creased from 9,021 miles in 1850 to 201,839 miles in 1902, and the estimated wealth of the country from \$7,135,780,000 in 1850 to \$94,300,000,000 in 1900—a per capita increase of from \$308 in 1850 to \$1,236 in 1900. This increase in wealth has been accompanied by an increase in deposits in banks, those in savings banks alone increasing from \$43,431,130 in 1850 to \$2,597,094,580 in 1901.

Meantime the foreign commerce has made rapid increase, though not at a rate of speed proportionate to that of internal commerce. The imports of 1850 were \$173,509,526; those of 1902, \$903,320,948. The exports in 1850 were \$144,375,726; in 1902, \$1,381,719,401.

While it is not practicable to measure the internal commerce of other countries with the same accuracy as that of the United States, it is known that in agricultural products, manufactures, and minerals the United States now outranks the other nations of the world, and that the transactions in these products, which form the internal commerce, may therefore be assumed to surpass those of any other country. The manufactures of the United States are now about double those of the United Kingdom and nearly equal to those of France, Germany and Russia combined, while the value of the agricultural products of the United States far exceeds that of any other single country.

CRYSTALLIZED PEROXIDE OF HYDROGEN.

By WILHELM STAEDEL.

THE firm of E. Merck has been supplying a solution of peroxide of hydrogen at 30 per cent for some years past; this peroxide fulfills all our requirements as regards purity and stability. This preparation is appreciated as an antiseptic, more especially in connection with surgical instruments and appliances. They have been able to manufacture also a sufficiently concentrated solution on a large scale. The author of this article is indebted to the courtesy of this firm for large quantities of the latter product for the purposes of research.

This research is not yet completed, but it is possible, nevertheless, to announce one fact chosen from among the most interesting ones observed, viz., that peroxide of hydrogen, contrary to recent assertions, crystallizes with ease, and in a very distinct manner. Its melting point appears to be about -2°C , but it may be possibly a little higher. The preparation used contained from 95 to 96 per cent of H_2O_2 . In a freezing mixture at -20°C it remained liquid; in a mixture of ether and solid carbonic anhydride it solidified into a hard resisting mass. Further, this phenomenon also occurred in chloride of methyl. The eutectic point thus appears to be between -20°C and -23°C . If we throw a trace of the solid peroxide into the liquid cooled down to -8°C or -10°C , there immediately form magnificent needle-shaped crystals, as transparent as water, and which soon permeate the whole mass. By draining the mother-liquor from the crystals and allowing these to regain their liquid state by fusion, we can obtain, by means of a second crystallization, peroxide of hydrogen free from water.

Repeated analyses have given the composition of these crystals as 100 per cent H_2O_2 . Similar crystals can be obtained from more dilute solutions titrating 90 or even 80 per cent of H_2O_2 . It seems that practically we may look upon it as possible to prepare a pure peroxide of hydrogen without having recourse to an operation which is not always free from danger; that is to say, to the distillation of high percentage solutions, as done by Wolfenstein and Brühl, or Spring, to obtain anhydrous peroxide of hydrogen.

For the better manifestation of the most marked properties of peroxide of hydrogen, a series of experiments was devised. Thus, an extremely small quantity of platinum black produced a catalytic decomposition accompanied by a violent explosion; powdered binocide of manganese, or a mixture of carbon and powdered magnesium with a trace of binocide of manganese, takes fire immediately when put in contact with anhydrous peroxide of hydrogen, or thrown into its solution at 90–95 per cent. Finely divided iron (reduced iron) alone is without action; the liquid simply mixes with the powder, but if we add now a little binocide of manganese a flame is produced, and the iron burns, throwing off sparks. Powdered lead becomes inflamed in the same manner. A few drops of anhydrous peroxide of hydrogen thrown on to wool or a moist sponge immediately bursts into flame.

Monohydrated sulphuric acid can be mixed with anhydrous peroxide of hydrogen if it is done at a low temperature.

The refrigeration must be sufficient to counteract the evolution of heat which takes place. If the operation is not conducted under these conditions, oxygen very rich in ozone is given off. The examination of this reaction is not yet complete; it may be possible to produce per-sulphuric acid by these means.

We can also make use of peroxide of hydrogen in two reactions. The most interesting one, that is to say, that of which the best use can be made, takes place with sulphate of titanium. By its help we are able to detect 1 part of peroxide of hydrogen in solution in 1,800,000 parts of water. When the ratio is only 1 : 18,000 the reaction is manifested by the appearance of a deep yellow coloration, becoming bright yellow for 1 in 180,000, and remaining yellowish in a fairly thick layer with 1 part in 1,800,000. The action on ceric sulphate and ammonia is less sensitive; it reaches its limit of sensitiveness when the solution is diluted to 1 in 180,000. It must also be remarked that if the solutions in which we have produced the titanium reaction are still colored after several days, this cannot be said of the cerium solutions, which in a very few days become completely colorless.

