produced. In principle the method is the same as that which produces the *damascening* of a sword-blade or gun-barrel, and depends on the fact that under certain conditions metals behave like viscous solids, and as truly "*flow*" as pitch or honey does, only in the case of mokume the art workman has a wide range of tinted metals at command.

Throughout Japanese art metal-work, in which I hope you will take increasing interest, there is the one principle of extreme simplicity and absolute fidelity to nature. The brilliant metals, gold and silver, are used most sparingly, only for enrichment, and to heighten the general effect; these precious metals are never allowed to assert themselves unduly, and are only employed where their presence will serve some definite end in relation to the design as a whole. A Japanese proverb asserts that "He who works in gold puts his brains into the melting-pot," meaning, I suppose, that this metal, so precious from an artistic point of view, demands for its successful application the utmost effort of the workman, and suggesting that gold should not be employed in massive forms such as would result from melting and casting, but should be daintily handled, beaten on to the work, or embedded with the hammer.

Bear in mind that in Birmingham, when a really fine work is produced in silver, the surface is often made gray by chemical means, "oxidised," as it is termed, and this subordination of the brilliancy of silver to artistic effect, is well understood by the celebrated American firm, Messrs. Tiffany, of New York, who are doing so much to catch the spirit of Japanese art metal-work. All I ask you to do is to carry this still further—to cover base metals with these glowing coloured oxides, and thus to add to the permanence of art work, by producing surfaces which will resist the unfavourable atmospheric influences of our cities.

Hitherto we have considered the union of metals by fusion, but fire is not the only agent which can be employed for this purpose. Two or more metals may be deposited side by side by the aid of the electric battery. Birmingham was, as you well know, the early home of electro-metallurgy, an industry to the development of which the great firm of Elkington has so materially contributed. I have no statistics as to the amount of precious metals annually employed for electro-deposition in Birmingham, but it is known that a single works in Paris, belonging to M. Christofle, deposits annually six tons of silver, and it has been estimated that the layer of silver of the thickness actually deposited on various articles would, if spread out continuously, cover an area of 140 acres.[1] I will not, however, dwell upon the deposition of gold and silver in their normal colours. I would remind you that copper and zinc may be deposited by electrolysis so as to form brass, and that all the beautiful bronzes and alloys of the Japanese can be obtained by galvanic agency; and further, by suitable admixtures of gold, silver, and copper, red-gold, rose-coloured gold, or green gold may be deposited, so that the electro-metallurgist has at his command the varied palette of the decorative artist.

[The images of beautiful deposits of coloured gold, specially prepared by Messrs. Elkington, were then projected on the screen.]

I ought to allude to what has been called the moral aspect of colour, and although I cannot follow Goethe[2] in his attributes of colour, which seem to me to be fantastic and over-strained, I quite recognise the poetic sympathy of Shakespeare in making Bassanio select the casket of lead, which contained the warrant for his earthly happiness, because "its paleness moved him more than eloquence." I ask you to remember Ruskin's words, that "all men completely organised and justly tempered enjoy colour; it is meant for the perpetual comfort and delight of the human heart; it is richly bestowed on the highest works of creation, and the eminent sign and seal of perfection in them being associated with life in the

[1] The following solder was found to answer well:—

Silver	55·5
Zinc...	26·0
Copper	18·5
	100·0

[1] H. Bouilhet, *Ann. de Chim. et de Phys.* t. xxiv. p. 549, 1881.
[2] Farbenlehre.

human body, with light in the sky, with purity and hardness in the earth; death, night, and pollution of all kinds being colourless."

I must briefly turn to the concluding part of our subject. It has long been known that thin films of certain metals and certain metallic oxides act on light in the same way as thin films of other translucent substances. I have here such thin films of oxide of lead, which, many years ago, Nobili, Becquerel, and Gassiot taught us to deposit, and such films have since been used in decorative metal-work.

[Beautiful examples of such films were projected on the screen.]

I wish I had time to point to the great interest and importance of films of coloured oxide of iron in the tempering of steel, for it is well known that, apart from the scientific interest of the subject, the shades from straw-colour to blue which pass over the surface of hardened steel when it is heated in air, afford precious indications as to the degree of temper the metal has attained, and in no industry is this better shown than in the manufacture of steel pens. I must pass this over, and turn to one other instance of the formation of coloured films on metals. Here is an ordinary plumber's ladle filled with lead, which will soon be molten when it is placed over this flame. The air will play freely on the surface of the melted lead, and, as a certain temperature is reached, very beautiful films will pass over the surface of the metal. If the lead contains very minute quantities of cadmium or of antimony, the effect will be greatly heightened. If the light from the electric lamp be allowed to fall on the surface of the bath of lead, it will be easy to throw the image of the metallic surface on the screen, and you will see how beautiful the films are and how rapidly they succeed each other when the metal is skimmed. What, then, is the special significance of the experiment from our point of view? It represents in a singularly refined way the one experiment which stands out prominently in the whole history of chemistry; for the formation of a coloured scum on lead when heated in air has been appealed to, more thany any other fact, in support of particular sets of views from the time of Geber in the seventh century to that of Lavoisier in the eighteenth. It was the increase in weight of the lead when heated in air that so profoundly astonished the early chemists; and, finally, the formation of a coloured oxide by heating lead in air was the important step which led on your great townsman, Priestley,[1] to the discovery of oxygen; and, as the fact of his residence among you will never be forgotten, Birmingham may claim to have been connected, through him, with one of the most splendid contribution ever offered to Chemical Science.

