theoretical intensity of the hard component is far smaller than that observed.

This absorption of hard gamma rays by atoms, resulting in the production of pairs of oppositely charged electrons, may be thought of as a photo-electric absorption by the 'virtual' electrons, that is, by electrons with negative kinetic energy, near the nucleus. According to Beck[10], these virtual electrons may be considered to have a binding energy of the order of 2 mc^2. Beck also shows that the number of these virtual electrons which are effective for the absorption are proportional to the square of the atomic number and that they amount to about one for each lead atom. The theory also indicates that the birth process takes place within a distance of $h/2\pi mc = 3 \cdot 85 \times 10^{-11}$ cm. of the nucleus, that is, well inside the K ring.

Curie and Joliot[11] have found that positive electrons are produced when *aluminium* and *boron* are bombarded by alpha particles, and that these positive electrons have a higher energy than the accompanying negative electrons. *Silver*, *lithium* and *paraffin*, however, give no positive electrons. Curie and Joliot suggest that the positive electrons originate in the disintegrating nucleus, but it seems possible that they may be produced mainly outside the nucleus by the internal conversion of a gamma ray emitted by the nucleus. To explain the effect in this way, the probability of internal conversion must be nearly unity.* The greater energy of the positives may be explained by the fact that a positive electron gains kinetic energy and a negative electron loses it, on escaping from the field of a nucleus. This resulting difference in kinetic energy will be the larger the nearer to the nucleus that the pair is born, and so should be larger in the case of such an internal conversion process, which depends on a spherical wave, than in the usual case of external absorption, which depends on a plane wave.

Though it was in association with cosmic radiation that positive electrons were first detected, the exact part they play in these complicated phenomena is not yet clear. But certain facts are established[12]. (*i*) Of the fast particles which produce the cosmic ray ionisation at sea-level, about half are positive and half negative electrons. Their energies range from a few million to nearly 10^{10} volts. (*ii*) The same ratio is found in the 'showers'. The showers appear therefore to represent the birth of multiple pairs of positive and negative electrons, as a result of one or more collision processes induced by the primary radiation. Dirac's theory shows that the production of single pairs is of primary importance in the absorption of both gamma rays and particles of high energy[13], but has, as yet, given no hint of the cause of the multiple pairs forming the showers. (*iii*) It has been shown that the majority of the particles incident on the earth's atmosphere are positively charged[14].

Since protons are rarely observed at sea-level, it is probable that the positively charged incident particles are not protons but positive electrons. If this is so, the main part of the flux of cosmic radiation in inter-galactic space must be in the form of positive electrons; and since the total mass of this radiation has been estimated as possibly as large as 1/1,000 part of the mass of all the stars and nebulæ[15], it appears that the positive electron, though rare, because ephemeral, on earth, is an important constituent of the universe as a whole.

* Oppenheimer and Plesset (*loc. cit.*) predict theoretically far smaller values.

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Progress in Non-Ferrous Metallurgy, 1908–1933

THE first meeting of the Institute of Metals was held in Birmingham twenty-five years ago. The autumn meeting was again held in that city this year, on September 18–21, and a review of the progress in those spheres of metallurgical activity with which the Institute is concerned was given by Dr. W. Rosenhain.

Dr. Rosenhain began by pointing out the unsatisfactory state of knowledge of the thermal equilibrium diagrams of metallic systems at the time when the Institute was founded, and the vast improvement in that respect which has since taken place—an improvement for which he and those working under his supervision have been in no small measure responsible. One of the points in regard to which the earlier diagrams were particularly deficient was in the determination of the limits of solid solubility in metals of other metals or their compounds, and the discovery by Wilm of the complex aluminium alloy known as 'duralumin' has emphasised the profound industrial importance of such knowledge. Where the solid solubility is appreciably higher at elevated temperatures than at lower ones, it becomes possible by quenching from an appropriate temperature to retain a super-saturated solution. Such a solution may afterwards undergo decomposition either at room, or some higher, temperature, resulting in what is generally known as 'age-hardening'. The prime importance of this discovery lies in the fact that, previous to the work of Wilm, steel was the only material which could be hardened by heat treatment. Since the establishment of the fundamental factors controlling the process—many details in the full explanation still require elucidation—an ever increasing number of alloys have become known which are capable of improvement in a similar manner. Apart from the alloys of aluminium itself, perhaps the most interesting example is that of copper alloyed with a small percentage of beryllium, in which a degree of hardness can be induced approaching that of a quenched steel. The range of such alloys is steadily widening and is placing at the disposal of the engineer and other users a whole series of products of a novel and valuable nature.

