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Density Effect on Energy versus Range of Fission Fragments in Gases*

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The density effect on specific energy loss of fission fragments in gases is discussed. Previously reported range-versus-energy data for median-mass light and heavy fission fragments in H_2, He, air, and Ar are corrected for saturation of the density effect.

IN a previously reported experiment,[1] fission fragments were degraded in energy by various stopping materials. Energies were measured as a function of thickness of stopping material traversed by the fragments. These data were used to obtain range-versus-energy curves for median-mass light and heavy fragments in the several materials. The materials included gases and metallic foils. The energies were determined by scintillation pulse-height measurements at the focal plane of a magnetic spectrograph.[2] The flight path from the fission foil to the focal plane was $\sim$7.5 m. For the measurements with gases the system was filled with the gas being studied. The pressure varied up to a few Torr. For presentation of the data in Ref. 1, the 7.5-m path lengths in gas at low pressures were converted to equivalent thicknesses of gas at atmospheric pressure. The data as presented in Ref. 1 are not corrected for the density effect on the specific energy loss of the fission fragments,[3] and hence are valid only for pressures at which the data points were taken. The purpose of this note is to present the previously reported range-energy data for fission fragments in gases with corrections for saturation of the density effect.

The density effect on specific energy loss of fission fragments in gases is due to the variation of equilibrium charge Z_{av} with pressure at low gas pressures.[4] The density effect on Z_{av} was studied experimentally (Ref. 4) for light and heavy fission fragments in hydrogen, helium, air, and argon. The results of that

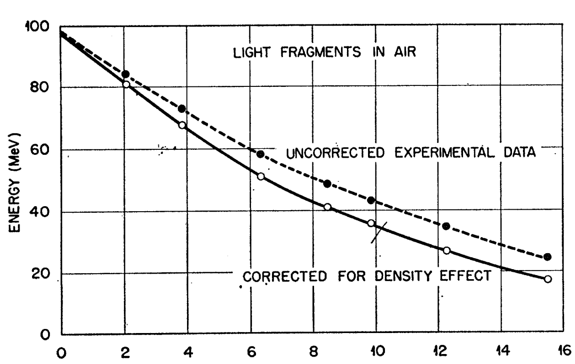

FIG. 1. Uncorrected and corrected data for light fragments in air.

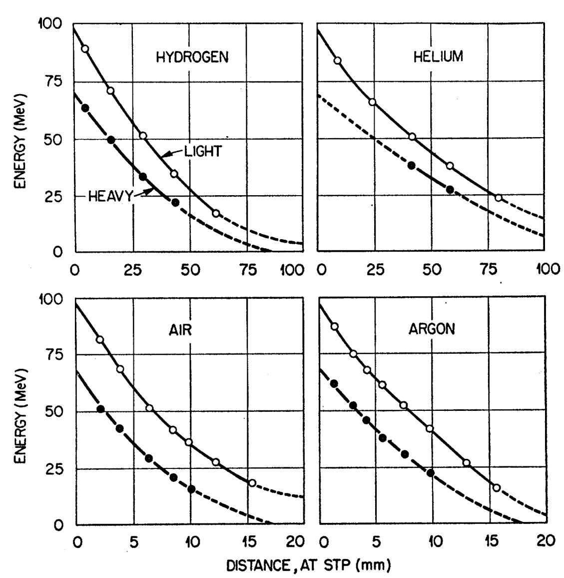

FIG. 2. Energy versus distance traveled for median-mass light and heavy fission fragments in gases. The data are corrected for saturation of the density effect.

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[2] B. L. Cohen and C. B. Fulmer, Nucl. Phys. **6**, 547 (1958).
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study showed that Z_{av} increases with gas pressure until saturation of the effect occurs at $\sim$10 to 50 Torr, for the various gases studied. Z_{av} is $\sim$10% larger at saturation than at pressures approaching zero. Since $dE/dx \propto Z^2{}_{av}$, the density effect on Z_{av} is an important factor in specific energy loss.

The pressure effect on the equilibrium charge is attributable to incomplete radiative dissipation of electron-excitation energy of the fragments between successive collisions with gas atoms.[4,5] For a charge-change cross section that is $1/v$-dependent, as is indicated by the work of Bohr and Lindhard,[5] the pressure effect on Z_{av} should be independent of fragment velocity. Experimental study of the pressure effect on Z_{av} for fragments of a single mass[4] showed Z_{av} to be insensitive to fragment velocity.

The range-energy data for fission fragments in gases are corrected for the density effect by the relation

$$E=E_0-(E_0-E_{exp})[1+((H\rho)_p-(H\rho)_{min})/(H\rho)_p]^2. \quad (1)$$

E_0 is the initial energy of the fragments (98 MeV for the light fragments and 68 MeV for the heavy fragments). E_{exp} is the measured energy of the fragments that arrive at the focal plane of the system at pressure p; $(H\rho)_p$ is the measured magnetic rigidity of the fragments in gas at pressure p; and $H\rho_{min}$ is the magnetic rigidity of the fragments for saturation of the density effect on Z_{av}. The $H\rho$ values used in (1) were obtained from the data presented in Ref. 4.

The density effect on energy versus range is illustrated in Fig. 1. The light-fragment range-energy data for air are shown uncorrected for the density effect and corrected for saturation of the density effect. The flight path of the fragments was 750 cm; thus the flight path in the system at a pressure of 1 Torr corresponds to $\sim$10 mm at atmospheric pressure. The range-energy data for the various gases studied, corrected for saturation of the density effect, are shown in Figs. 2 and 3. It was shown in Ref. 4 that the density effect saturates for hydrogen and helium at $\sim$50 Torr and for air and argon at $\sim$10 Torr.

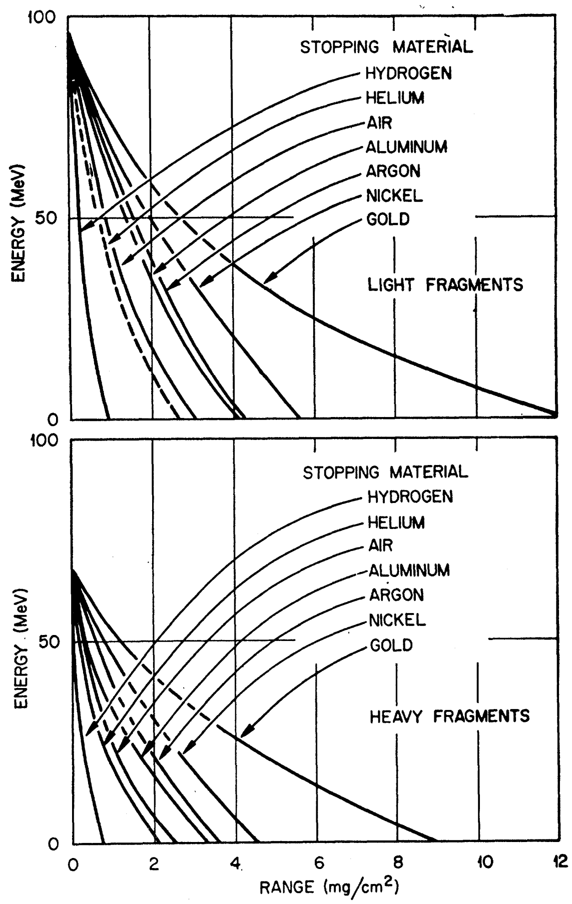

FIG. 3. Energy of median-mass light and heavy fission fragments as a function of range in various materials. The curves for the gaseous materials are corrected for saturation of the density effect at atmospheric pressure.

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