of α. This range of α decreases in extent as $y\beta^2$ increases. When $y\beta^2$ goes to infinity the range of α goes to zero. Consequently, the expressions for Φ, B, and D for the achromatic case are not valid in the limit as $\beta \rightarrow 1$.

The expressions for the Wien velocity filter are given in the last column of the table. In a Wien velocity filter a parallel plate condenser replaces the cylindrical condenser. The length of the filter, L, i.e., the distance between source and image, may be obtained from the limit of $r_0\Phi$ as $r_0 \rightarrow \infty$, with $r_0/y = (mv^2/eE)_0$. The calculation of the relativistic value of L was also contained in the note of Schwinger which was referred to above.

The expressions for B and D_v for the Wien filter result from the same limiting process. The R_H which appears in the table stands for the radius the particle would describe if the magnetic field alone were present. The minus sign in the expression for B is included to indicate that B and D_v have opposite signs.

To Professor K. T. Bainbridge, who suggested this problem, the author is deeply indebted for valuable suggestions and aid. Henneberg's article as well as problems arising in the relativistic treatment were discussed with Professor Bainbridge and Mr. F. L. Niemann. Professor E. M. Purcell and Professor W. H. Furry have read this article and suggested several changes.

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Contributions to the Nuclear Processes Induced in Magnesium by Polonium Alpha-Particles

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Mg metal was bombarded in hemispherical symmetrical arrangements from the center by a strong Po source. The excitation function of the induced Al^{28} activity and of the induced γ-radiation was determined with an improved resolving power and accuracy. The absolute yields were determined carefully. Possibilities for the origin of the γ-radiation are discussed.

As is known, Mg consists of 3 isotopes ($A = 24$, 25, 26) amounting to 77.4, 11.5 and 11.1 percent. Six possible nuclear transformations may occur in the case of the immigration of an α-particle:

1. $Mg^{24}(\alpha,p)Al^{27}$
2. $Mg^{25}(\alpha,p)Al^{28}$
3. $Mg^{26}(\alpha,p)Al^{29}$
4. $Mg^{24}(\alpha,n)Si^{27}$
5. $Mg^{25}(\alpha,n)Si^{28}$
6. $Mg^{26}(\alpha,n)Si^{29}$

and there is the possibility of the inelastic scattering of the α-particle followed by the γ-radiation of the excited Mg nucleus.

The main subject of this paper is to investigate the exact shape of the excitation function and the absolute yield of the short-living artificial radioactivity (Al^{28}), and the excitation function, quantum energy, absolute yield and origin of the γ-radiation at α-energies below 5.3 Mev.

APPARATUS

Po Preparation

The technics of Po preparations used at this Institute enabled us—by means of a volatilization method[1]—to obtain very pure Po-sources with a strength of about 10 mC or more, on a highly polished Pt-Ir disk of 3 mm diameter.

Activation Apparatus

The Po-source was located in the center of the activation apparatus and brass hemispheres of 5 cm diameter, coated on the inside with a thick pressed Mg metal plate, were placed over it (Fig. 1). Then the air was removed and CO_2 gas of suitable pressure was let in to keep the α-particles down to the energy required. The geometry

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[1] A. Szalay, Zeits. f. Physik 112, 29 (1939).

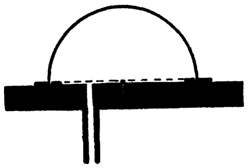

FIG. 1. Activation apparatus for Mg hemispheres bombarded from the center by Po-α-particles.

of this apparatus enabled us to make use of a solid angle of 2π and assured a very good homogeneity of the energy of the bombarding α-particles as well.

Activity Counting Equipment

The counter was a special one of hemispherical shape, developed and used by one of us years ago for the counting of weak induced activities.[1] (Fig. 2.) It was a wire-loop type counter, somewhat a transitional type between the point-counter and the G-M counter tube. Its hemispherical wall consisted of about 0.2 mm Al. Its sensitivity was carefully tested from various angles of incidence by means of a Ra-E β-gun. The hemispherical counter was situated in the middle of a lead cylinder of 4 cm thickness. The closing of the cover automatically switched on the electromagnetic counter-mechanism and started the stop-watch.

