On the Showers of Mesons and Nucleons

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January 3, 1949

RECENT experimental results induce us to attempt a revised formulation of the fundamental assumptions proposed in previous papers in order to give a quantitative description of the production of mesons.[1]

1. We assume, of course, that the fundamental process occurring in a high energy collision of nucleons or nuclei is the production of showers of mesons (probably π-mesons and, eventually, other short-lived mesons) and nucleons. The direct production of photons and electrons is assumed to be a secondary phenomenon in most cases (except, perhaps, in the case of highly charged incident nuclei).

2. Indicating by ΔE the fraction of the energy E of the incident nucleon lost in the collision and measured in the terrestrial frame, we assume: $\Delta E/W\sim 1$, and we denote: $av(\Delta E/E)=k$. Considering the possible change of the spin and the charge, we can say that after the collision there will be usually one nucleon having an average energy $E-\Delta E=(1-k)E=qE\sim E$.

3. The energy amount ΔE lost by the incident nucleon will be shared between the created mesons and some nucleons taking part in the collision. We shall consider the center of mass system of this assemblage of mesons and nucleons and apply to it statistical laws. Then, following the deduction indicated in previous work,[1] we find: $\Delta E\cong An^2+Bn+C$ where A, B, and C are constants having values depending on the masses of the colliding nuclei and n is the number of mesons produced. For large values of n (e.g. $n>100$) we can put $\Delta E\sim An^2$ and thus, approximately, $n\sim(E)^{\frac{1}{2}}$ as pointed out.[1] For smaller showers $10\lesssim n\lesssim 100$ one has: $\Delta E\sim Bn$.

4. The cross section for meson production σ of a primary proton or a fast nucleon with a nucleon at rest is $\sim 3\times 10^{-26}$ cm². Thus the collision thickness l for production in cascade of showers of mesons and nucleons by fast nucleons is: $l\sim(M/\sigma)\sim 50$ g/cm².

Observations show that almost all energetic showers contain mesons and, therefore, are originated by nucleons. The average value of q can be found from the known value of the frequency of the primary protons and of the fast nucleons at sea level. Indeed, from the assumptions 2 and 4 it follows that the energy of a primary proton is reduced after n collisions by a factor $q^n=q^{x/l}$, where x is the atmospheric depth in g/cm². If we neglect the contribution of low energy nucleons, and assume the spectral distribution of the primary protons to be of the type: $dN_P=CE_P{}^{-\gamma}dE_P$ where $\gamma\cong 2.5$, the spectral distribution of fast nucleons after n collisions will be: $dN_N=Cq^{n(\gamma-1)}E_N{}^{-\gamma}dE_N$. Thus the spectral power law is conserved and the reduction factor is: $q^{n(\gamma-1)}=q^{0.03x}$. From the observations we have for the ratio of the primary and the sea-level intensity of fast nucleons a value $\sim 3\times 10^5$. Therefore we obtain $q\sim 0.7$. The resulting approximate description of showers of mesons and nucleons permits one to understand many observed phenomena. Here we want to discuss the remarkable formula giving the number dN' of showers having densities δ in the interval $(\delta, \delta+d\delta)$: $dN'=C'g(\delta)\delta^{-\gamma}d\delta$, where $g(\delta)\rightarrow 1$ for high δ, and $\lim_{\delta\rightarrow 0}g(\delta)\delta^{-\gamma'}=0$ and where $\gamma'\sim 2.5$. This spectral distribution is very similar to the distribution of primary protons ($\gamma'=\gamma$). Indeed for local showers the electronic density can be assumed proportional to the meson density. The latter is proportional to the multiplicity n, and thus to $Bn\sim\Delta E\sim E_N$. Comparing the formulas for dN' and dN_N we see: $\gamma'=\gamma$.

[1] G. Wataghin, Phys. Rev. **74**, 975 (1948).

The Isotopic Constitution of Dysprosium

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December 29, 1948

THE isotopic constitution of dysprosium was first investigated by Aston[1] who found isotopes of masses 161, 162, 163, and 164. He obtained the relative abundances of these isotopes by using a discharge tube with $DyBr_3$ as an ion source, and estimating line intensities on his photographic plates by photometry. Later, Dempster[2] discovered weak isotopes at masses 158 and 160 and estimated the abundance of these isotopes. He did not quote the percentage abundances of the other isotopes. Dempster's values for the percentages of Dy^{158} and Dy^{160} and Aston's values for the heavier isotopes, corrected for the presence of Dy^{158} and Dy^{160}, are given in Table I. Later Wahl[3] made a photometric determination of the abundances of all these isotopes in which he quoted more significant figures than did Aston. Recently[4] two of the authors reported the existence of a stable Dy^{156} isotope present to about one-twentieth of one percent. Because of the discrepancies between the values of Wahl (Table I) and the earlier investigators and because of the large errors inherent in the photometric method, it seemed desirable to measure electrometrically the relative abundances of the dysprosium isotopes. In the course of this work upper limits for the existence of other isotopes were set.

A sample of Dy^2O^3, especially purified with an ion exchange column by Dr. D. H. Harris of the Clinton Laboratories, was analyzed by a filament source mass spectrometer utilizing a recording vibrating reed electrometer to detect the ion beam. The instrument and techniques used in this mass analysis have been described elsewhere.[5] Dysprosium peaks of types Dy^+ and DyO^+ were both observed, but due to the weaker emission in the DyO^+ position, the precision of the measurements at this position was much less. Thus, the values given have been calculated only from the Dy^+ position. The DyO^+ values are, however, consistent with the Dy^+ results. The third row in Table I gives our values for the percentage abundances of the various dysprosium isotopes. The errors quoted are larger than the probable mean deviations in the percentages based on twenty separate determinations. Despite an apparent accuracy of about $\frac{1}{4}$ percent obtained for the probable error calculated on the basis of mean deviations, we do not wish to quote probable errors in any