elements changes considerably when in compounds. So the values of ΔE_A and ΔE_B measured as the distance between the two peaks of the valence bands may not be accurate.

(2) The appearance of structures in the valence band spectra create much difficulty in ascertaining the correct values for ΔE_A and ΔE_B.

(3) If one of the constituents is ordinarily a gas, usually a position for the gaseous state is determined from the formula, knowing the value of the heat of formation of the particular compound. Once this has been done, the values of ΔE for other compounds involving the particular gas are determined with respect to the calculated position.

Although there are so many limitations, the equation helps to identify and explain the origin of particular bands in soft x-ray spectra, to indicate the direction and the amount of shift for the elements in compounds and alloy, and to suggest a straightforward picture as the mechanism of the evolution or absorption of heat in a chemical reaction.

I wish to express my sincere thanks to Professor S. N. Bose, Head of the Department of Physics, University College of Science, Calcutta, who has given me the facilities of work in his laboratory and encouraged me during the progress of the work. My thanks are also due to the National Institute of Sciences of India for appointing me a Research Fellow of the Institute.

[1] O'Bryan and Skinner, Proc. Roy. Soc. **A176**, 229 (1940).

The Gamma-Ray Spectrum from the Absorption of π^--Mesons in Deuterium*

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THE gamma-ray spectrum resulting from the absorption of π^--mesons in deuterium has been analyzed with a pair spectrometer having 30 channels covering a range of 3 to 1 in energy. The experimental arrangement is similar to that discussed in previous letters by the same authors.[1,2] The deuterium is contained in the pressure vessel at 2700 p.s.i. at the temperature of liquid nitrogen. Its density[3] is 0.096 as compared with a hydrogen density of 0.046 under the same conditions.

Ten runs were made over a 72-hour period without changing the physical set-up. The regions centering on 130 Mev and 70 Mev were examined with full sensitivity. Comparisons were obtained between hydrogen, deuterium, helium, and vacuum background in the upper energy region. In the lower energy region deuterium, helium, and background were examined so that a limit might be set to the null effect observed there in deuterium.

The spectrum from π^--capture in hydrogen has been attributed to the reactions

(a) $\pi^-+p\rightarrow n+\gamma$ $\qquad (E_\gamma=131$ Mev).
(b) $\pi^-+p\rightarrow n+\pi^0\rightarrow n+2\gamma$ $\qquad (E_\gamma=70$ Mev).

In deuterium one or more of the following reactions are probable:

(c) $\pi^-+d\rightarrow 2n+\gamma$ $\qquad (E_\gamma=0$ to 135 Mev).
(d) $\pi^-+d\rightarrow 2n+\pi^0\rightarrow 2n+2\gamma$ $\qquad (E_\gamma=70$ Mev).
(e) $\pi^-+d\rightarrow 2n$.

By combining the channels in which a positive counting rate is observed we find the following total counting rates for the various processes:

(a)	0.470±0.046 c.p.m.	For a total of 0.925±0.1 c.p.m.
(b)	0.455±0.09 c.p.m.	in hydrogen.
(c)	0.275±0.034 c.p.m.	For a total of 0.275±0.04 c.p.m.
(d)	−0.008±0.020 c.p.m.	in deuterium.

The ratio of the yield in deuterium to that in hydrogen is 0.30±0.04.

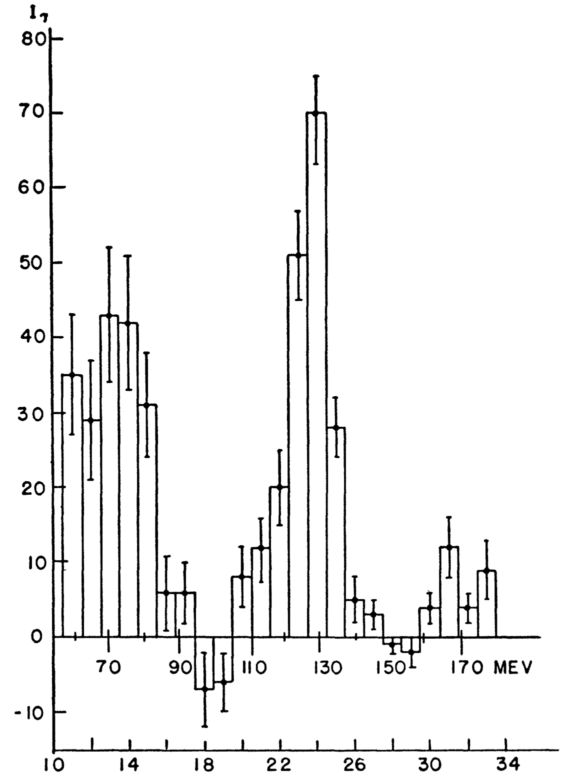

FIG. 1. Gamma-ray spectrum from absorption of π^--mesons in hydrogen. The lower numbers represent spectrometer channels.

