REVIEW OF RECENT RESULTS ON INTERNAL CONVERSION *

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UNTIL a few years ago it was believed that all was well with the theory of internal conversion as originally developed by Rose[1] and his collaborators. This theory was based on the rather simplifying assumption that the nucleus can be treated as point charge. There was so much faith in this theory that experimentalists interpreted all their data on this and assigned multipolarities for gamma transitions. Experiments on some M 1 transitions soon revealed discrepancies between theory and experiment in spite of the rather moderate precision with which the α_K's were determined. Sliv[2] recalculated the α_K on a more realistic model, namely, the one in which the charge on the nucleus is distributed uniformly on a sphere of radius R. The inclusion of this effect (static approximation) removed the anomalies observed in the case of M 1 transitions. In general, the new calculations differed from Rose's especially for heavy nuclei, and predicted values which were a good deal larger than the point nucleus values. It must be pointed out that the α(E 2) was unaffected by these calculations.

Church and Weneser[3] made an important contribution to the theory of internal conversion when they pointed out the importance of the so-called penetration effect or dynamic effect. This effect which arises from the penetration of the atomic electron into the nuclear volume introduces new matrix elements into the conversion electron ejection different from that due to gamma-ray emission. This had the interesting consequence that when the gamma-ray matrix element was vanishingly small due to some selection rule, the new matrix element would in-

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troduce anomalous conversion coefficients, as for example, in the case of the *l*-forbidden M 1 transitions which should have a vanishing gamma-matrix element. The effect on M 1 transitions was defined in terms of an equation

$$\beta(\lambda) = \beta(\lambda = 1)\,[1 - (\lambda - 1)\,C\,(Z, k)]^2$$

in the usual notation where $\lambda = 1$ corresponds to Sliv's values.

$(\lambda = m_e / m_\gamma)$ is the ratio of the matrix element due to penetration and gamma-ray emission.

The factor C (Z, *k*) characterizes a quantity which is a function of the atomic number and transition energy.

Depending on the phase of the two matrix elements λ can be positive or negative which can thus make the observed α_K values larger or smaller than Sliv's values, determined entirely by the structure of the nucleus. For instance, Church and Weneser calculated λ for $\Delta l = 2$ M 1 transitions, using single particle wave function to calculate m_e and empirical gamma-matrix element to determine m_γ. They found values of λ falling in the range 5–10 corresponding to a change of $\beta(\lambda)$ up to 20% for a typical nucleus $(Z = 55)$. It must be emphasized that very accurate experimental data are required to discern these small effects. As illustrations of the dynamic effect (Church and Weneser) one may cite the example of the 80 kev. *l*-forbidden M 1 transition in Cs^{133} which was initially discussed by the author[4] and more recently by Subba Rao.[5] and in Hg^{203} discussed by Deutsch and Goldberg.[6]

Side by side with refinements in theory, within the past few years significant improvements in techniques for measuring the internal conversion coefficient have been made. In particular, the internal-external method developed by Hultberg and Stockendal[7] has been effectively and extensively used for an accurate determination of ICC. In brief, this method consists in measuring the ratio of internal and external conversion electrons, the latter being produced in a thin radiator in a magnetic spectrometer. The conversion coefficient is obtained by the use of the following equation

$$\alpha_i = (A_{in.} / A_{ext.})\, f \tau k d b c.$$

Here α = internal conversion coefficient of the *i*-th shell : A_{in} = intensity of the internal conversion electrons : $A_{ext.}$ = intensity of the external photoelectrons ; f = correction factor which accounts for the anisotropical distribution of photoelectrons ; τ = photoelectric cross-section ; k = ratio of external and internal electron source strengths ; d = thickness of the converter in mg./cm.^{2} ; b = a dimensional factor ; and c = a correction factor to account for differences in transmission of the magnetic spectrometer for the external and internal sources.

If the same source is used $k = 1$. τ and f are calculated theoretically and found to be quite accurate. Using this technique it has been possible to measure ICC to an accuracy of 3% or better. The internal-external method has the merit that ICC can be determined even in a complicated decay scheme which feature is absent in the peak to beta-spectrum (PBS) method which has the additional complication introduced by the uncertainty in the spectral shape.

