ultrasonic waves of high intensity which develop higher frequencies and enhanced absorbtion as they progress.

* Supported by contract with the Office of Naval Research.

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A Suggested Mechanism for the Generation of Thunderstorm Electricity

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IN October 1946 the authors undertook laboratory investigations of the electrical properties of water and ice with the hope of discovering a physical process for the development of thunderstorm electricity which would be consistent with what is now known about thunderstorms.[1]

Initial tests reported to the sponsors in January 1947 showed effects wherein large differences of potential were developed between the liquid and solid phases of water when rapid freezing was in progress. These investigations were interrupted and work was not resumed until early 1948.

In continuing, attention was first directed toward determining whether our earlier observations were related to the phenomena reported by Dinger and Gunn wherein observations suggestive of the same phenomena were interpreted as contact potential differences of from 6 to 10 volts.[2]

The authors, using apparatus similar to that of Dinger and Gunn, were able to obtain relatively larger electrical effects, but having such differences in sign, magnitude, and character as to indicate a different interpretation than that of contact potential. In further tests samples of relatively pure water (resistivity about 10^6 ohms-cm) were frozen in a small nickel-plated copper dish floated on a mercury pool at about $-16°C$. The cup was grounded and the surface of the water was connected to an electrometer through a platinum wire. As soon as a thin film of ice separated the water from the cup, the electrometer indicated a negative potential which usually increased to about 40 volts. Occasionally values of -90 volts were obtained. Frequently, a reversal in potential was observed as the freezing approached completion. These potentials varied in magnitude, but 20 or 30 volts was expected. The measured resistivity of the remaining water was less during the reversed polarity phase than that of the sample before freezing started.

When water samples of one-tenth the resistivity (contaminated with sodium chloride) were used, a positive, instead of negative, potential developed as the ice covered the metal cup reaching a maximum value of something like 25 volts. For water of intermediate conductivity (4×10^5 to 8×10^5 ohm-cm) little or no electrical activity was observed.

Amounts of charge transferred during the freezing process were determined by measuring voltage across an electrometer shunt (5×10^6 ohms). As much as 30,000 e.s.u. per cc of water was common in the low resistivity cases.

Other tests including the impingement of water drops on cold ice in a cold chamber indicated that this process appears to satisfy the requirements for the initial electrification in thunderstorms. Water drops in the low resistivity range caused the ice to become negatively charged as the drops sheared and partially froze on the ice surface; the residue of the drops leaving the ice after impact was positively charged. After the ice was warmed by continued dropping to the extent that the drops no longer partially froze, successive drops drained negative charge from the ice by the process of charge sharing. This, or a similar process of cycling, appears necessary in a thunderstorm for consistency with field observation, showing that the negative charge center does not descend much below the zero isotherm. Our limited information on the resistance of water from melted hail gives values consistent with the negative ice and positive water situation.

A more complete report giving definite information bearing on the nature of the effects here reported is in progress, and further applications to possible thunderstorm formation will be discussed.

[1] This work has been supported by the Signal Corps of the United States Army.

[2] J. E. Dinger and Ross Gunn, Terr. Mag. 51, 477 (1946).

Preparation and Radiation of U^{237}

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LITERATURE contains very little information about the uranium isotope U^{237}. Only the half-life, 6.5–7 days,[1,2] and the upper limit of the β-spectrum, 0.26 Mev,[2] are reported. Starke[3] pointed out the possibility of using the Szilard-Chalmers reaction for the concentration of U^{237}, obtained in the process $U^{238}(n,2n)U^{237}$. We have modified the method[4] used in earlier experiments[5] on U^{239} and Np^{239}, carried out in this institute, for the case of U^{237}.

Solid uranyl salicylaldehyde-orthophenylenediimine[6] was shielded by boron and cadmium and irradiated with fast neutrons from lithium, bombarded with deuterons in the

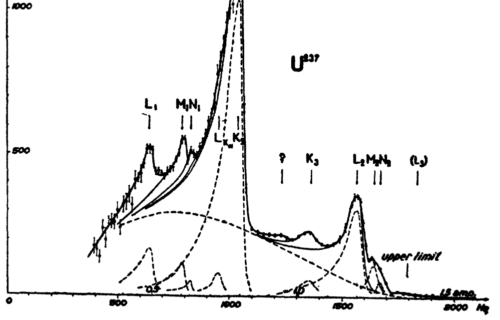

FIG. 1. The β-spectrum of U^{237}.

TABLE I. β-ray lines of U^{237}.

