and has been decaying since the separation of the earth from the sun. From the work of Aston, it is known that with two exceptions the most abundant isotope in an even numbered element is of even atomic weight. If it be supposed that uranium, like other heavy elements, is formed from stellar matter, it is likely that actino-uranium of odd atomic weight would be formed in smaller quantity than the main isotope of even atomic weight. Even, however, if we suppose they were formed in equal quantity, it can be shown that it would require only $3 \cdot 4 \times 10^9$ years to bring down the amount to the 0·28 per cent observed to-day.

If we suppose that the production of uranium in the earth ceased as soon as the earth separated from the sun, it follows that the earth cannot be older than $3 \cdot 4 \times 10^9$ years—about twice the age of the oldest known radioactive minerals. In addition, if the age of the sun is of the order of magnitude estimated by Jeans, namely, $7 \times 10^{12}$ years, it is clear that the uranium isotopes which we observe in the earth must have been forming in the sun at a late period of its history, namely, about $4 \times 10^9$ years ago. If the uranium could only be formed under special conditions in the early history of our sun, the actino-uranium on account of its shorter average life would have practically disappeared long ago. We may thus conclude, I think with some confidence, that the processes of production of elements like uranium were certainly taking place in the sun $4 \times 10^9$ years ago and probably still continue to-day. E. RUTHERFORD.

## The Theory of Electrical Rectification.

IT is an experimental fact that certain electrical conductors, when connected in series so as to form a circuit, present a different resistance to currents flowing through them in opposite directions. Examples are the electrolytic rectifiers, the crystal rectifiers, and the dry-plate rectifiers recently developed. In some cases the rectification undoubtedly is due to the circuit itself being modified by the flow of the current. Thus, for example, in an electrolytic rectifier a layer of oxide may be formed on one of the electrodes when the current is passing in a given direction, obstructing its further flow, while no such layer appears at the other electrode, made of a different material, when the current is reversed. Thermoelectric effects may occasionally play a rôle too. In crystal rectifiers, however, the rectification must in general be caused directly by the interaction of the crystal lattices with the conduction electrons (W. Schottky, *Zeit. f. Phys.*, **14**, 63; **1923**). For it appears that they rectify alternating currents of frequency $10^7$, and of the order of a microampere only (R. Ettenreich, *Phys. Zeit.*, **21**, 208; 1920), and the amount of substance chemically changed in an electrolytic action during a half period of such an alternating current is altogether too small to be made responsible for the phenomenon, quite apart from the fact that chemical changes would scarcely be capable of taking place with a frequency of $10^7$. As Ettenreich (*l.c.*) remarks himself, the thermoelectric explanation too is invalidated by his experiments. The question arises then as to what is the elementary mechanism underlying this kind of rectification.

The resistance of a metallic conductor is caused by the transfer of momentum which the conduction electrons have gained under the influence of the applied electric field to the ions of the crystal lattice through collisions or, in the language of wave mechanics, by the scattering of the waves representing the conduction electrons under the action of these ions. Rectification signifies here, therefore, a difference in the scattering power of the circuit for electron waves travelling in opposite directions.

If in first approximation we regard the ions in the lattices as fixed in space, we are led to study the influence on a plane monochromatic electron wave of a field of force the potential $V$ of which vanishes for $x = \pm \infty$, while in planes parallel to the $y$-$z$-plane it is doubly periodic. According to wave mechanics such a wave, representing a stream of electrons of definite velocity parallel to the wave normal, on encountering the potential $V$ is partially reflected and partially transmitted. We inquire then if the coefficient of reflection for a given $V$ is the same for incident waves travelling in opposite directions. It can easily be proved that even if the potential $V$ is not symmetrical along the $x$-axis, as in the case of a number of conductors in series, there is no difference in the coefficient of reflection. It is hence not possible to explain the rectification here considered on the basis of the assumption that the ionic lattices act on the conduction electrons like a field with a given potential $V$.

If now we regard the ions of the lattice no longer as fixed centres of force, we come to investigate if there will be a difference in the scattering action on electron waves travelling in opposite directions, of particles bound to positions of equilibrium by restoring forces not symmetrical for equal and opposite displacements. It can be shown by a perturbation method that in general the scattering is indeed different. Assymmetrical binding of the ions, which, for some of the substances used in rectifiers actually has been ascertained even for the interior of the crystal by X-ray analysis, will come mostly into play near the boundary, and to a still greater degree at the edges and corners of a crystal lattice. This may be the explanation why some crystal rectifiers consisting of a metal point in loose contact with the crystal have their rectifying properties diminished or entirely spoiled if the point is pressed tightly against its base, for in this process the sharp corners are flattened out. From the viewpoint of the theory here set forth, there seems to exist the possibility of volume rectification in contradistinction to surface rectification for crystals in which, even in the interior of the lattice, the ions are subject to restoring forces not symmetrical for equal and opposite displacements. No experimental data appear at present available to show clearly the existence of this effect.

The proof of the reciprocity theorem for electron waves mentioned above, as well as a mathematical discussion of the difference in scattering caused by asymmetrically bound particles, will be given elsewhere. R. DE L. KRONIG.

Physisch Laboratorium
der Rijks Universiteit,
Utrecht, Jan. 28.

## The Extermination of Whales.

SIR SIDNEY HARMER, in an important paper (Linnean Society, May 24, 1928), directs attention to the wasteful way whales have been killed in the past and to the danger of exterminating them. As regards the Greenland whale, the facts seem to be worse than Sir Sidney states.

Scoresby, speaking of its capture in the Greenland Sea, says towards the end of the eighteenth century: "A striking epoch in the history of the fishing arose" . . . "two or three of the captains of the whale-fishing ships" . . . "instead of being contented with two or three large fish and (instead of) considering five or six a great cargo, set the example of doubling or trebling the latter quantity."

The increased activity thus initiated (which doubt-