As already indicated the inclusion of finite size effects (static and dynamic) removes the large discrepancies observed for M 1 transitions. However, E 2 conversion coefficients changed little in the new calculations. Sliv remarked that dynamic effects may affect the so-called retarded E 2 transitions.

Stelson and McGowan[8] measured the α_K of some fast E 2 transitions and found the experimental values to be about 20% higher than theory. Other discrepancies of 10 to 20% have been reported in the α_K values for some unhindered transitions. Subba Rao[9] collected all the available data on α_K for E 2 transitions of the type $(2^+ \rightarrow 0^+)$ and comparing with theory concluded that measured α_K tended to be systematically higher than theory. He also suggested that a correlation might exist between nuclear deformation and deviations in α_K values. A similar analysis on α_K of $0^+ - 2^+$ E 2 transitions carried out by the author[10] seemed to confirm Subba Rao's findings.

Other classes of E 2 transitions can be found in transitions of the type $(6^+ - 4^+)$, $(4^+ - 2^+)$, etc. In these cases it is necessary to prove that the M 3 admixture is either small or calculable. This can be done by means of angular correlation experiments. Recently data on E 2 conversion coefficients of several transitions including the type $(4^+ - 2^+)$ have come in. These indicate overall agreement with theory. Where deviations occur they are found to lie within experimental uncertainty. Only in the case of the 412 kev. $(2^+ - 0^+)$ E 2 transition in Hg^{198} the experimental value was found to be 6% *lower* than theory. More recent reinvestigations by Hamilton,[11] and Wapstra[12] on rare-earth transitions have confirmed previously-found deviations. An interesting and intriguing case has been reported by Edwards and Boehm.[13] They measured α_K for $8^+ - 6^+$, $6^+ - 4^+$, $4^+ - 2^+$ and $2^+ - 0^+$ E 2 transitions in Hf^{180}; for the first three transitions they found experimental values to be $(10 \pm 8)\%$ *lower* than theory and for the last transiton $(6 \pm 8)\%$ *higher* than theory. This situation, if confirmed, clearly calls for an explanation.

Summarising, it may be said that there is general agreement between theory and experiment when finite size effects are taken into account. The observed deviations from theory in the case of unhindered E 2 transitions are interesting in that they are, in the first place, unexpected and secondly, pose a challenge to theoreticians. More precise data in the rare-earth region may be expected in the near future which should help to clear up the question of whether or not there is any correlation between nuclear deformation and deviations in α_K from theory. Finally it would be highly welcome if independent checks on the results from the IEC method can be made. However, at the present time such a prospect does not appear bright.

1. Rose, M. F., In *Beta and Gamma Ray Spectroscopy*, North-Holland Publishing Co., 1955.
2. Sliv, L. A., *Zhur. Theoret. Fiz.*, 1951, **21**, 770.
3. Church, E. L. and Weneser, J., *Phys. Rev.*, 1956, **104**, 1382.
4. Ramaswamy, M. K., *Ibid.*, 1960, **119**, 2021.
5. Subba Rao, B. N. (Personal Communication).
6. Deutch, B. I. and Goldberg, N. R., *Phys. Rev.*, 1960, **117**, 818.
7. Hultberg S. and Stockendal, R., *Arkiv. Pysik.*, 1959, **14**, 565.
8. Stelson, P. H. and McGowan, F. K., *Phys. Rev.*, 1957, **107**, 1674.
9. Subba Rao, B. N., *Nuovo Cim.*, 1960, **17**, 189.
10. Ramaswamy, M. K., *Ibid.*, 1960, **18**, 1287.
11. Hamilton, J. H., *et al.*, *Nucl. Phys.*, 1962, **36**, 567.
12. Wapstra, *et al.*, *Ibid.*, 1962, **38**.
13. Edwards, W. and Boehm, F., *Phys. Rev.*, 1961, **121**, 1499.