(e) Attempts are being made to detect the fast neutrons from this process, but without conclusive results at this time. This process probably accounts for the remainder of the π^--captures in deuterium.

The runs with helium were made to see whether the background was increased by π^0-production from fast protons scattered into the deuterium, since it is known[4] that the cross section for production of π^0-mesons by protons on neutrons is much greater than for protons on protons. No counts above vacuum background

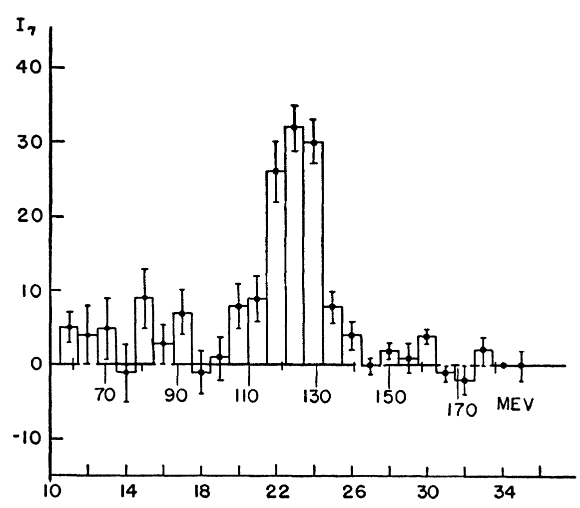

FIG. 2. Gamma-ray spectrum from absorption of π^--mesons in deuterium. Same relative scale as Fig. 1.

were observed from the helium, although the total number of counts was small (~120).

The observed spectrum from process (c) differs markedly from that calculated on phase space considerations alone, possibly because of the interaction of the outgoing neutrons. Process (d) is energetically possible; however, the yield is expected to be small, since energy available for the π^0 is small and selection rules require that the π^0 come off in the p state with respect to the two neutron system (assuming parity of π^0 same as π^- and capture from the S-state).

We wish to thank Mr. J. Vale and the cyclotron crew for providing the bombardments.

* The work described in this paper was performed under the auspices of the AEC.

[1] Panofsky, Aamodt, and York, Phys. Rev. 78, 825 (1950).
[2] Panofsky, Aamodt, Hadley, and Phillips, Phys. Rev. 80, 94 (1950).
[3] Johnston, Bozman, Rubin, Swanson, Corak, and Rifkin, MDDC 850, unpublished.
[4] Crandall, Moyer, and York (private communication).

On Advanced and Retarded Potentials

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WHEELER and Feynman[1] in their absorber theory of radiation have attempted to circumvent the classical infinities of point charges by introducing retarded and advanced potentials of interaction on an equal footing. Their theory has provoked much (unpublished) favorable as well as adverse comment. In view of the importance of the question whether a description of nature using advanced forces of interaction at a distance is possible, the following purely critical remarks may not be out of place.

That there are doubts about the consistency and physical applicability of the W-F theory is due to the dynamical incompleteness of the Maxwell-Lorentz theory, with fields determined by the world-lines of the charges, although the latter may be guided not only by self- and mutual electrodynamic forces and inertia but also by external forces, electromagnetic or mechanical, chosen at will, in short, by the arbitrary intervention of an experimenter. That the present motion of particles on a star 50 light years away should *actually* depend on whether a person on the earth arbitrarily will or will not decide to push a button in the year 2000 seems absurd, at least to our customary way of thinking. Closer analysis of the word "actually" shows that it could mean that the behavior of particles on the star in $(1950+n)$ for various n's shows a dependence on whether some one does or does not push a button on the earth in $(200+n)$ as established *post factum*. An "actual" dependence of the year 1950 on the year 2000 as confirmed by observation does not seem so absurd any more. It is quite a different question, however, whether waves converging on the "cause" are empirically acceptable. To reconcile us with this special form of retroaction, W-F wish to exclude arbitrary abrupt interventions, such as observers pushing buttons. They admit only built-in continuous mechanisms (W-F, II p. 427) which thereby become parts of the system itself. Thus they restrict their theory to closed deterministic systems in which "the distinction between cause and effect is pointless. The stone hits the ground because it was dropped from a height; equally well, the stone fell from the height because it was going to hit the ground" (W-F, II p. 428). The exclusion of arbitrary intervention, usually called an experimental test, for the sake of permitting a description by advanced and retarded potentials looks like a flight into unreality, however.