[1] He pointed out that the experiment with minium confirmed his view that he mercury calcined in air derived oxygen *from* the air.

NOTES

PROF. RÜCKER, F.R.S., has been appointed by the Lord President of the Council to the Professorship of Physics in the Normal School of Science and Royal School of Mines, rendered vacant by the death of Prof. Guthrie, F.R.S.

AT the Royal Society on Thursday last (November 25) a paper was read by Sir Richard Owen, containing some further evidence on the structure of the very remarkable extinct marsupial, *Thylacoleo carnifex*. The author re-affirmed his previous statements that it was a carnivorous beast of the size of a lion, the probable prey of which had been the larger herbivorous marsupials, also now extinct. Prof. Flower, after reviewing the additional evidence that had been adduced, repeated his conviction expressed eighteen years ago in a paper read before the Geological Society, that the dentition of *Thylacoleo* found no parallel in any existing predaceous carnivore, but was formed on a totally different type, and that there was therefore no justification for assigning to it habits for which it did not seem particularly well adapted. The essential conditions in a dentition which would enable an animal to seize and overcome large and struggling prey, as seen in both lions, tigers, wolves, and the existing carnivorous marsupials, are large canines set well apart, with incisors so small as not to interfere with their piercing action; whereas in *Thylacoleo* the canines are rudimentary, and the central incisors greatly developed. The alternative, sometimes suggested, that the animal was herbivorous, was equally improbable. In fact, it would not be safe to do more than speculate on the habits or food of an animal the dentition of which was so highly specialised, and without any analogy in the existing state of things. Prof. Huxley said that he agreed with the conclusions of the last speaker.

A COURSE of six lectures, adapted to a juvenile auditory, on "The Chemistry of Light and Photography" (with experimental illustrations), will be given at the Royal Institution by Prof. Dewar, M.A., F.R.S., on the following days, at three o'clock:—Tuesday, December 28, 1886; Thursday, December 30; Saturday, January 1, 1887; Tuesday, January 4; Thursday, January 6; Saturday, January 8.

THE Royal Society have just received from Egypt a consignment of specimens of the different strata of soil in the Delta. The borings have been carried out to a depth of nearly 200 feet, and the solid bottom has not yet been reached. The Royal Engineers in Egypt have been intrusted with the work. The specimens, which are chiefly of sand and clay strata, are deemed of great importance, and the Society has granted money for the continuance of the work, which will be carried out by the detachment of Engineers as hitherto.

THE Secretary of State for War has given permission for Sir Frederick Abel, C.B., the Chemist of the War Department, to accept the post of organising secretary to the Imperial Institute, provided that the duties do not interfere with those of his appointment under the War Office; and Sir Frederick Abel has been desired by the Prince of Wales, President of the Imperial Institute, to enter upon his work as soon as possible. The new secretary has just completed his work in connection with the electric lighting of the Indian and Colonial Exhibition, and is also retiring from his duties in connection with the Society of Arts.

ON November 17, at 7h. 18m. p.m., a fine fireball was seen at Stonyhurst College, Blackburn. It appeared to be several times as bright as Venus. In colour it was violet, and of a distinct pear shape. The part of its path observed, as far as could be judged from the stars seen through detached clouds, was from near ι Ceti to the small stars above Fomalhaut, about 88 Aquarii. Its path was slightly curved. So brightly did it shine that attention was first called to it by the illumination of the sky, although seen from a room in which the gas was lighted.

THE *Morning Star* of Jaffna, in Ceylon, reports the death of the taxidermist of the Victoria Museum in that town from the bite of a cobra, under very curious circumstances. While feeding a cobra, which he had supposed was harmless from previous extraction of the poison-bag, it suddenly bit his hand. For a few minutes he took no notice, thinking the bite harmless, but pain and nausea soon began. Carbolic acid was applied, ligatures were bound round the arm, an incision was made at the bite, and the blood of the arm was wholly removed. Various antidotes were used, but the unfortunate man lost the power of speech, and soon after every muscle seemed to have become paralysed, and breathing entirely ceased.