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Ernest O. Lawrence Radiation Laboratory

CLOSING REMARKS

(International Conference on Hyperfine Interactions Detected by Nuclear Radiation, Asilomar, Pacific Grove, California, August 25-30, 1967)

John O. Rasmussen

November 1967

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In the time remaining for this conference I should like to give some general impressions of where we stand in the research fields here discussed. I would not presume to make a real summary of the past week, for here the unifying theme of hyperfine interactions has encompassed a wide and diverse range of studies, many in a new and active stage of development. Our chairman, Martin Deutsch's γ-γ angular correlation work of 1948 and Mössbauer's discovery of 1957 have spawned vast fields of study.

There are two principal parent conferences in 1963 from which Asilomar 1967 stems, namely the Third Mössbauer Effect Conference at Cornell and the Perturbed Angular Correlation Conference in Uppsala. A check of the attendance lists at these conferences showed only eleven persons attending both, i.e., 1 in 20 at Cornell and 1 in 7 at Uppsala. The past week has brought together many people from these two hitherto-rather-separate groups, as well as others, the dynamic nuclear orienters, the ultra low temperature orienters, and the mu-mesic atomists. For even the most broadly informed among us there was at least one unfamiliar field to learn about, and for nuclear specialists, like me, there was very much to learn and better appreciate.

This mixing of different schools and traditions here will hopefully contribute to new and valuable ideas on all sides.

A scientific historian might suppose that the succession of technique-centered conferences by such a conference as this, focussing on an abstract

end-product, hyperfine interactions, marked the end of the phase of fashioning new experimental tools, a settling down to a more comfortable maturity. This week has shown such a supposition to be far from the truth. In the parent conferences of four years ago the techniques were applied almost exclusively to radioactivity. Now the in-beam experiments based on nuclear reactions have come in to greatly extend the range of nuclei and phenomena accessible to study. Fluctuating hyperfine fields of tens of megagauss seem present in vacuum recoils--enough to affect angular correlations in picosecond states and hence to probe their g-factors. With the in-beam experiments have come new problems, how to "hold" the orientations of reaction products (Do you use a whiff of gas or 60 atmospheres?; a few gauss or tens of kilogauss?). To those of us who have despaired over attenuation processes killing our angular anisotropies in nanoseconds or less, the retention of polarization for many seconds by spin 5/2 F^{17} recoiled into a solid is nothing short of miraculous. That this was possible makes us hopeful that much future progress is to be expected in the production and retention of nuclear spin systems in non-Boltzmann distributions for extended time periods, though we have much to learn about choice of materials, temperatures, and alignment of holding fields with respect to crystalline axes. The remarkable spin refrigerator using Yb in yttrium ethyl sulfate serves as an example of what might come from taming those beasts, the relaxation processes, turning them on and off at will. Careful studies of Mössbauer spectral changes for small increments in temperature have added much to knowledge of relaxation times.

Not only has the cyclotron or Van de Graaff newly appeared, coupled to the Mössbauer spectrometer or angular correlation table, but also the

r.f. oscillator has dramatically "made the scene". The ferromagnetic enhancement effect has provided the magic for the enormous r.f. fields at the nucleus needed to induce n.m.r. transitions on a nanosecond time scale. This same magic also made possible resonance destruction of ultra-low-temperature-oriented spin systems at the very low power levels necessary to avoid heating the foils. The r.f. method of altering spin distributions came into its own also in the beta emitters as a consequence of learning how to hold the polarization so long.

We have heard reference this week to combinations of techniques as "weddings" or "polygamous arrangements." Both words are too simple to apply to what I fear the future holds--such as r.f. destruction of polarization of recoil nuclei as detected by a Mössbauer polarimeter. Sorry, I couldn't work optical pumping into it.

Before we leave the realm of techniques we do well to note that since the preceding conferences, nuclear gamma ray spectroscopy has been revolutionized by the development of the lithium-drifted Ge counter. Many of the studies here discussed have benefitted by this development, perhaps none so dramatically as mu-mesic x-ray spectroscopy--a rough game at best when only sodium iodide was available. Now, as we have just heard, a new world has opened up, offering independent measurements of nuclear quadrupole moments and r.m.s. charge radius shifts between ground and excited rotational states. Both of these nuclear moments, the E2 and E0, are often troublesome to determine from atomic h.f.s. measurements, since the electric field gradient at the nucleus and the electron density at the nucleus are hard to calibrate. Not only do mu-mesons sample the lowest radial moments felt by atomic electrons

but also they sense finer details of the nuclear charge distribution, since the muonic K-orbit in a heavy nucleus lies almost entirely inside the nucleus.

Turning to the status of the theory behind hyperfine structure we get similar stories from the atomic and from the nuclear sides. The fields at the nucleus or the nuclear moments are calculable for certain cases and not for others. We have seen that the atomic Hartree-Fock theory yields good numerical results for magnetic hyperfine fields for isolated atoms, although the core polarization effects come out as small differences of very large numbers for spin-up and spin-down electrons in various s-orbitals. For ionic solids the theory is still reliable, but for metals or alloys we are told that there are many uncertain contributions.

On the nuclear theory side, the magnetic dipole and electric quadrupole moments can be predicted within 10% in two regions. 1) The single-closed shell nuclei, where the spherical shell model modified by pairing force effects works well, and 2) the strongly deformed nuclei, where the Nilsson model works. In the other nuclear regions theory has more difficulty, even for magnetic moments of mass 12 nuclei, as we saw.

It is important to measure more M1 and E2 static moments of excited nuclear states. Many theories can fit energy spectra, but static and transition moments may more critically test theories. Magnetic moments, despite some renormalization uncertainties on the intrinsic spin contributions, do measure the microscopic composition of nuclear states--that is, they measure from which orbitals the quasi-particle components arise. The large static quadrupole moments measured for 2+ states in cadmium, tin, and other spherical nuclei have provided a strong impetus for modifying both the vibrational

models and the microscopic models. That is, it appears that the closed proton structure of tin is not so inert as theorists might like. Proton excitations must evidently be coupled with neutron excitations for adequate description of states of tin. Indeed, we know the pairing force acts to make excitation of closed shell structures less costly in energy. When we promote a pair across the shell gap, we get back some energy as pairing energy.

The nuclear side of the chemical isomer shift problem needs much work. My own tentative attempts to calculate by microscopic theory the r.m.s charge radius shifts in a couple of cases gave the wrong sign. Certainly there are going to be delicate balances between opposite contributions for these small effects. Here it is most exciting to see the systematics of isomeric size shifts emerge from experiments with μ mesons and with the Mössbauer effect. There is a close connection between r.m.s. charge radii and E0 transition matrix elements to which we have been directing theoretical attention lately. Ultimately the sophisticated Hartree-Fock and Hartree-Bogoliubov nuclear calculations now centering on light nuclei may be able to calculate isomeric nuclear size shifts in a fundamental way.

Finally, it seems clear that the nuclear probes are providing much of value to the understanding of magnetic behavior of solids--a field of greatest importance.

Since I am only a nominal member of the Berkeley hosts, being one who was away for the summer and missed the hard work of preparation for the conference, I think I can speak as a guest to thank those whose efforts have been so central. Especially is thanks due to Eckart Matthias, who envisioned this conference and overcame all obstacles to bring it about so successfully.

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