Gamma-Radiation from Rhenium

We have produced by proton bombardment of tungsten (purity 99.95 percent) the long period rhenium isotope which Fajans and Sullivan[1] obtained by W(D,n) and Re(n,2n) and assigned to Re^{184}. We have also produced the 90-hour and 30-minute periods by proton bombardment and checked the fact that they follow rhenium chemistry.

After removal from the cyclotron, the tungsten strip which had been bombarded intermittently for four months with currents of the order of 20 microamperes, was allowed to age for two months before observations began, so that the shorter periods might die out, after which the activity was followed for four months. The original intensity of the long period was about 100 divisions per minute on the Lauritsen electroscope. Our value of the half-life is 54±2 days. See Fig. 1.

Absorption measurements of the radiation showed negative electrons of three kinds, of ranges 12, 50, and 350 mg/cm² of aluminum, corresponding to energies of roughly 0.1, 0.22, and 0.86 Mev, respectively, and gamma-radiation of about 1 Mev, as seen from Fig. 2. The highest energy group may be conversion electrons from this gamma-ray, which was also reported by the above authors.[1] The intermediate energy electrons were too few for careful study, and indeed may be from a tungsten isotope produced from the neutrons around the cyclotron.

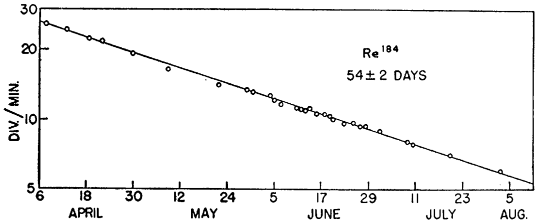

FIG. 1. Decay curve of Re^{184}.

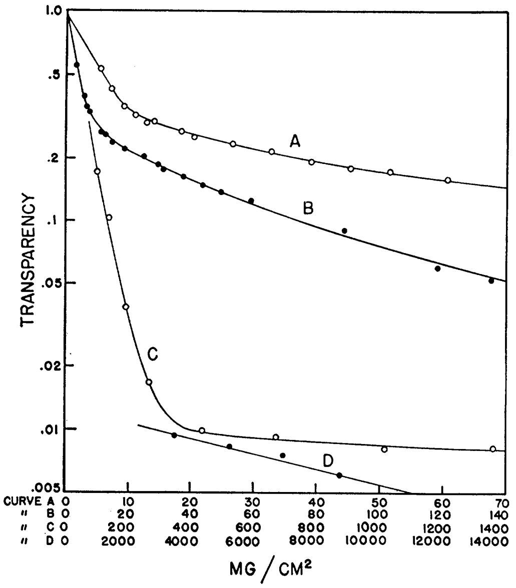

FIG. 2. Absorption of radiation from 54-day Re. Curves A, B, and C; absorption in Al. Curve D; absorption in Pb.

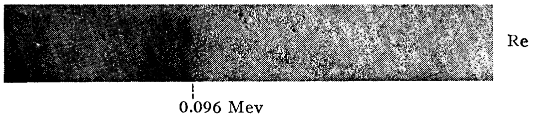

FIG. 3. Conversion electrons from tungsten bombarded with protons.

Previous experience had shown that a beta-ray spectrograph could be used to photograph a line of electrons of around 100 kev energy if the intensity was such that the equivalent of about 10^5 divisions of the electroscope were available. This corresponds roughly to 10^9 particles. Since the fraction of these striking the photographic film in our spectrograph is about 10^{-5}, as an estimate 10^6 electrons are required to produce a usable image. Because various workers[2] have shown the reciprocity law to be valid for electrons, it seemed worth while to attempt a long exposure to measure the low energy group from our target. A twenty-one-day exposure showed a line at 0.096 Mev, reproduced in Fig. 3. If these are K-conversion electrons, there must be a gamma-ray from the 54-day rhenium isotope of 0.096±0.071 (Re K edge) = 0.17 Mev.

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[1] K. Fajans and W. H. Sullivan, Phys. Rev. **58**, 276 (1940).

[2] A. Becker and E. Kipphan, Ann. d. Physik **10**, 15 (1931); also M. J. Nacken, Physik. Zeits. **31**, 296 (1930).

The Electric Fields in Vibrating Polar Crystals

Within a vibrating polar crystal there are electric forces caused by the polarization, $\mathbf{P}$, associated with the displacements of the ions of the crystal during the vibration. These forces give rise to an electric field, $\mathbf{E}$, and an electric displacement, $\mathbf{D}$, which, according to Lyddane and Herzfeld,[1] are connected with the polarization by

$$\mathbf{E} = -4\pi\mathbf{P}, \quad \mathbf{D} = 0, \tag{1}$$

if the wave-length of the vibration is short compared to the size of the crystal but long compared to the lattice distance. This result is stated to be independent of whether the waves in the crystal are longitudinal or transverse. On the other hand, Fröhlich and Mott[2] have given formulae that agree with (1) for the longitudinal displacement but become

$$\mathbf{E} = 0, \quad \mathbf{D} = 4\pi\mathbf{P} \tag{2}$$

for the transverse case.

That the latter result is the correct one becomes apparent from the following direct calculation based on formulae given by Lyddane and Herzfeld[1] for the electric force, $\mathbf{F}$, within a crystal. When the wave-length is long compared to the dimension of a crystal slab, these formulae are:

(1a) $\mathbf{F}=-(8\pi/3)\mathbf{P}$ if P is perpendicular to the face of the slab,
(1b) $\mathbf{F}=(4\pi/3)\mathbf{P}$ if P is parallel to the face of the slab.

