It is easy to see that in the classical theory (1) leads to the correct results. As in the classical theory all the scattering is dipole scattering, we must simply insert for σ_0 the full Thomson's scattering cross section, this leading to $e^2/mc^2 \ll \bar{\lambda}$.

We now apply (1) to the quantum theory of the electron. We must first of all transform the Klein-Nishina formula to the proper frame of reference and then take part of the scattering corresponding to the angular momentum of the order 1. This gives $\sigma_0 \sim (e^2/mc^2)^2 mc^2/E$ (E being the energy of the photon in the frame of reference where the electron is at rest). σ_0 differs from the total cross section by the absence of the factor $\log E/mc^2$ which arises from the scattering with large angular momenta. The energy ϵ of the photon in the frame of reference moving with the center of inertia is given by $2\epsilon^2 = mc^2 E$ (when $E \gg mc^2$) so that $\bar{\lambda} \sim \hbar c/\epsilon \sim \hbar c/(mc^2 E)^{\frac{1}{2}}$. The energy E disappears now from (1) and we get $e^2 \ll \hbar c$ which is always fulfilled. This means that in the quantum theory of the electron there are no limits of its applicability, arising from itself. The "radius" of the electron in quantum electrodynamics is in some sense equal to zero.

One gets the same result for particles with zero spin, if the corresponding expression for Compton effect[4] is used.

The Compton effect for particles with spin 1 (mass μ) was recently calculated by F. Booth and A. H. Wilson[5] and by J. Smorodinski.[6] The result is $\sigma_0 \sim (e^2/\mu c^2)^2 E/\mu c^2$. Hence the condition (1) gives $E \ll \mu c^2 \hbar c/e^2$. The "radius" of the particle is equal to the corresponding wave-length in the frame of reference in which the particle is at rest, i.e.

$$r \sim \hbar c/E \sim e^2/\mu c^2. \tag{2}$$

Hence the "radius" of the particle with spin 1 is equal to its classical value.

A more detailed discussion of the problem with the application to the scattering of particles with spin 1 by a charged particle, is to be published in *Journal of Physics*, volume 3, 1940.

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[1] Cf. W. Heitler, *The Quantum Theory of Radiation* (Oxford, 1936), pp. 33, 232.
[2] W. Heisenberg, Zeits. f. Physik **110**, 251 (1938).
[3] V. Weisskopf, Phys. Rev. **56**, 73 (1939).
[4] W. Gordon, Zeits. f. Physik **40**, 117 (1927).
[5] F. Booth, and A. H. Wilson, Proc. Roy. Soc. **A175**, 483 (1940).
[6] J. Smorodinski, J. Phys. **3** (1940).

Relative Intensities of $^1S - {}^3P$ and $^1S - {}^1P$ Transitions in Mg

The relative intensity of singlet-triplet and singlet-singlet transitions in cases where the spin-orbit interaction is weak is given by

$$f_3 = |S_3|^2 (\nu_3/\nu_1) f_1, \tag{1}$$

where the subscripts 3 and 1 denote singlet-triplet and singlet-singlet values, respectively. The factor S_3 is the coefficient which represents the contamination of the singlet state by the triplet state; that is, approximately

$$\psi(^1P) = \psi_0(^1P) + S_3 \psi_0(^3P), \tag{2}$$

where the ψ_0's are Russell-Saunders wave functions. One has from perturbation theory

$$|S_3| = H(ij)/h\nu_{ji}, \tag{3}$$

where $H(ij)$ is the matrix element of the Hamiltonian. Furthermore, the deviation of the central component of the triplet from the interval rule is

$$\Delta W = [H(ij)]^2/h\nu_{ji}. \tag{4}$$

According to Houston,[1] we may take for P states

$$H(ij) = [l(l+1)]^{\frac{1}{2}} A = \sqrt{2} A, \tag{5}$$

if A is the constant of the spin-orbit interaction $AL \cdot S$. In practice A is determined from the over-all width of the triplet, $3A$. The theoretical expression for A is

$$A = \frac{h^2}{16\pi^2 m^2 c^2} \int R_{3P}^2 \left(\frac{1}{r} \frac{\partial V}{\partial r} \right) r^2 dr. \tag{6}$$

The radial wave function, R_{3P}, of the triplet state is here assumed to be identical with that of the singlet state.

Since the relative intensities found from (1), (3), and (5) are in only fair agreement with observation, King and Van Vleck[2] have suggested that an undetermined parameter λ be inserted in (5) and (6) to account for the difference between R_{3P} and R_{1P} which was previously neglected. Then A refers to the integral (6) with R_{3P}^2 in the integrand while λA denotes the integral with $R_{3P} R_{1P}$. The value of λ is determined so as to make the deviation (4) from the interval rule correct. In this way King and Van Vleck[2] find for the atoms Hg, Cd, Zn, Ba, Sr, and Ca that $\lambda \sim 0.8$. If, however, we try to apply their procedure to the transition $3s^2\,{}^1S - 3s3p\,{}^3P$ of Mg, we find $\lambda = 2.4$, a value out of line with those previously found. It seems, then, that in this case the deviations from the interval rule are not due simply to perturbations by ^1P but that other effects enter. Mg is so light that spin-spin interaction may contribute appreciably to the observed deviation, 0.3 cm^{-1}, from the interval rule. One should therefore not place much trust in the value of λ for Mg derived above.

It is thus uncertain whether to use the value $\lambda = 0.8$ by analogy with previous calculations, or merely to use the Houston formula, where $\lambda = 1$. The relative intensities found in the two cases are

$$\begin{aligned} f_1/f_3 &= 340{,}000 \quad \text{for} \quad \lambda = 1, \\ f_1/f_3 &= 530{,}000 \quad \text{for} \quad \lambda = 0.8. \end{aligned} \tag{7}$$

We may consider these values as correct within a factor 2 or 3.

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[1] W. V. Houston, Phys. Rev. **33**, 297 (1929).
[2] G. W. King and J. H. Van Vleck, Phys. Rev. **56**, 464 (1939).