Careful determinations were made for the absorption of the electrons in the wall of the counter in the following way: Al hemispheres of the same (0.2 mm) thickness, prepared in the same way, were put as absorbing media over the hemisphere of the counter.

After finished activation (duration 6 min.) the Mg target was quickly placed on the counter and the activity was measured several times without additional absorbing hemispheres and under the same conditions, with one or two additional absorbing hemispheres. The measurements indicated that the mass absorption coefficient of the β-radiation of Al^{28} possesses under such geometrical conditions a value of $\mu = 3.9 \pm 0.9$ cm^2/g Al. In this way the accurate correction was determined for the absorption in the wall of the counter. The value of the correction factor was 1.19. Further corrections were made for the half-life. The duration of activation and observation was numerically extrapolated back to the time of stopping of the activation and up to infinite.

RESULTS

At first it had to be decided, which of the three possible artificial radioactive nuclei are observable at so small α-energies and what is the yield of them. For this purpose, we raised the duration of the activation of the Mg targets to 30 min. The decay of the activity was observed for 35 min. and noted every minute. The decay curve showed a predominating short-living activity of Al^{28} and a weak long-living activity of Al^{29}. The activity of the long-living product was too weak to estimate its half-life exactly. It seemed to be about 7–8 min. with a probable error of ±3 min. The total yield of the long-living activity was about 20 percent of the total activity observed during 35 min., after 30 min. activation. The ratio of the intensity (number of particles/min.) of the long-living activity to the short-living one was about 8 percent at saturation activation. There is no doubt that this is the well-known Al^{29} activity of 6.7 min. half-life.[2]

We eliminated the influence of the long-living activity by means of short activation and measurement-times. In the case of the used 6-min. period for activation and for measurement as well, the long-living activity could not amount to more than 3 percent of the observed total. This error could be left out of consideration. We estimated the half-life of Al^{28} by means of ten repeated 6-min. activations with full α-energy. The activity was registered at the end of every minute for 6 min. The evaluation in the

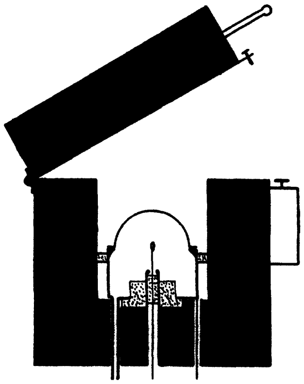

FIG. 2. Wire-loop counter for the measurement of the Al^{28} activity excited in Mg hemispheres.

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[2] W. J. Henderson and R. L. Doran, Phys. Rev. 56, 123 (1939).

usual way resulted in a half-life of $T=2.07\pm 0.05$ min. These measurements were carried out carefully, with a small statistical error. We state with certainty that the half-life is shorter than the 2.3 or 2.5 min. given by some earlier observers.[3, 4]

THE EXCITATION FUNCTION OF THE PROCESS $Mg^{25}(\alpha,p)Al^{28}$

Measurements and considerations above showed that in the case of 6-min. activations and measurements, the observed activity can be ascribed, at least up to 97 percent, to this transmutation. The thick Mg hemispherical targets were used for the determination of the excitation curve, represented in Fig. 3. Ten repeated series of activations were made over the whole measured interval for each α-particle energy. Each point on the graph represents the sum of ten activity observations. The total activity of one activation induced by the full energy of the α-particles of the 10 mC Po-source amounted to about 600 counted particles. This gave an absolute yield (number of Al^{28} atoms/number of incident α-particles) of 1.4×10^{-7} for the natural isotope mixture and for a thick Mg target (integral yield), when corrections mentioned above and corrections for the geometrical losses are taken into account. The differential yield amounts to 0.24×10^{-7} for 5.3 Mev α-energy and for a Mg target of 1 mm air-equivalent thickness.