Should the wave-length be short compared to the dimensions of the slab but long compared to the lattice distance:

(2a) $\mathbf{F}=-(8\pi/3)\mathbf{P}$ for the longitudinal vibration
(2b) $\mathbf{F}=(4\pi/3)\mathbf{P}$ for the transverse vibration.

According to the conventional definition, the electric field is the electric force in a slot in the crystal with its short dimension perpendicular to the direction of the electric force. We consider a slot of dimensions short compared to the wave-length. Then $\mathbf{E}$ is obtained by subtracting from (2a) or (2b) the effect of the material that has been removed to form the slot. Since the electric force is always parallel to $\mathbf{P}$, the effect of this material is just the force (1b). Therefore

$$\mathbf{E}=-4\pi\mathbf{P} \text{ for the longitudinal vibration,}$$
$$\mathbf{E}=0 \text{ for the transverse.}$$

The displacement, $\mathbf{D}$, is given by the electric force in the slot when its short dimension is parallel to the polarization. Therefore, subtracting (1a) as the effect of the material in the slot from (2a) and (2b)

$$\mathbf{D}=0, \quad \mathbf{D}=4\pi\mathbf{P}$$

for the longitudinal and transverse vibrations, respectively.

These formulae are consistent with $\mathbf{D}=\mathbf{E}+4\pi\mathbf{P}$, and they also lead, according to (2a) and (2b), to the Lorentz-Lorenz force for both types of vibration; that is:

$$\mathbf{F}=\mathbf{E}+(4\pi/3)\mathbf{P}.$$

At first sight, the fact that the electric displacement does not vanish for the transverse vibration may appear to be inconsistent with the absence of an impressed external field. However, the polarized crystal itself gives rise to an external field which is just $4\pi\mathbf{P}$ at the surface and vanishes exponentially with distance from the surface. This may be seen by considering a charge distribution on a plane surface that is periodic in one direction with wave-length λ and constant in the perpendicular direction. Such a charge distribution gives rise to a field proportional to $\exp(-2\pi x/\lambda)$, if x is perpendicular to the surface. A transversely displaced crystal with the polarization perpendicular to the face of the slab may be considered as made up of a series of such planes, and it is apparent that there will be an exponentially decreasing external field over a distance approximately given by the wave-length of the vibration under consideration. The result obtained directly from the lattice sums by Kellerman[3] is in agreement with this qualitative argument.

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The $C^{12}H_2-N^{14}$ Mass Difference

Three years ago the author, in an attempt to obtain more accurate mass values, undertook to construct a new type of mass spectrograph having a very high resolving power and dispersion. This instrument was completed last spring and reported[1] at the Washington meeting of the American Physical Society.

Its constants are given in Table I together with those of other instruments being used at the present time to study the light element doublets.

The mass scale is correction free, mass differences being obtained directly by taking the mean of the ratios of the doublet separation to the forward and backward dispersion line separations. In the case of the $C^{12}H_2-N^{14}$ doublet, this method of calculation gives the mass difference directly to 0.000015 mass unit, a figure which is several times smaller than the error introduced in making a single doublet distance measurement. In addition, exact methods have been worked out for correcting this small deviation and it is estimated that the resulting error due to the method of computation alone is approximately three to four units in the sixth decimal place. The above relation holds true regardless of the plate position within rather wide limits.

Recently a considerable number of matched as well as unmatched $C^{12}H_2-N^{14}$ doublets were obtained in a series of spectra which were photographed under different conditions and used to verify the theoretically expected relations. The values of the mass differences corresponding to these doublets are listed in Table II in order that a birdseye view of the variations may be obtained. These data result from measurements taken on three different plates, three to five measurements of the doublet distance being made in each instance. Although the difference in density between the doublet lines is not large in any case, only about half the doublets corresponding to the values listed are matched. It so happens that if the matched doublets alone are considered, the same average value is obtained, the probable error also being approximately the same.

For comparison purposes, this mass difference, together with other published values for the light element doublets is listed in Table III. Although no cross check doublets

TABLE I. *Mass-spectrograph constants.*

MASS SPECTROGRAPH	RESOLVING POWER $M/\Delta M$	DISPERSION (MM FOR 1% MASS DIFF.)
Aston	2,000	4.5
Mattauch	6,500	1.4
Asada and others	17,000	4.65
Jordan	30,000	14.6

TABLE II. *The* $C^{12}H_2-N^{14}$ *doublet mass differences.*

0.01255	0.01255	0.01257	0.01258	0.01254
0.01258	0.01254	0.01263	0.01254	0.01255
0.01256	0.01252	0.01258	0.01257	0.01251
0.01253	0.01260	0.01256	0.01265	0.01252
			0.01254	0.01256

Average 0.01256±0.000015*

* This error is three times the probable error computed from the internal consistency of the data.

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[1] R. H. Lyddane and K. F. Herzfeld, Phys. Rev. **54**, 846 (1938).
[2] H. Fröhlich and N. F. Mott, Proc. Roy. Soc. **A171**, 496 (1939).
[3] E. W. Kellerman, Phil. Trans. Roy. Soc. **A238**, 513 (1940).