Notation	$H\rho$	E_β kev	W kev	E_γ kev	Origin
L_1	635	34.3	22.3	56.6	γ_1
M_1	781	51.0	5.7	56.7	γ_1
N_1	820	56.0	1.5	57.5	γ_1
LK_α	944	73.1	22.3	95.4	K_α
K_2	1029	85.9	118.2	204.1	γ_2
?	1224	118.2	118.2	236.4	?
K_3	1354	141.7	118.2	259.9	γ_3
L_2	1556	181.0	22.3	203.3	γ_2
M_2	1634	196.9	5.7	202.6	γ_2
N_2	1660	202.0	1.5	203.5	γ_2
(L_3)	1823	236.6	22.3	258.9	(γ_3)

cyclotron. In the case of U^{237} the concentration of the activity was almost exactly the same as with U^{239} and Np^{239} and will be discussed but shortly here. The purification, however, had to be changed, since in the present case it was desired to remove Np^{239} which might have been formed by possible slow neutrons, and all UX_1 had to be removed after the irradiation.

After the irradiation and after a time lag sufficient for possible U^{239} to vanish, the sample was dissolved in pyridine and the solution treated as in the former experiments: the activity was adsorbed on charcoal and the charcoal shaken with ammonium carbonate solution in the presence of some barium. The result was an ammonium carbonate solution containing those activities which are soluble under these conditions.

Precipitation as fluorides in acid solution was supposed to be the best method to get rid of such active impurities as UX_1 (thorium), four-valent neptunium, and three-valent rare earth metals (cerium, for example). During such a precipitation, uranium should be kept in the valence state six, the fluoride of which is soluble. In order to ensure the six-valent state to uranium, the solution was acidified with hydrochloric acid and some solid ceric sulfate added (it evolves chlorine and forms cerous ion). After that, sulfur dioxide was introduced into the solution. It is known to reduce neptunium but not uranium from the valence six to four, and hence the solution now contained its uranium, neptunium, and cerium as the ions UO_2^{2+}, Np^{4+}, and Ce^{3+}, respectively. Hydrofluoric acid was added and precipitated cerous fluoride, which carried such activities as neptunium, UX_1, etc.

Among the methods tried for the precipitation of uranium from the filtrate the following was the simplest and best one. By means of zinc powder the uranium was reduced to U^{4+} and a small amount of cerous ion added. The cerous fluoride then carried the uranium as tetrafluoride. (The amount of uranium is always very small and hardly visible.) The precipitate, washed and ignited, was used for the physical measurements.

In order to establish the yield and the concentration factor, a part of the originally irradiated sample was converted into sodium uranyl acetate in the presence of sulfur dioxide (and thus freed from foreign activities) and the specific activity of that uranium measured.

According to β-activity measurements on the concentration product and the sodium uranyl acetate, the latter of which represents the specific activity attainable without any concentration, the yield was 15–25 percent and the concentration factor at least 500. These values are in accordance with those found for slow neutrons.[4] The purification methods, however, were different and hardly permit close comparison.

Figure 1 shows the β-spectrum of U^{237}. The statistical error in each point is represented. The resolving power is limited by the granulate structure of the sample rather than by the properties of the magnetic lens spectrograph,[7] as shown by the anomalously small slope at the low energy side of the lines. This circumstance and the occurrence of many internal conversion lines mask the continuous β-spectrum almost completely.

From the assumption of a single Fermi distribution, an upper limit at $H\rho = 1784$ ($E_\beta \approx 0.23$ Mev), and visibility of the continuous spectrum at $H\rho = 1120$, the latter was calculated and is represented by a dotted line. There is, however, some indication for a complex β-distribution (see below).

At least eight internal conversion lines and one converted x-ray line have been found. The thin curves belong to the construction of the individual conversion lines, which are plotted separately with dotted lines.

In Table I the data for the lines are given. The first column contains the symbols for the lines, as also marked in Fig. 1. The other columns give the momentum $H\rho$, the energy of the β-particles E_β, the ionization work W, the energy of the corresponding γ- quanta E_γ, and the origin of the lines, respectively.

The ionization work W for Np was obtained by extrapolation of the known ionization works[8] of the corresponding electrons in bismuth, thorium, and uranium.

The evidence for the line LK_α in the β-spectrum is not very strong, but it seems natural that this line should appear, because the K-conversion of γ_2 is high (see below), and K_α-radiation is to be emitted when the K-shell is completed. The energy of this K_α-radiation, then, is $118.2 - 22.3 = 95.9$ kev in agreement with the computed value in Table I.

The two hardest γ-components, γ_2 (204 kev) and γ_3 (260 kev), did not appear as two separated components in absorption measurements. Their mean value, however, corresponds to the hardest γ-component, 230 kev, found in such measurements. The energy of the weak component γ_1 (57 kev) is in good agreement with the absorption value 59 kev.

Weak γ-radiation, 32 kev and x-radiation, was also found in the absorption measurements, but because of the low energy, which is still reduced by the ionization work, possible conversion lines from these radiations cannot be recorded.

The weighted means for the energies of γ_1 and γ_2 are 56.7 and 203.9 kev, respectively. The sum of these is 260.6 kev, within the limit of experimental error agreeing with the energy of γ_3, 259.9 kev. Thus the latter probably is a crossover transition, and the three γ-radiations, γ_1, γ_2, and γ_3, belong to two excited levels in the Np^{237} nucleus. The intensities of the different conversion lines give evidence for the existence of more than one way of β-decay.

