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CALCULATION OF THE NUMBER OF DISPLACEMENTS IN CASCADES OF IDENTICAL PARTICLE COLLISIONS

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ABSTRACT*

The calculation of the total number of displacements (ionizations, excitations, displaced atoms and so forth) is the starting point in the explanation of physico-chemical transformations in a matter subject to action of nuclear radiations. If $J(\varepsilon)\, d\varepsilon$ is the radiation flux in the energy interval ε, $\varepsilon + d\varepsilon$ and $\sigma(\varepsilon, E)\, dE$ is the cross section of energy transfer to medium's particle in the interval dE, the rate of accumulation of displacements is determined by the expression

$$\dot{N} = n_a \int_{\varepsilon} J(\varepsilon)\, d\varepsilon \int_{E > E_d} \sigma(\varepsilon, E)\, \nu(E)\, dE. \qquad (1)$$

The particle is then considered as displaced if the energy E, transferred to it, is greater than the threshold energy E_d. The quantity $\nu(E)$ is the number of displacing collisions induced by one primary particle having obtained from the penetrating radiation the energy E; n_a is the density of atoms.

We shall consider the cascades of identical particle collisions (electron-electron, atom-atom), inasmuch as the formation of defects is linked precisely with them.

Let us denote the cross section of such a collision by $\sigma_a(E, \varepsilon)$. Then $n_a \sigma_a(E, \varepsilon)\, d\varepsilon dx$ is the number of collisions of this type with energy transfer by impacting particles in the interval $d\varepsilon$ over the path dx. Multiplying this expression by $\nu(\varepsilon)$, and integrating it over $d\varepsilon$ and dx, we shall obtain the following integral equation for $\nu(E)$:

$$\nu(E) = \int_{E_d}^{E} n_a \left(\frac{dE'}{dx}\right)^{-1} dE' \int_{E_d}^{E'} \sigma_a(E', \varepsilon)\, \nu(\varepsilon)\, d\varepsilon + 1. \qquad (2)$$

Here $\frac{dE'}{dx}$ are the total losses of energy by the cascade particle over a unit of path.

(*) K RASCHETU CHISLA SMESHCHENIY V KASKADAKH STOLKNOVENIY ODINAKOVYKH CHASTITS

** [The "in extenso" paper on the subject bears the No.114/3828. Manuscript released on 17 May 1966, apparently to be published later].

We shall describe the atom-atom collisions at not high energies as collisions of solid spheres:

$$\sigma_a(E, \varepsilon)=\frac{\sigma_0}{E} \tag{3}$$

and corresponding to energy losses:

$$\frac{dE}{dx}=\frac{n_a\sigma_0}{2}\left(E+\frac{q}{E}\right), \tag{4}$$

where σ_0 and $\underline{q}$ are semiempirical constants.

Taking into account expressions (3) and (4) and the initial condition $\nu = 1$ for $E_d \leqslant E \leqslant 2E_d$, Eq.(2) has the following solution:

$$\nu(E)=\frac{E}{q}\,\mathrm{arctg}\,\frac{q(E-2E_d)}{q^2+2EE_d}+1. \tag{5}$$

At q = 0 this expression passes into the well known Kinchin & Pease formula [1]. At nonrelativistic energies the electron-electron collisions are well described by formulas

$$\sigma_a(E, \varepsilon)=\frac{A}{E}\cdot\frac{1}{\varepsilon^2}; \qquad \frac{dE}{dx}=\frac{An_a}{E}\left(\ln\frac{E}{\varepsilon_i}+a\right), \tag{6}$$

where ε_i is the mean ionization potential; A and $\underline{a}$ are constants.

For this case the solution of Eq.(2) has the form

$$\nu(E)=\frac{E}{\varepsilon_i}\int_{2\varepsilon_i}^{E} dE'\,\frac{\ln\frac{E'}{2\varepsilon_i}+1}{\left(\ln\frac{E'}{\varepsilon_i}+a\right)E'^2}+1. \tag{7}$$

Hence for $E \ll 2\varepsilon_i$ and $a \approx 1$, we find $\nu \approx E/3\varepsilon_i$ which corresponds to well known experimental facts according to which the mean energy expenditures for the formation of a pair of ions in the medium are about equal to three ionization potentials [2]. For condensed media $a \gg 1$ and this is why, according to expression (7), $\nu \leqslant \frac{E}{3\varepsilon_i}$; for gases $a \leqslant 1$ and this is why $\nu \geqslant E/3\varepsilon_i$. These results have a great significance for radiation physics, chemistry and dosimetry.

**** THE END ****

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