The ordinate of Fig. 3 shows the integral absolute yield of the process $Mg^{25}(\alpha,p)Al^{28}$ for the natural isotope mixture.

The abscissa shows the maximum ranges of the bombarding α-particles and their corresponding maximum energy, estimated by means of the graphs of Livingstone and Bethe.[5]

The excitation curve completes earlier measurements made by Chang and Szalay,[6] which were made for α-energies from 7 Mev down to 5 Mev, and which Szalay made for α-energies below 5.3 Mev.[7] It seems to show some signs of resonances, but the resonances are scarcely greater than the statistical errors. It seems to us to be unjustified to give some values of α-energy as resonance-energies.

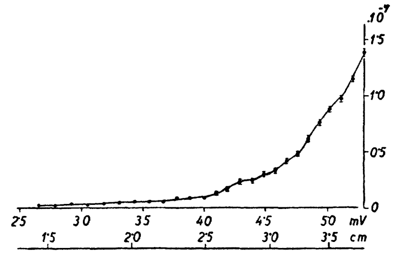

FIG. 3. The excitation function of the Al^{28} activity induced in Mg by α-particle bombardment. Abscissa: maximum range resp. energy of the α-particles; ordinate: integral absolute yield of the transmutation $Mg^{25}(\alpha,p)Al^{28}$ for a thick layer of Mg consisting of natural isotope mixture.

INVESTIGATION OF THE GAMMA-RADIATION

It was shown by Bothe and Becker[8] that a weak γ-radiation is excited in Mg when bombarded by Po α-particles. They reported a yield of the magnitude 1 γ-quant/10^6 α-particles of maximum Po α-energy. Savel[9] investigated the excitation function, but only for 6 different α-energies, therefore the resolving power is low. He reported a quantum energy of 0.5 Mev from absorption measurements. In contradiction to his measurements Webster[10] reported a quantum energy of 5.0 Mev.

It is the task of these measurements to settle this question by employing greater accuracy.

Excitation Function

The same Po-source and Mg target of 5 cm diameter was used for the investigation of the integral γ-excitation curve. Figure 4 shows the arrangement of the target and the G-M counter-tube. The whole arrangement was surrounded by a massive lead shield of 3 cm thickness to reduce the natural effect. The G-M counter-tube consisted of 1.8 mm thick brass, had a diameter of 45 mm and a length of 88 mm.

We observed a natural effect of 2033 ± 15 impulses/hour, in addition to this came the γ-radiation of the 10 mC Po-source of 4530 ± 9

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[3] C. D. Ellis and W. J. Henderson, Proc. Roy. Soc. **156**, 358 (1936).

[4] L. N. Ridenour and W. J. Henderson, Phys. Rev. **52**, 889 (1937).

[5] M. S. Livingstone and H. A. Bethe, Rev. Mod. Phys. **9**, 266 (1937).

[6] W. Y. Chang and A. Szalay, Proc. Roy. Soc. **159**, 72 (1937).

[7] A. Szalay, Naturwiss. **32**, 72 (1944).

[8] W. Bothe and H. Becker, Zeits. f. Physik **66**, 289 (1930).

[9] P. Savel, Ann. de physique **4**, 88 (1935).

[10] H. C. Webster, Proc. Roy. Soc. **136**, 428 (1932).

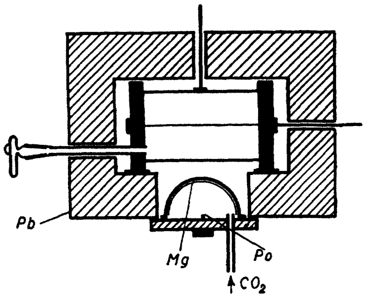

FIG. 4. Apparatus for the investigation of the excitation function of the Mg γ-radiation.

observed γ-quanta/hour. The maximum intensity of the γ-radiation, excited in the Mg target, amounted to 952±45 quanta/hour, at 5.3 Mev α-energy, actually counted in the given geometrical arrangement.