Wheeler and Feynman's reply to this objection is that their absorber theory permits a *consistent* derivation of the *tested* results of the usual retarded theory. In particular, they point out that the well known self-force experienced by a particle a under an acceleration (which may also be represented by Dirac's antisymmetric expression

$$F^a(a)=\tfrac{1}{2}[F^a{}_{\text{ret}}(a)-F^a{}_{\text{adv}}(a)],) \tag{1}$$

can be derived from the symmetric sum of half-advanced, half-retarded forces produced by the particles k other than a:

$$F^a(a)=\tfrac{1}{2}\Sigma_{k\neq a}[F^k{}_{\text{ret}}(a)+F^k{}_{\text{adv}}(a)]. \tag{2}$$

The equivalence of (1) and (2) which is the central point of W-F's theory rests on two assumptions, namely, *first*, that the body of all particles constitutes a "perfect absorber" characterized by the equation [W-F, I (37)]:

$$\Sigma_{\text{all }k}F^k{}_{\text{ret}}(P)=\Sigma_{\text{all }k}F^k{}_{\text{adv}}(P) \tag{3}$$

valid in all world points P including those of a particle; *second*, that the following initial conditions hold at the place of particle a at the instant when a alone is accelerated (by any test force whatsoever):

$$\tfrac{1}{2}\Sigma_{k\neq a}F^k{}_{\text{ret}}(a)=0, \tag{4}$$

although

$$\tfrac{1}{2}\Sigma_{k\neq a}F^k{}_{\text{adv}}(a)\neq 0. \tag{4'}$$

The left-hand side of (4′) then is identical on the one hand with (2), and on the other hand with (1), by virtue of (3) and (4), thus proving the equivalence of (1) and (2).

Now, although there is no mathematical contradiction between the assumptions (3), (4) and (4′), nevertheless the following physical objection against the simultaneous validity of (3) and (4), (4′) at the time of acceleration of a may be raised. Equation (4) implies that before and at the instant $t=0$ when particle a is accelerated, the other particles are in a state of disorder so that their retarded force contributions which arrive in a at $t=0$, average out to zero. At times $t>0$, however, the other particles are affected by what happens to a at $t=0$ and thus yield a non-vanishing advanced contribution (4′) arriving at a at $t=0$. The privileged rôle of particle a at $t=0$ leads to the unsymmetric initial conditions (4) and (4′). The absorber hypothesis (3), however, implies and can be accepted only (a) when all particles are on an equal footing, thus excluding any privileged part played by the particle a, and (b) when we are assured that no particle has, or ever will be, subjected to an arbitrary disturbance; otherwise (3) would be self-contradictory, as is shown by the example of keeping all particles at rest before $t=0$, and on prescribed paths after $t=0$. Thus, although (3) alone, or (4) and (4′) alone may be acceptable, it is physically *inconsistent* to couple the symmetric assumption (3) with the asymmetric initial conditions (4), (4′). It seems that other ways will have to be found in order to get rid of the classical infinities of point charges.[2]

[1] J. A. Wheeler and R. P. Feynman, Rev. Mod. Phys. 17, 157 (1945), Bohr commemoration number; Rev. Mod. Phys. 21, 425 (1949), Einstein number. Referred to as W-F, I and II.
[2] We mention in this connection M. Born's theory of reciprocity, Rev. Mod. Phys. 21, 463 (1949), Einstein number; also A. Landé, Phys. Rev. 76, 1176 (1949); 77, 814 (1950).

Collimated and Wide-Angle Meson Groups in a Hard-Shower Star

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SPRAYS of relativistic particles associated with cosmic-ray stars have been observed in ultrasensitive photographic emulsions by many workers.[1–6] These sprays are now known to consist principally of π-mesons,[7,8] and they can be identified with the penetrating showers observed in cloud chambers and with counter