For some time after the discovery of 'duralumin', age-hardening was confined to wrought alloys. The explanation gradually arrived at concerning the mechanism of the process suggested, however, that cast alloys should be available which were susceptible of similar improvement. This prediction was later confirmed, one of the most commonly employed of such materials being the 'Y' alloy containing 4 per cent of copper, 2 per cent of nickel and 1·5 per cent of magnesium, with the discovery of which Dr. Rosenhain was himself intimately concerned. This alloy and modifications of it, some of which contain small amounts of titanium, possess the further advantage that they will retain their strength as the temperature is raised to an extent which is distinctly better than that of many other aluminium alloys.

Another type of treatment which again is, as yet, almost entirely confined to alloys of aluminium, is the 'modification' of properties which results from the addition of certain materials to the slag under which the alloy is melted. Silicon alloys with about 12 per cent of that element are the most important of this class. The effect is associated with super-cooling phenomena, and 'modification' can be produced in other types of alloy, though not as yet to anything like the same extent. The importance of the discovery lies in the fact that it shows that materials which, in normal circumstances, are brittle to the point of uselessness may, by suitable manipulation during melting, be rendered among the most valuable of the alloys of the particular metal.

Among new materials which are still in course of development, one of the most interesting groups is that of the alloys of beryllium with copper and nickel, to the age-hardening properties of some of which reference has already been made. Other work has concerned itself with the metal itself, research on which is complicated by its remarkable reactivity with almost every element with which it comes in contact. It may be produced in a ductile form with a high degree of strength, a low density and a relatively high melting point. The development of cutting tools consisting of non-ferrous metals is another direction in which considerable progress has been, and still is being, made. 'Stellite' and the sintered products of tungsten carbide with cobalt and other sintering additions are the outstanding examples of such materials and both are being increasingly employed. An application of the sintered tungsten carbide to which Dr. Rosenhain did not refer, but which is already established industrially, is in connexion with dies for the drawing of wire, which, for the finer gauges, are being increasingly employed.

Defects in ingots and castings due to the presence of dissolved gas is another subject which has called for considerable investigation. From aluminium alloys these gases can be removed, at any rate in part, by presolidification, the passage through the melt of nitrogen or the vapours of volatile chlorides such as those of titanium or boron. Such treatment, in addition to rendering the casting free from gas inclusions, may in certain cases have a marked effect on the size of the crystals and thus bear on the whole subject of grain refinement.

In no direction probably has progress been more marked than in the production of the metals themselves in a high state of purity. Zinc, magnesium, aluminium, tungsten, manganese, etc., are now available of a purity and in some cases, therefore, with properties, of a totally different order from that of twenty-five years ago. Some brittle metals are shown to be ductile if the last small traces of impurities are removed, and new uses are opened up for elements which, but a few years ago, were of no more than laboratory interest.

The production by Carpenter and Elam of the first large single crystals of aluminium, and subsequent work on such single crystals of that and other metals, has opened up an avenue for direct experimental research on the reaction of metals to stresses which is gradually throwing a flood of light on factors of immediate importance to the engineer. Through the phenomenon known as 'corrosion-fatigue', a type of failure of parts in service which has only been generally recognised during the last few years, the effects of stress are being linked up with those due to corrosion itself. Not only is our information regarding the underlying causes of corrosion on an altogether surer foundation—though much still remains to be done—but also processes are available for the reduction, or elimination, of the trouble which are now well established. The addition of aluminium to brass condenser tubes, and the use of cupro-nickel alloys afford examples of the adoption of new and superior materials. The surface protection of metallic articles by highly resistant films of oxide, either naturally as in the stainless steels, or artificially on aluminium and certain of its alloys by the anodic oxidation process developed by Bengough and Stuart, are instances of a similar effect produced by an alternative line of approach.

In all these developments the Institute of Metals has itself played a most important if, perhaps, indirect part and can justifiably claim a share of the credit for the progress which has been made.

F. C. T.