Figure 5 shows the integral excitation function of the γ-radiation. It becomes observable for 4.0 Mev and then rises quickly up to higher values. The intensity is small in comparison with the natural effect, therefore the statistical errors are considerable. Resonance effects could not be stated decisively.

Absorption

Figure 6 shows the apparatus. It was the same as for the investigation of the excitation function, with the difference that a hemispherical target of 2 cm diameter was used. The stopping power of the CO_2 was not sufficient to stop the Po α-particles from bombarding the target, so a brass shutter was used, which could be moved from the outside. In this way the α-particles could be retarded from the target and so the natural effect +Po γ-radiation could be measured separately from the induced γ-radiation. The absorption measurements were carried out always at 5.3 Mev α-energy. The actual rates of counting were 2035±15 quanta/hour for the natural effect, 6819±42 quanta/hour for the Po-γ and 1371±56 quanta/hour for Mg γ-radiation, without lead absorbents.

We combined one, two, or three lead absorbents of half cylindrical shape, with thicknesses of 2.7, 2.7, and 1.9 mm.

Figure 7 shows the results of the absorption measurements of the γ-radiation. The ordinate shows the intensity represented by the logarithm of the rate of counting ($\log I/I_0$); the abscissa shows above the actual thickness, below the "effective thickness" of the absorbing lead in cm. (The "effective lead thickness" is related to the spherical absorption coefficient μ and was estimated experimentally by the absorption of the well-known γ-radiation of ThC+C′+C″.)

For the calibration of this absorption equipment we prepared pure sources of RaC and ThC in equilibrium with their daughter products (C′ and C″ bodies). These sources were made on nickel hemispheres of exactly the same shape as the Mg target and were situated on exactly the same place.

Further we measured the absorption of the γ-radiation of the used Po source situated at the center.

Figure 7 shows the absorption of the γ-radiation induced in Mg and of the other investigated γ-radiations of Po, ThC+C′+C″ and RaC+C′+C″.

The difficulties of γ-absorption measurements, especially in cases when the very small intensity prevents the use of clear, well-defined geometrical conditions, are well known. Here we must point out some possible sources of errors in detail, and how we tried to reduce them. At first: the γ-quanta traverse the lead absorbents at various angles of incidence and for this reason it would be erroneous to use the actual thickness of the lead without any correcting factor. A "mean effective thickness" (related to the spherical absorption arrangement) must be determined experimentally. It is greater than the actual

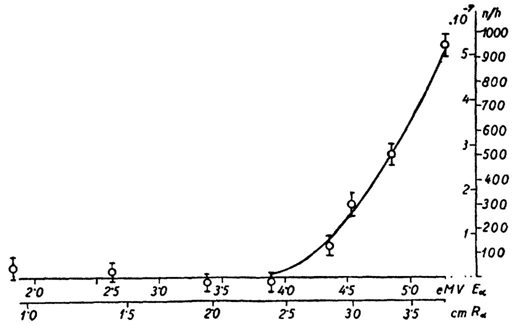

FIG. 5. Excitation function of the γ-radiation excited in a thick Mg layer by α-particles. Abscissa: maximum range resp. energy of the α-particles. Ordinates, right: rate of counting/hour; left: integral absolute yield of the γ radiation, i.e., number of γ quanta/number of incident α-particles.

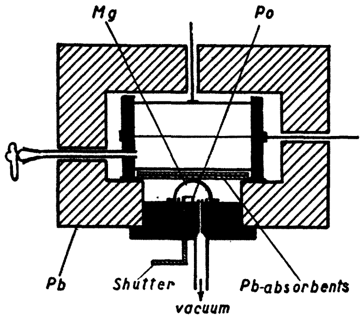

FIG. 6. Measuring equipment for the determination of the energy of the γ-radiation excited in Mg by Po-α-particles of full energy.

thickness of the lead screens. The lack of a clear geometry prevents an exact estimation of the participation of the three different components (photo-, Compton- and materialization-effects) in the total absorption coefficient μ. Disagreement of the measurements of Savel[9] and Webster[10] can be ascribed in this case certainly to the above reasons. We tried to eliminate such sources of errors by means of the calibration of the apparatus by the known γ-radiation of the natural radioactive sources of well-known lead absorption coefficient, resp. quantum energy.