We know that peroxide of hydrogen is capable of forming crystallized compounds with metallic salts. M. Tanatar has described some of these bodies. The compound containing cadmium lends itself very well to the demonstration. On pouring a 90–95 per cent solution of peroxide of hydrogen into a concentrated solution of chloride of cadmium the mass becomes thickened by the formation of small, fine, white silky flakes. When collected and dried it has been found that they contained about 23 per cent of peroxide of hydrogen.

It may be concluded from the above that the problem of the preparation of anhydrous peroxide of hydrogen on the large scale has been solved. The economic results of this achievement will be known to us in the future. But from the point of view of facts already known, we may say with safety, that the use in surgery of an antiseptic product incapable of introducing foreign matters into wounds, or of producing anything besides water and oxygen by its decomposition, is made practicable by the present preparation; we are perfectly justified in hoping for great results in this direction.

In conclusion, we may remark that anhydrous peroxide of hydrogen, prepared by means of crystallization, appears to be easily transported. A well-packed sample was placed on a truck and sent on a journey of 50 or 60 kilometers, without undergoing any change. A second sample was treated in the same manner for three days without experiencing any injury.—*Zeitschrift für Angewandte Chemie*.

THE RADIO-ACTIVITY OF URANIUM.

By FREDERICK SODDY.

DURING the course of the investigation contained in the preceding paper on the radio-activity of thorium, it became advisable to investigate in parallel a radio-active element that does not give out an emanation, or excite radio-activity upon surrounding bodies. It has been shown that these secondary actions always form a possible factor in the results obtained with thorium. For this purpose the radio-activity of uranium was chosen, but at the outset great differences arose between the results obtained and those published in the same field by prior investigators. These differences led to a comparative study being made in certain cases of the photographic and electrometer methods of measuring uranium radio-activity, which resulted in explanation of the anomalous results that had been obtained.

Sir William Crookes (*Proc. Roy. Soc.*, 1900, p. 409) made the beautiful discovery that in one chemical operation uranium could be obtained inactive to the photographic plate, while the whole of the inactivity was concentrated in a small non-uranium residue. This residue, to which he gave the name UrX , was at least a hundred times more active than the uranium from which it had been separated.

On repeating this separation, which consists in precipitating solutions of uranium with ammonium carbonate, and re-dissolving the precipitate in excess of the reagent, it was found that the small residue of UrX was almost inactive, while the uranium, contained in the ammonium carbonate filtrate, possessed about the normal amount of activity. The electrical methods of Prof. Rutherford were employed for measuring radio-activity. The same negative result was obtained by the other method of separation employed by Crookes. If crystallized uranium nitrate is dissolved in ether, the uranium divides itself in two unequal fractions between the ether and water present. That dissolved in the ether layer, which is the major fraction, was found by Crookes to be inactive to the photographic plate, while the small part dissolved in the aqueous layer possessed all the activity contained in original uranium nitrate. But as in the former case, on repeating the operations, both fractions appeared almost equally active to the electrometer, and no separation had apparently been effected.

The same preparations were then examined for their action on the photographic film, and gave results exactly the converse of those observed with the electrometer and in accord with the published results of Sir William Crookes.

Rutherford (*Phil. Mag.*, 1899, p. 109) showed that uranium radiation consists of two different types, which he named the α and β radiation. The α is absorbed very readily even by gases, being reduced to half value by passage through 4.3 mm. of air. The β , on the other hand, is very penetrating in character, and is but little absorbed by gases. It is able to pass through 0.5 mm. of aluminium before it is reduced to half value. This latter part constitutes only a few per cent of the total radiation of the uranium. In addition, by the electrometer method of measurement under ordinary circumstances, a fraction only of the intensity of the β radiation is recorded, for this method depends upon the ionization of the air, and this is proportional to the absorption of the rays by the air. It follows, therefore, that under ordinary circumstances, in which the rays traverse a few centimeters only of air, that the electrometer method measures practically the α radiation of uranium alone. The photographic method employed by Crookes, in which the rays are made to pass through glass or card before reaching the sensitive film, will, on the other hand, measure only the β radiation. Hence the results obtained would be explained if the methods employed separated the β radiation only and left the α radiation intact.

Becquerel has shown (*Comptes Rendus*, 1900, cxxx., p. 1,584) that the rays from uranium are deflected in the magnetic field, and therefore consist of cathode rays. Rutherford and Grier (*Phys. Zeit.*, 1902), in a general investigation of the rays from various radio-active substances to determine what proportion in each case was deviable in the magnetic field, and therefore cathodic in nature, had already at this time shown that the β radiation of uranium is entirely cathodic, and the α radiation not at all. They undertook the examination of the specimens that had been prepared in the course of the present work, the details of which appear in their paper with the special apparatus employed. It suffices to state here that in the arrangement they adopted the rays are made to pass through a sufficient thickness of air to absorb a considerable part, and the sensitive Dolezalek electrometer was employed. Under these circumstances UrX was found to be giving out ionizing rays abundantly. This radiation was shown to be the β radiation of uranium only, practically free from α , for it passed through aluminium foil without great loss, and is deviable to the same extent by the magnetic field. The rays from the photographically inactive uranium were found, on the other hand, to consist entirely of α radiation, and gave no rays deviable in the magnetic

field, or capable of passing through thin aluminium foil. I must here express my great obligation to Prof. Rutherford and Mr. Grier for permission to use their results.

