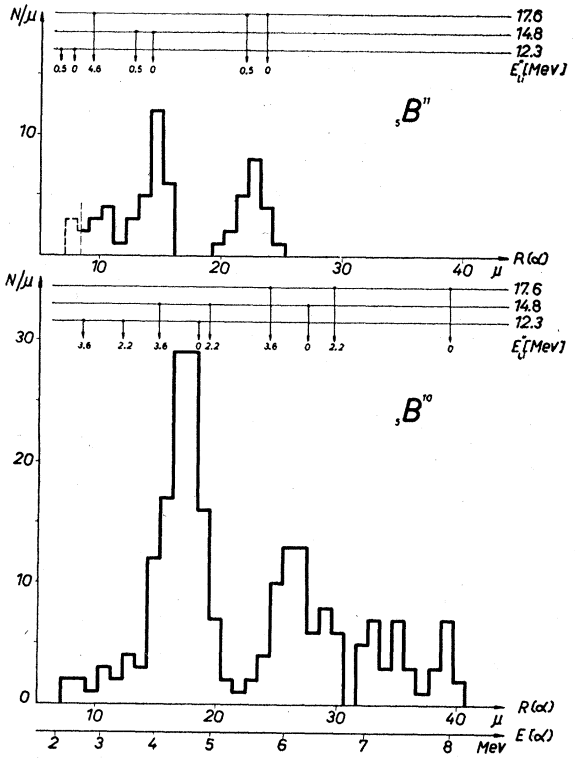

FIG. 2. Range distributions for the reactions: $B^{11}(\gamma, \alpha)Li^7$ and $B^{11}(\gamma, \alpha)Li^{7*}$ ($Li^{7*}\rightarrow\gamma+Li^7$), $B^{10}(\gamma, \alpha)Li^8$ and $B^{10}(\gamma, \alpha)Li^{6*}$ ($Li^{6*}\rightarrow\gamma+Li^6$). Only tracks with $|p| \lesssim 0.35$ unit are considered. p = momentum unbalance vector. (By definition: 1 p unit = momentum of a 1-Mev alpha-particle.)

The three different probabilities of the alpha-transition can be understood by assuming mainly dipole absorption of 17.6- and 14.8-Mev quanta, changing to quadrupole absorption for 12.3 Mev. The most probable transition (s wave) is initiated by 12.3-Mev γ-rays, while transitions according to higher quantum-energies are only possible as p waves.

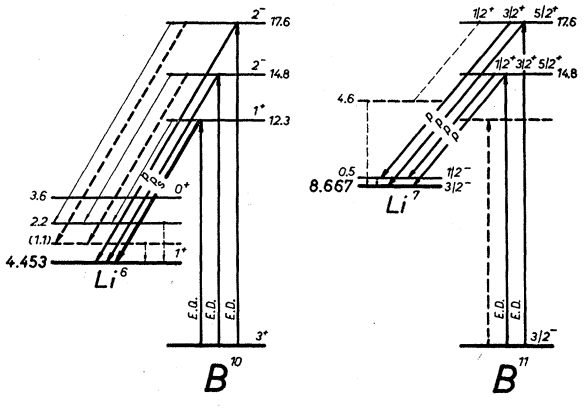

FIG. 3. Decay scheme for the (γ, α) reaction on B^{11} and B^{10}.

The measurements confirm the calculations of Levinger and Bethe.[5] The distribution of angles between emitted alpha-particle and incident γ-ray should furnish further information.

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The Existence of Positronium Chloride

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A POSITRON passing through chlorine gas may, upon striking a chlorine molecule,[1] form a complex consisting of a neutral chlorine atom (Cl), an electron (e^-) and a positron (e^+). The combinations $(Cle^-)e^+$ and $Cl(e^-e^+)$ then suggest themselves, where the two particles in the parentheses would be more closely bound to one another than to the third.

It is possible to treat mathematically the system $(Cle^-)e^+$ quite accurately, as even in its ground state the positron proves to be relatively far away from the (Cle^-) group (mean distance about 1.7A). A Hartree-Fock field[2] has been assumed for the Cl^- ion. Sets of radial parts, $\Psi_0(r)$ and $\Psi_\infty(r)$, of the wave functions were calculated for different energies E so as to be finite for $r=0$ and to vanish for $r=\infty$. For a fixed value of the logarithmic derivative the corresponding values of r were determined. Relations $f(r, E)=0$ and $g(r, E)=0$ were then derived for the functions Ψ_0 and Ψ_∞, respectively, and the eigenvalues were found from the intersections of these curves.