The small intensity of the γ-radiation prevented the use of thicker lead absorbents. The intensity was reduced in the case of the used greatest thickness up to 63 percent for the Mg-γ, 58 percent for the ThC$''$-γ, 50 percent for the RaC-γ, and 43 percent for the Po-γ-radiation.

As Fig. 7 shows, the Mg γ-radiation possesses certainly a smaller absorption coefficient than the well-known γ-radiation of the ThC$''$, consisting of a component of overwhelming intensity of 2.65 Mev quantum energy.

We determined the effective thickness of the lead absorbents (abscissa, below) by the use of the well-known absorption coefficient for this nearby monochromatic radiation ($\mu = 0.47$ cm^{-1} in Pb). In this way we obtained an absorption coefficient for the induced γ-radiation of the Mg $\mu = 0.38 \pm 0.08$ cm^{-1} in Pb. It is remarkable that this value seems to be smaller than the smallest absorption coefficient measured for any γ-radiation in lead in the case of spherical absorption equipment. A look at Fig. 7 makes it sure that the difference of the absorption coefficient against the ThC$''$ γ-radiation is definitely emerging over the statistical error. The reason for the unexpectedly small value of the Mg γ-absorption coefficient must be in the reduced share of the Compton effect in the absorption, as a result of the unfavorable geometrical arrangement.

The total absorption coefficient in lead shows a flat minimum for about 3 Mev quantum energy,[11] an estimation of the quantum energy by means of lead absorption measurements is here very inaccurate. For these reasons we are unable to evaluate the quantum energy of the Mg γ-radiation with accuracy. It must possess a value somewhat greater than 3 Mev. Values of the probable error cannot be given.

Some sources of errors are eliminated in this way, because (1) the quantum energy of both radiations is nearly the same and so the shares of Compton, materialization and photo-effects are in both cases the same; and (2) the geometrical arrangement is—in both cases compared—exactly the same.

Criticism may arise by the fact that ThC+C$'$ +C$''$ possesses in addition to this 2.65 Mev γ-radiation other components of 0.58 and 0.51 Mev[12], with about the same number of γ-quanta/unit time. We were unable to apply a thick lead absorbent before to make the radiation homogeneous. But measurements of v. Droste[13] showed that the sensitivity of a brass G-M counter-

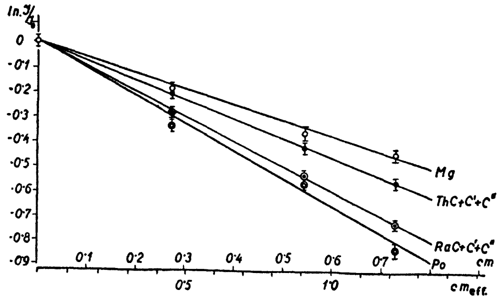

FIG. 7. Absorption of the γ-radiations in lead. Abscissa, above: actual thickness of the absorbing lead sheets; below: corrected "effective thickness" of the lead absorbents. Ordinates: logarithm of the relative decrease of the intensity of the γ radiation with *vs.* without lead absorbents for the Mg-γ. ThC+C$'$+C$''$$-\gamma$, RaC+C$'$ +C$''$$-\gamma$ and for the Po$-\gamma$-radiation.

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[11] Mme P. Curie *Radioactivité*, (Herman et Cie, Paris, 1935), Vol. II, Appendix 11.

[12] W. Gentner, Physik. Zeits. **36**, 836 (1937).

[13] G. v. Droste, Zeits. f. Physik **100**, 529 (1936), and **104**, 474 (1936).

tube is about 5 times smaller (0.32 percent) for 0.5 Mev quantum energy than for 2.65 Mev (1.61 percent). The very careful measurements of v. Droste showed that the practical absorption curve of this composed radiation does not differ much from the absorption curve of the filtered hard radiation, if a brass G-M counter-tube has been used for the measurement.

