where K is the low frequency dielectric constant, K_0 is the optical constant, ρ the density, and χ the compressibility. In Table I are listed the values of $\partial \ln K/\partial p$ calculated from (4) and (1) next to the experimental values of $\partial \ln K/\partial p$. The calculated values of $\partial \ln K/\partial p$ differ from those of Rao by the term $a(K-K_0)/K$, which arises from the difference between (1a) and (2a).

Equation (4) is derived assuming that the inner field polarizing the dielectric is independent of pressure. Since the values of $-\partial \ln K/\partial p$ obtained from (4) do not account for all the change in the dielectric constant, it seems consistent to expect that the inner field is not constant but does decrease with increasing pressure. This conclusion agrees with the one reached in my original paper using the theories of Hojendahl and Mott and Littleton.

[1] D. A. A. S. Narayana Rao, Phys. Rev. **82**, 118 (1951).
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Radiative Transition Probabilities in Nuclei

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CONSIDER a transition from nuclear state a to nuclear state b with emission of a quantum of multipole radiation of angular momentum l (2^l-pole) and z component m. The transition probability per unit time is given by[1]

$$T(l,m)=\frac{8\pi(l+1)}{l[(2l+1)!!]^2}\frac{\kappa^{2l+1}}{\hbar}|A(l,m)+A'(l,m)|^2, \quad (1)$$

where $\kappa=2\pi\nu/c$ is the wave number of the emitted radiation, and the quantities A, A' are the multipole matrix elements caused by the electric currents and by the magnetization (spins), respectively. We find for electric radiation

$$A(l,m)=Q(l,m)=e\sum_{k=1}^{Z}\int r_k{}^l\, Y_{lm}{}^*(\theta_k,\phi_k)\ \varphi_b{}^*\varphi_a\, d\tau, \quad (2)$$

$$A'(l,m)=Q'(l,m)=-\frac{i\kappa}{l+1}\frac{e\hbar}{2Mc}\sum_{k=1}^{A}\mu_k \times\int r_k{}^l\, Y_{lm}{}^*(\theta_k,\phi_k)\ \mathrm{div}(\varphi_b{}^*\mathbf{r}_k\times\boldsymbol{\sigma}_k\varphi_a)\, d\tau, \quad (3)$$

where φ_a and φ_b are the wave functions of the nuclear states, M is the mass of each nucleon, $\mathbf{r}_k=(r_k,\theta_k,\phi_k)$ is the position vector of the kth nucleon, $\boldsymbol{\sigma}_k$ is its Pauli spin vector, and μ_k is its magnetic moment in nuclear magnetons. The sum in (2) extends over the protons, the sum in (3) over both protons and neutrons. These expressions are approximations valid for $\kappa R\ll 1$, where R is the nuclear radius.

The corresponding expressions for magnetic multipole radiation are

$$A(l,m)=M(l,m)=-\frac{1}{l+1}\frac{e\hbar}{Mc}\sum_{k=1}^{Z} \times\int r_k{}^l\, Y_{lm}{}^*(\theta_k,\phi_k)\ \mathrm{div}(\varphi_b{}^*\mathbf{L}_k\varphi_a)\, d\tau, \quad (4)$$

$$A'(l,m)=M'(l,m)=-\frac{e\hbar}{2Mc}\sum_{k=1}^{A}\mu_k \times\int r_k{}^l\, Y_{lm}{}^*(\theta_k,\phi_k)\ \mathrm{div}(\varphi_b{}^*\boldsymbol{\sigma}_k\varphi_a)\, d\tau, \quad (5)$$

where $\mathbf{L}_k=-i\mathbf{r}_k\times\nabla_k$ is the orbital angular momentum operator (in units of $\hbar$) for the kth nucleon.

We can estimate these matrix elements by the following exceedingly crude method. We assume that the radiation is caused by a transition of one single proton which moves independently within the nucleus, its wave function being given by $u(r)Y_{lm}(\theta,\phi)$. In addition we also assume that the final state of the proton is an S state.[2] We then obtain

$$Q(l,m)\sim[e/(4\pi)^{\frac{1}{2}}][3/(l+3)]R^l \quad (6)$$

where the integral $\int r^l u_b(r)u_a(r)r^2dr$ over the radial parts of the proton wave functions was set approximately equal to $3R^l/(l+3)$. The other matrix elements are estimated by replacing div by R^{-1}. We get the rough order-of-magnitude guess

$$M(l,m)\sim[e/(4\pi)^{\frac{1}{2}}][3/(l+3)][\hbar/Mc]R^{l-1}, \quad (7)$$

$$M'(l,m)\sim[e/(4\pi)^{\frac{1}{2}}][3/(l+3)]\mu_P[\hbar/Mc]R^{l-1}, \quad (8)$$

where μ_P is the magnetic moment of the proton ($=2.78$). $Q'(l,m)$ can be neglected compared to $Q(l,m)$. We therefore get a ratio of roughly

$$(1+\mu_P{}^2)(\hbar/McR)^2\sim 10(\hbar/McR)^2$$

between the transition probability of a magnetic multipole and an electric one of the same order. This ratio is energy-independent in contrast to widespread belief.

Inserting these estimates into (1) we get for the transition probability of an electric 2^l-pole

$$T_E(l)\cong\frac{4.4(l+1)}{l[(2l+1)!!]^2}\left(\frac{3}{l+3}\right)^2\left(\frac{\hbar\omega}{197\ \mathrm{Mev}}\right)^{2l+1} \times(R\text{ in }10^{-13}\text{ cm})^{2l}\ 10^{21}\ \mathrm{sec}^{-1} \quad (9)$$

and for a magnetic 2^l-pole

$$T_M(l)\cong\frac{1.9(l+1)}{l[(2l+1)!!]^2}\left(\frac{3}{l+3}\right)^2\left(\frac{\hbar\omega}{197\ \mathrm{Mev}}\right)^{2l+1} \times(R\text{ in }10^{-13}\text{ cm})^{2l-2}\ 10^{21}\ \mathrm{sec}^{-1}. \quad (10)$$

The assumptions made in deriving these estimates are extremely crude and they should be applied to actual transitions with the greatest reservations. They are based upon an extreme application of the independent-particle model of the nucleus and it was assumed that a proton is responsible for the transition. On the basis of our assumptions the electric multipole radiation with $l>1$ should be much weaker for transitions in which a single neutron changes its quantum state. No such differentiation is apparent in the data.

In spite of these difficulties it may be possible that the order of magnitude of the actual transition probabilities is correctly described by these formulas. We have published these exceedingly crude estimates only because of the rather unexpected agreement with the experimental material which was pointed out to us by many workers in this field.

The author wishes to express his appreciation especially to Dr. M. Goldhaber and Dr. J. M. Blatt for their great help in discussing the experimental material and in improving the theoretical reasoning.

[1] We use the notation $(2l+1)!!=1\cdot 3\cdot 5\cdots(2l+1)$.
[2] This latter assumption can be removed; the corrections consist in unimportant numerical factors.

Nuclear Magnetic Resonance in Metals: Temperature Effects for Na^{23}

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KNIGHT reported[1] that nuclear magnetic resonance frequencies are higher in metals than in chemical compounds. It has been proposed[2] that such frequency shifts are primarily the result of the contribution of conduction electrons to the magnetic field at the nuclei in the metal. This note gives an account of some related preliminary results including temperature and chemical effects, and also detailed line shape studies. Our experiments have been[1] at fixed frequency using equipment and procedures outlined previously.[3,4]

The effect of temperature on the Na^{23} magnetic resonance shift in the metal, relative to a sodium chloride solution, is given in