The earlier computation[3] for the quantum number $l=0$ has now been completed for the whole spectrum. The values of $-E$ obtained by the above method for the different energy levels are given in Table I with an accuracy of about one percent.

The values of $-E$ not found in the table can be calculated by the formula

$$E\approx -1/[2(n+\alpha)^2],$$

where $\alpha\approx 1$, for $l=0$ and $\alpha\approx 0$ for $l\geq 1$.

The method has also been tried on sodium and in agreement with Jastrow;[4] the Prokofjew[5] field gives very accurate values for the energy levels of the valency electron of the sodium atom.

If the system $Cl(e^-e^+)$ has a smaller energy than the system $(Cle^-)e^+$, it is possible for the latter to be transformed into the former in a rather short time by the positron catching one of the M electrons. In this case,

$$\epsilon+A<E-B,$$

where $-\epsilon$ is the binding energy of positronium to the chlorine atom, $-A$ is the binding energy of the positronium atom (e^-e^+), $-E$ is the binding energy of e^+ to (Cle^-) and B the electron affinity of the chlorine atom, here taken equal to 3.76 ev. The binding energy of positronium to chlorine is then greater than 0.73 ev when $A=-0.25$ and $E=-0.138$ Hartree units. Consequently, if the probability of formation of $Cl(e^-e^+)$ is large, the system must be dynamically stable. Further consideration of different cases where annihilation is not taken into account also leads to the conclusion that positronium chloride is stable.

When annihilation is taken into consideration, we get according to Dirac[6] and Wheeler[1] the following mean annihilation probability per unit time for different spin constellations:

$$I=\pi c\left(\frac{e^2}{mc^2}\right)^2\int\rho\Psi^2 dV,$$

where ρ is the electron density and Ψ the normalized eigenfunction of the positron. The integration is taken over the whole space. In this case a mean life $\tau=1/I=5\times 10^{-9}$ sec is obtained for the system $(Cle^-)e^+$ when the positron is in its normal state and ρ is evaluated according to the Hartree-Fock-field. But if the probability of antiparallel spins is only 1:4, as in the case of positronium,

TABLE I. Spectrum of Positronium Chloride.

l \ n	1	2	3	4	5	6	7	8	9
0	0.138	0.060	0.033	0.021	0.014				
1		0.097	0.046	0.027	0.0175	0.0125	0.0095	0.0074	0.0058
2			0.054	0.031	0.0195	0.0138			
3				0.0312	0.0198	0.0139	0.0100	0.0077	

τ has to be divided by four. On the other hand, the mean life of the system $Cl(e^-e^+)$ should be of the same order of magnitude as that of positronium, i.e., 10^{-10} sec. However, inasmuch as the time necessary for the emission of light is of the order of 10^{-8} sec and as the probability of annihilation and of catching an M electron is small in the higher states of the system $(Cle^-)e^+$, the conclusion must be made that the spectrum given in Table I is to be expected.

A more detailed account of this work will be presented in *Societas Scientiarum Fennica Commentationes Physico-Mathematicae* in the near future.

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The Formation of a Compound Nucleus in Neutron Reactions*

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IN the theory of nuclear reactions with particles of moderate energy (<50 Mev), one generally makes the following assumption: The incident particle, upon entering the target nucleus, immediately forms a compound nucleus in which its motion is completely integrated into a complicated collective motion of the entire system. There are some reasons to doubt the validity of this assumption. The success of the shell model of nuclear structure suggests that nucleons do not interact very strongly with each other when moving inside the nucleus. The motion is rather like that of an independent particle in a potential well. Recent measurements by Barschall[1] and co-workers of the total cross sections for neutrons on various nuclei as a function of energy have brought some new evidence corroborating the latter point of view.

A theory for total neutron cross sections was developed by Feshbach and Weisskopf[2] under the assumption that the incident neutron and the target nucleus immediately form a compound nucleus. The resulting total cross sections decrease *monotonically* with increasing energy,

$$\begin{aligned} \sigma_t &\approx 4\pi/(kK) \quad (\lambda\!\!\!^{-} \gg R) \\ &\approx 2\pi(R+\lambda\!\!\!^{-})^2 \quad (\lambda\!\!\!^{-} \ll R). \end{aligned} \tag{1}$$

Here $k=\lambda\!\!\!^{-1}$ is the wave number of the incident neutron; $K \approx 10^{13}$ cm^{-1} is the wave number of the neutron in the interior of the nucleus; and R is the nuclear radius. These results are at variance with the experiments which are shown in a three-dimensional plot in the upper part of Fig. 1.