Recently Pollard and Alburger[14] measured the quantum energy of the γ-radiation of Mg induced by α-bombardment. They obtained a value of 3.2 ± 0.6 Mev in fairly good accordance with the value obtained above. Considering the fact that we were forced to work with sources of very low intensity and therefore under not sufficiently clear geometrical conditions, we will use in the following the value obtained by Pollard and Alburger of 3.2 Mev. (As E. Pollard kindly informed me in a private communication, Alburger's newest measurements, in the course of publication, are indicating a still higher energy of 3.8 Mev.)

MEASUREMENTS ABOUT THE ORIGIN OF THE GAMMA-RADIATION

It is well known that the electron emission of Al^{28} is followed by the emission of a γ-quant of 2.05 Mev,[15, 16] the last belonging to the excited state of Si^{28}. If the induced γ-radiation observed here belonged to this process, it would show a decay period of 2.1 min. We decided this question in the following way: we measured the number of emitted γ-quanta during a period of 120 minutes in such a way that we activated the Mg target for 2 minutes, then we stopped the α-rays with the shutter. Simultaneously the counter was switched on and the γ-radiation was counted for 2 minutes. After this, the whole process of measurement was repeated 60 times periodically, so that altogether 120 minute observations of the γ-intensity could be summarized. The periodically interrupted and summarized measurements gave altogether 13,886 $\pm$164 counts/120 min., included the natural effect+Po γ-radiation, the last two amounting to $13{,}714\pm162$ quanta/120 min., with closed shutter. These values above are nearly the same, within the limits of statistical errors. In the case of continuous measurements during bombardment by Po α-radiation of maximum range, the total rate of counting amounted to $16{,}936\pm184$ quanta/120 min. We can state with certainty that the induced γ-radiation of Mg is not identical with the γ-radiation connected with the electron emission of Al^{28}, moreover it is at least one order of magnitude more intense.

THE ABSOLUTE YIELD OF THE GAMMA-RADIATION

Knowledge of the absolute yield of the Mg γ-radiation may lead us to the decision of the question, which of the six possible nuclear processes is it connected with?

The actual measured intensity of the Mg γ-radiation was 1371 ± 56 observed γ-quanta/hour, when a hemisphere of 20 mm diameter was bombarded with the full energy of the 10.0 mC Po-source. (See geometrical arrangement in Fig. 6.)

We determined the absolute yield of the γ-radiation in the following two ways:

1st method. We estimated the geometrical angle (solid angle) of the apparatus and the absolute sensitivity of the G-M counter:

(a) an approximative calculation of the solid angle based on the maximum cross section of the G-M tube, taking the point of the solid angle into the center of gravity of the hemisphere, gave a solid angle of $0.22\cdot4\pi$.

(b) an approximative numerical integration for several zones of the hemisphere gave a total solid angle of $0.23\cdot4\pi$.

(c) another estimation based on the surface measurement of the shadow of the G-M counter projected by a point light source situated on the place of the Po source, gave a solid angle of $0.21\cdot4\pi$.

The most probable value of the solid angle is herewith $0.22\cdot4\pi$, a mean of the values above.

The absolute sensitivity of a brass G-M counter was estimated by v. Droste[13] for various wave-lengths and for the wave-length of the 2.65 Mev ThC″ γ-radiation ($\lambda=4.7$A). V. Droste estimated the sensitivity of a brass counter as 1.61 percent for the 2.65 Mev ThC″ γ-radiation.

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[14] E. Pollard and D. E. Alburger, Phys. Rev. **72**, 1196 (1947).

[15] Eklund and Hole, Ark. Mat. Ast. Phys. **29A**, No. 26 (1943).

[16] J. V. Dunworth, Nature **159**, 436 (1947).

The Mg γ-radiation has an energy of about 3.2 Mev as recently estimated by Pollard and Alburger.[14] The sensitivity of a brass G-M counter can be extrapolated, by means of the measurements of v. Droste, and a sensitivity of 2 percent is to be expected for this energy. Using this value and the solid angle of our apparatus, we obtain an absolute integral yield of the Mg γ-radiation excited by full range Po-α-particles as $4.6\cdot 10^{-7}$ γ-quanta/α-particles.