It thus appears that the methods of chemical separation employed by Crookes effect a separation only of the constituent responsible for the β radiation. The uranium after the process still retains the whole of the non-deviable radiation, which in the electrometer method contributes the greater part of the effect. In this respect uranium is analogous to thorium, as shown in the preceding paper. But the excited radio-activity produced by ThX as a secondary effect, which itself comprises both deviable and non-deviable radiation, makes it impossible at present to say whether the primary radiation of ThX is, like that of UrX , wholly cathodic or not. The non-separable parts in both cases consist entirely of rays non-deviable in the magnetic field.

The next point to be decided was whether the α radiation of uranium could affect the photographic plate. A sample of the preparation free from β radiation was exposed about 5 mm. away from a sensitive film for seventy-two hours without intervening screen. Only a very slight darkening occurred, so that the action, if any, of the α radiation may be considered negligible in comparison to the effect of the β radiation. It is not possible to try longer exposures than three days by this method, owing to the regeneration of the β radiation which will be referred to later. However, Becquerel (*Comptes Rendus*, 1902, cxxxiv., p. 208) exposed plates for twenty and forty-nine days near uncovered uranium salts, in a magnetic field where the β radiation would be deflected and eliminated, and failed even after these long periods to obtain an impression on the sensitive film. He concluded that the whole of the uranium radiation is cathodic, and can be deflected by the magnetic field. But the foregoing considerations make it clear that the α or non-deviable radiation of uranium, which contributes the major part of the ionization effect, is without appreciable action on the photographic plate.

In light of these results, and those obtained for thorium in the preceding paper, the method employed by Becquerel (*Comptes Rendus*, 1900, cxxxi., p. 137) to separate the active constituent of uranium is of interest. M. Becquerel precipitated barium as sulphate in solutions of uranium, and found that after successive precipitation the activity of the latter was much enfeebled, both toward the electrometer and the sensitive film. As, however, he inclosed the salt in paper for the electrometer measurements, and this absorbs the α radiation almost or quite completely, the result must not be taken to mean that both the α and the β radiations were separated by the process. On repeating the separation it was found that, as in the case of the methods of Crookes, the β radiation only was removed. After four successive precipitations in one day, the β radiation was found to be reduced to 8 per cent of its original value, and eight more precipitations on the day following completely removed it. But the activity of the resulting uranium preparation to the electrometer under ordinary circumstances was hardly appreciably decreased. The α radiation had therefore not been affected.

Becquerel has already shown (*Comptes Rendus*, 1901, cxxxiii., p. 977) that the uranium after this treatment recovered its normal activity on standing. With the sensitive electrometer the presence of cathode rays in a product originally quite freed from them, can be detected after three days. It thus appears probable that what has been shown to hold true for ThX applies equally to UrX , and the subject is under investigation conjointly with Prof. Rutherford. The same question therefore arises for the non-separable activity of uranium already discussed for that of thorium.

1. Is this residual activity to be regarded as a secondary radiation produced by the presence of UrX ?
2. Or, is it caused by a distinct material substance capable of chemical separation?

On the first view, if UrX —the cause of the phenomenon—is removed, the residual activity will decay with time. The following experiment was therefore performed: The solution of uranium nitrate which had been successively precipitated with barium sulphate twelve times, and had been shown to be free from β radiation, was allowed to stand. Every three or four days it was once more precipitated in the same manner, and the UrX produced during that period removed from the uranium. After twenty-one days, the uranium in the solution was precipitated with ammonia and converted into the green oxide. For comparison, a sample of the same uranium nitrate, as obtained from the maker, was subjected to two precipitations with barium sulphate to remove most of the β radiation, the uranium then being precipitated and converted into oxide as in the former case. The radiations from the two samples were then directly compared. In the one the α radiation had been given three weeks to decay, and by comparison with the other a direct measure of the diminution suffered during this period could be obtained. Not the least difference, however, could be detected in the intensities of the radiations in the two cases. The actual values obtained were within 1 per cent of each other. If it is assumed that in this experiment a difference of 5 per cent could be with certainty detected, the conclusion is arrived at that if the α radiation of uranium is a secondary phenomenon produced by the β , it takes at least a year to decay to half value. As this is not in accordance with what is known of the nature of excited radio-activity, the view cannot be regarded as probable.

On the second view, the irradiation is produced by a second distinct type of matter. But as in the case of thorium, all attempts made to separate such a constituent of uranium by chemical methods have so far failed, although the methods have not yet been exhausted. It is, however, interesting to note that polonium, discovered by Curie, fulfills in almost all respects the functions of this hypothetical constituent. It gives only non-deviable radiation, and Prof. Rutherford, to whom the suggestion is due, found that the penetration power of the rays from polonium is very