The half-life was found to be 6.63 ± 0.05 days.

A more complete description of these experiments will be published soon.[9]

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On the Faraday Effect at Microwave Frequencies†

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A MICROWAVE analog of the Faraday effect has been found experimentally at a wave-length of 3.338 centimeters. The sensitivity of the apparatus was adequate to measure Verdet constants as small as 0.5×10^{-3}, with a probable error of 25 percent under worst conditions.

The effect was found by use of a TE_{11} wave in circular pipe. The dielectric was placed within this pipe, and the pipe inserted on the longitudinal axis of a solenoid having a maximum field strength of 1350 gauss. Position of the electric vector within the pipe was determined by side probes extending into the pipe at each end of the solenoid. Angular displacement of the electric vector caused by the applied magnetic field was measured by rotating one of the side probes about the axis and reading the angle on a scale accurate to one minute of arc.

Two of the materials measured have Verdet constants of the customary order of magnitude. The materials are paramagnetic salts, $MnCl_2\cdot4H_2O$ and $MnSO_4\cdot H_2O$. These salts are known to exhibit microwave absorption at 3 and 10 centimeters in the presence of a magnetic field.[1] The chief results for these two salts are given in Table I.

The basic equation for the Faraday effect is $\theta=RLH$, where θ is the angular rotation of the polarization plane in minutes, L is the path length, H is the magnetic field strength, and R is the Verdet constant (a function of wave-length).

TABLE I.

Substance: manganous sulfate; $MnSO_4\cdot H_2O$

L (cm)	H (gauss)	λ (cm)	θ (min.)*	R ($\times10^3$)
9.2	1350	3.34	9.5	0.766
9.2	1350	3.45	12.5	1.01
9.2	1350	3.338	12.5	1.01

Substance: manganous chloride; $MnCl_2\cdot4H_2O$

L (cm)	H (gauss)	λ (cm)	θ (min.)*	Dev.	R ($\times10^3$)
9.2	1350	3.338	22.7	±35%	1.83 (*a*)
9.65	1350	3.338	28.7	±19%	2.21 (*b*)
23.4	1350	3.338	61.5		**1.94 (*c*)
30.5	1350	3.338	73.3	±13%	1.78 (*d*)
30.5	920	3.338	55.2	±17%	1.96 (*e*)
30.5	460	3.338	25.9	±23%	1.84 (*f*)
30.5	1350	3.442	25.7	±23%	***0.62 (*g*)
30.5	1350	3.553	46.9	±12%	***1.14 (*h*)

* Rotation to left when wave was in direction of magnetic field.
** Percentage deviation ±14 percent; additional possible error 15 percent; total possible error 29 percent. Material in this specimen was loosely packed. Mean Verdet constant for values $(a-f)=1.90\times10^{-3}$.
*** One large deviation omitted from percentage calculation.

For the material most thoroughly investigated, manganous chloride, three principal observations may be made from the table:

(1) The Faraday rotation was proportional to the path length L; see table values (*a*) and (*d*).

(2) The Faraday rotation was proportional to the field strength H; values (*d*) and (*f*).

(3) There was some variation in the Verdet constant with wave-length; values (*d*), (*g*), (*h*). This suggested an absorption band within the wave-length region measured; however, available data was not adequate to substantiate this.

The salts were in crystalline form, in general no greater than 2 millimeters in the largest dimension. The crystals were tamped slightly when inserted into the pipe.

A large number of materials gave no measurable effect; these are listed in Table II. For some of these, measurement was doubtful, since very small path lengths L were used because of high attenuation. The substances were in various forms; ammonia gas was at atmospheric pressure.

TABLE II.

Ethyl alcohol
Nitrobenzene
Carbon disulfide
Methyl alcohol
Ammonium nitrate
Ammonium hydroxide
Water (distilled)
Ether (anhydrous)
Chloroform
Ethylene chloride
Methylene chloride
Benzene
Polystyrene (clear)
Ammonia (gas)
Sodium chloride
Glycerine
Ferrous sulfate (crystal)
Ferric chloride (powder)
Carbon tetrachloride
Manganous carbonate
Ferric nitrate
Ferric sulfate
Cobalt chloride
Cobalt sulfate
Ferrous ammonium sulfate

† Abstract of M.A. thesis, submitted by the first author at Dartmouth College, June 1948.

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The Change of Photo-Conductivity of Cadmium Sulfide between Room Temperature and the Temperature of Liquid Air

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THE photo-conductive properties of cadmium sulfide crystals have been described by R. Frerichs.[1] He showed that crystals prepared by a reaction between cadmium and H_2S become conductive when exposed to light and lose their conductivity after illumination with a certain decay time. He showed that at liquid air temperature the decay period is increased and that delay is also observed between the onset of illumination and the time when conductivity begins. In our experiments we examined the photo-conductivity of such cadmium sulfide crystals at intermediate temperatures between room temperature and that of liquid air. Two facts were observed: (1) When using unfiltered radiation from a metal filament as illumi-