2nd method. The second way was the measurement of the absolute yield by direct comparison with a ThC″ γ-source of well-known strength. We prepared a ThC+C′+C″-source on a nickel hemisphere of the same diameter (20 mm) and have placed it in the place of the Mg hemisphere. We measured the actual number of countings/hour. The strength of the source was measured separately, by counting the number of the ThC-α-particles by a mica window counter, which was situated at the end of an evacuated tube. The activated nickel hemisphere was enclosed at the other end within the tube. The solid angle was defined by the small circular opening of the mica window counter. Successive changes in the air pressure within the tube stopped and separated the ThC-α, ThC′-α and the β-particles. In this way the number of emitted ThC-α particles could be separately determined. The number of the emitted ThC″-β-particles is the same and it is generally accepted in the literature that each ThC″-β-particle is followed by a 2.65 Mev γ-quantum. This means that a ThC+C′+C″ source is emitting nearly equal number of ThC-α particles and 2.65 Mev γ-quanta/unit time. A source of 0.9×10^{-4} mC (relating to ThC″) gave 10.5 γ-quanta/sec. in the equipment on Fig. 6.

By the numerical comparison of the ThC″ γ-radiation and the Mg γ-radiation, the error in the estimation of the solid angle is entirely eliminated and the error in the absolute sensitivity of the G-M counter is very much reduced, because only the quotient of the two sensitivities comes into the formula. Using the data of v. Droste, the sensitivity of the brass counter is expected to be 1.25 times greater for the 3.2 Mev Mg γ-radiation, than for the 2.65 Mev ThC″ γ-radiation. These numerical values give an integral absolute yield of 5.2×10^{-7} γ-quanta/full range Po-α-particles. This second way of measurement is certainly more accurate than the first.

DISCUSSION ABOUT THE ORIGIN OF THE GAMMA-RADIATION

Let us consider now the six possible processes when Mg is bombarded by α-particles.

1. $Mg^{24}(\alpha,p)Al^{27}$. The isotope mass values given by Mattauch and Flügge[17] give a mass defect of -1.96 ± 0.8 TMU; the process is herewith endoergic by -1.8 ± 0.7 Mev. Taking into account 3.2 Mev energy or more for the γ-radiation, the bombarding α-particle has to possess more than 5 Mev energy, or this process is excluded by reasons of energy. As the γ-radiation is first somewhat above 4.0 Mev α-energy observable, this possibility can be excluded certainly.

2. $Mg^{25}(\alpha,p)Al^{28}$ process was investigated carefully and our measurements show that the absolute yield of this transmutation (being 1.4×10^{-7} protons/α-particles) is definitely much smaller than that of the γ-radiation (5.2×10^{-7} γ-quanta/α-particles). The process is endoergic having a mass defect of -2.3 TMU, or -2.14 Mev calculated with the new mass value of Al^{28} of 27.99265 MU$\pm$0.7 TMU. This value is obtained by considering the recently experimentally testified fact[16] that Al^{28} emits at first a β-particle of 2.98 ± 0.18 Mev energy which is followed by a γ-quant of 2.05 Mev.[15] When we consider this fact, we obtain a new value of the mass difference between the stable Si^{28} nucleus and the Al^{28} nucleus, and so a new mass value, differing from that given by Mattauch.[17] Herewith it is excluded that the Mg γ-radiation could belong to this process.

3. $Mg^{26}(\alpha,p)Al^{29}$. We measured roughly the yield of this transmutation being even smaller than the yield of process (2). Its mass defect is about -3.3 TMU. Added to this the quantum energy of the γ-radiation, we get a minimum α-energy of 6 Mev. It is excluded by energy-conservation considerations, that the γ-radiation could belong to this process.

