Short Range Alpha-Particles from $F^{19}+H^1$

The gamma-ray spectrum from the bombardment of F^{19} by protons of energies up to 750 kv has been shown[1] to consist of a single line at 6.0 ± 0.2 Mev. This result has recently been confirmed.[2] Resonance in the production of this radiation occurs at 330 kv[3, 4] as well as at numerous higher voltages.[5] In this letter we are concerned only with results secured at or near the first resonance.

Excited states of Ne^{20} and O^{16} have frequently been discussed[6] as possible sources of the radiation. If the reaction terminates in the formation of Ne^{20} in the ground state, a total energy of 13.0 Mev must be emitted as gamma-radiation. The obvious difficulty of accounting for a single line at 6.0 Mev on this hypothesis has strongly suggested that normal O^{16} and He^4 may be the terminal products. A total energy of 7.95 Mev is available[7] on this alternative hence an energy of approximately two Mev, in addition to the kinetic energy contributed by the incident proton at resonance, should be available as kinetic energy of recoil for the heavy particles. If observations are made at 90° with the incident proton beam, alpha-particles of approximately nine mm range should be observed.

Previous attempts to detect these alpha-particles, both in this laboratory and elsewhere,[7] have not been successful. This can be explained on the basis that accelerating potentials of over 500 kv were employed and that for such high potentials the range of the protons scattered from the target is equal to or greater than that to be expected for the alpha-particles. The large ratio of scattered to disintegration particles almost entirely precludes the possibility of observing the latter under these conditions.

In the present investigation a small electrostatic generator was employed at and below the first gamma-ray resonance. A cloud chamber was used containing a mixture of helium and alcohol vapor having a stopping power approximately ten percent that of air under standard conditions. The disintegration products from a thick CaF_2 target inclined at 45° with the incident beam were admitted to the chamber through a thin mica or lacquer window (~3 mm equivalent range). Diaphragms limited the observed particles to those making an angle of $90°\pm8°$ with the incident beam.

In Fig. 1 is shown the number range curve of the tracks observed on 1800 cloud-chamber photographs with an accelerating potential of 350 kv and a proton current of one to five microamperes. The range scale was calibrated[8] by measuring under similar conditions the He^3 and He^4 groups from Li^6+H^1. The continuous distribution in Fig. 1 terminating at six mm is due to the protons scattered by the target. The mean range of the discrete group of particles is found to be 0.86 ± 0.05 cm. That this group is produced at a resonance voltage equal or very near to that of the first gamma-ray resonance was demonstrated by taking cloud-chamber pictures at 300 and 350 kv. On 200 pictures taken at 300 kv no tracks in this group were observed, while on 300 pictures taken immediately afterward at 350 kv 49 tracks of range near nine mm were observed. The fact that this group is much narrower than the Li^6+H^1 groups is also evidence for resonance. The observed track density is consistent with the assumption that

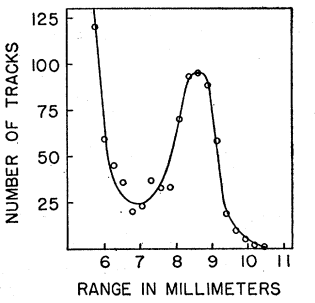

FIG. 1. The distribution in range of particles produced by the bombardment of F^{19} with 350-kv protons. The points represent the number of tracks in 0.5 mm overlapping intervals.

the group consists of alpha-particles. We suggest that they are the alpha-particles discussed above and are then to be attributed to the reaction

$$F^{19}+H^1\rightarrow(Ne^{20})\rightarrow O^{16*}+He^4+Q$$
$$O^{16*}\rightarrow O^{16}+h\nu.$$

Using the methods described by Bethe[8] we compute the energy released in the reaction to be $Q=1.74\pm0.10$ Mev so that the excited state of oxygen involved lies 6.2 Mev above the ground state in good agreement with the observed gamma-ray energy. The yield of alpha-particles is apparently smaller than that observed for the gamma-rays. Our results also indicate that the yield above resonance on a thick target is thirty times that of the nonresonance reaction

$$F^{19}+H^1\rightarrow(Ne^{20})\rightarrow O^{16}+He^4+7.95\text{ Mev},$$

in which the total available energy appears as kinetic energy of the heavy particles. These results are based on preliminary measurements at an angle of 90° and may be in error if the alpha-particle distributions are markedly anisotropic.

Further investigations are now in progress to determine more accurately the resonance voltage of the alpha-particles and their distribution in angle with the proton beam.

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The Evolution of Red Giants

It was recently shown by the author and E. Teller[1] that there exist in the mass-luminosity diagram a number of bands parallel to the main sequence in which different thermonuclear reactions of the light elements (D, Li, Be, B) play a predominant role. A star, starting its evolution with an appreciable amount of these elements, should proceed in the direction of decreasing radii and slowly increasing luminosities, and spend a comparatively long time within each of these bands and undergo a more rapid gravitational