The regular maxima and minima exhibited by the experimental results seem to indicate an interference of the incident wave with an outgoing one, suggesting that the neutron wave is not completely absorbed into collective motion in one passage through the nucleus. We therefore have recalculated the total neutron cross section with the following model. The nucleus is replaced by a potential well with a complex potential,

$$\begin{aligned} V(r) &= -V_0(1+i\zeta) \quad \text{for} \quad r<R \\ &= 0 \quad \text{for} \quad r>R, \end{aligned} \tag{2}$$

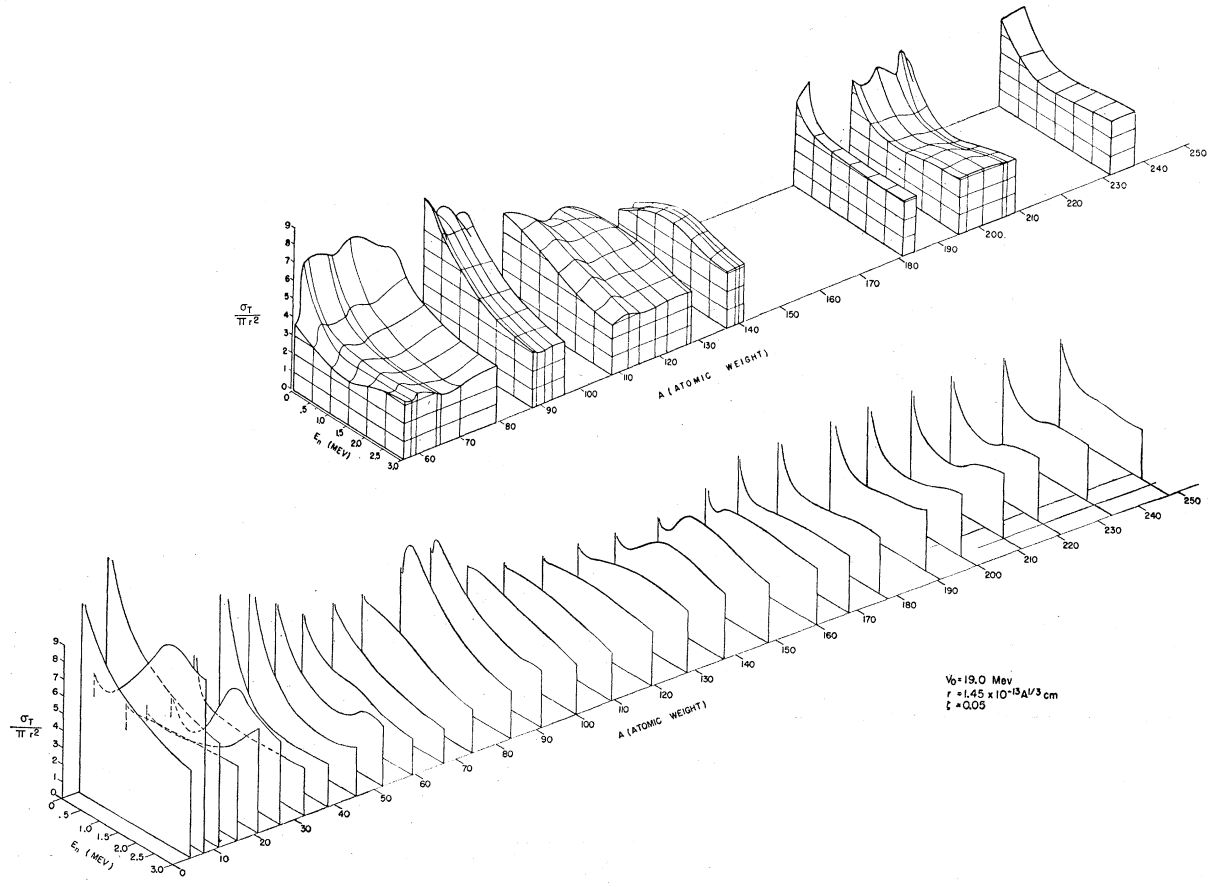

FIG. 1. Total neutron cross section as a function of energy and atomic number. Upper profile: experimental results (reference 1). Lower profile: theoretical results with the constants as indicated.