4. $Mg^{24}(\alpha,n)Si^{27}$, this process has a mass defect of -8.8 TMU and is definitely excluded

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[17] J. Mattauch, *Kernphysikalische Tabellen* (Verlag Julius Springer, Berlin, 1942).

for Po-α-energies. It definitely does not occur even at 16 Mev α-energy.[2]

5. $Mg^{25}(\alpha,n)Si^{28}$ process is exoergic by a mass defect of $+2.31\pm0.8$ TMU. It is energetically possible that the γ-radiation could belong to this process. The question could be decided by exact experimental determination of the excitation function and the absolute yield of this transmutation.

6. $Mg^{26}(\alpha,n)Si^{29}$, this transmutation having a mass defect of -1.5 ± 0.9 TMU may be connected with the γ-radiation as well, but it is as little investigated experimentally as process (5). We are intending in the near future to carry out measurements about the yield and the excitation function of the neutron emission of Mg, when bombarded by Po-α-particles.

SUMMARY

Mg hemispheres were bombarded by a very pure Po-α-source of small diameter from the center. The excitation function of the short-living artificial radioactivity belonging to the process $Mg^{25}(\alpha,p)Al^{28}$ has been investigated (Fig. 3). The absolute yield of this transmutation has been determined very carefully. It has a value of 1.4×10^{-7} transmutations/bombarding α-particle of 5.3 Mev energy, in a thick Mg layer consisting of the natural isotope mixture of the Mg isotopes.

The excitation function of the γ-radiation, which is excited in Mg by Po-α-particles, was investigated (Fig. 5).

The absolute yield of the γ-radiation has been determined very reliably by direct comparison with the ThC″-γ-radiation of a ThC+C′+C″ preparation of exactly known strength. The absolute yield of the γ-radiation excited in a thick Mg layer of natural isotopic composition under bombardment of full energy Po-α-particles amounts to 5.2×10^{-7} γ-quanta/α-particle.

A discussion of the origin of the γ-radiation is given. Four of the six possible processes can be excluded by considerations of energy, or by the comparison of the absolute yields as well. Two remain as possible origins of the γ-radiation, $Mg^{25}(\alpha,n)Si^{28}$ being the most probable by considerations of energy.

Further investigations in these processes are intended at this Institute.

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New Aspects of the Photon Self-Energy Problem

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A finite but non-vanishing value for the self-energy of the photon, corresponding to a finite rest-mass, can be deduced from the new invariant formulation of quantum electrodynamics developed by Tomonaga and Schwinger, in the e^2 order approximation. The implications of this result are discussed.

INTRODUCTION

THE new development in quantum electrodynamics has led to the conviction that the anomalies of the hydrogen 2*S* level and of the magnetic moment of the electron can be explained in terms of field-dependent parts of the electronic self-energy.[1] Accordingly, it seems that the concept of electromagnetic self-energy now acquires a more than merely mathematical significance. However, the field-dependent terms can, at best, be defined as finite parts of the still diverging, total self-energy of the electron which has to be eliminated from the Hamiltonian by a formal readjustment. Therefore, there is still but little hope for a final and satisfactory solution of the self-energy problems within the framework of the conventional quantum theory of fields.

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[1] J. Schwinger and V. Weisskopf, Phys. Rev. **73**, 1272 (1948); J. Schwinger, Phys. Rev. **73**, 416 (1948).

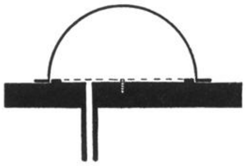

FIG. 1. Activation apparatus for Mg hemispheres bombarded from the center by Po-α-particles.

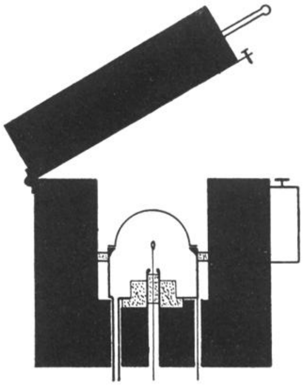

FIG. 2. Wire-loop counter for the measurement of the Al^{28} activity excited in Mg hemispheres.