INELASTIC ELECTRON SCATTERING FROM ^{63}Cu AND ^{62}Ni

A.A.C. Klaasse, P.F.A. Goudsmit and
P.K.A. de Witt Huberts
Institute for Nuclear Physics Research,
Amsterdam, The Netherlands

At the Institute for Nuclear Physics Research inelastic-electron-scattering experiments on the nuclides ^{63}Cu and ^{62}Ni were performed with the 90 MeV linear electron accelerator |1|. These measurements were undertaken as a supplementary study to the measurements of the β-decay of ^{63}Zn to levels in ^{63}Cu |2|.

The experimental conditions were the following:

incoming electron energy	$70\ \mathrm{MeV} < E_o < 90\ \mathrm{MeV}$
scattering angle	$51^o < \theta < 152^o$
momentum transfer	$0.35\ \mathrm{fm}^{-1} < q < 0.88\ \mathrm{fm}^{-1}$
targets: enrichment	>99%
thickness	20 mg/cm^2
excitation energy	up to 4 MeV

To facilitate computational aspects of the particle-core coupling calculations - the ^{63}Cu nucleus is then considered as a ^{62}Ni core coupled to an extra proton in the $2p_{3/2}$, $2p_{1/2}$, or $1f_{5/2}$ shell - both nuclides were measured at the same E_o, θ combinations.

Levels of interest in the electron-scattering experiments are shown in fig. 1. The lower levels in Cu are excited by E2 transitions, those from 2.5 MeV upward are excited by E3 transitions. In Ni the important levels are the 1.173 MeV one-phonon 2^+ state and the 3.75 MeV one-phonon 3^- state.

Fig. 2 gives an example of a spectrum of electrons inelastically scattered from ^{63}Cu, with peaks due to E2 transitions (those below 2.5 MeV) and E3 transitions (those between 2.5 and 4.0 MeV).

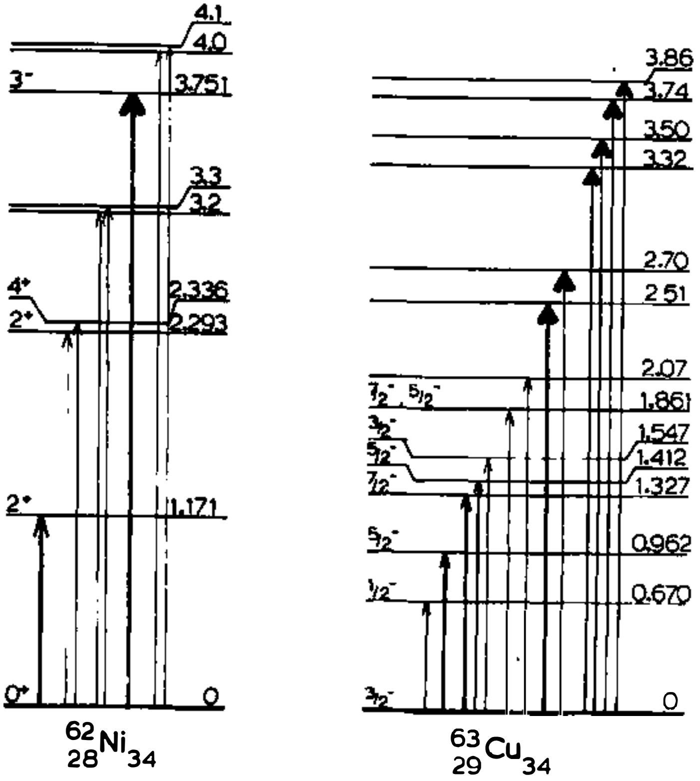

Fig.1. Levels in ^{63}Cu and ^{62}Ni excited in e,e′ measurements.

Theoreticians have calculated energy levels, spectroscopic factors, and electromagnetic properties for ^{63}Cu in many different ways.

Shell-model calculations are made |3,4| in the $2p_{3/2}$, $2p_{1/2}$, $1f_{5/2}$ base (outside the closed ^{56}Ni core).

In the particle-phonon coupling scheme a proton in the $2p_{3/2}$, $2p_{1/2}$, or $1f_{5/2}$ shell is coupled to 0, 1, 2 or 3 quadrupole phonons of the even-even core |5-12|.

In the particle-core coupling scheme a proton in the same shell-model states is coupled to an unspecified core |11-15|. The interaction Hamiltonian now consists

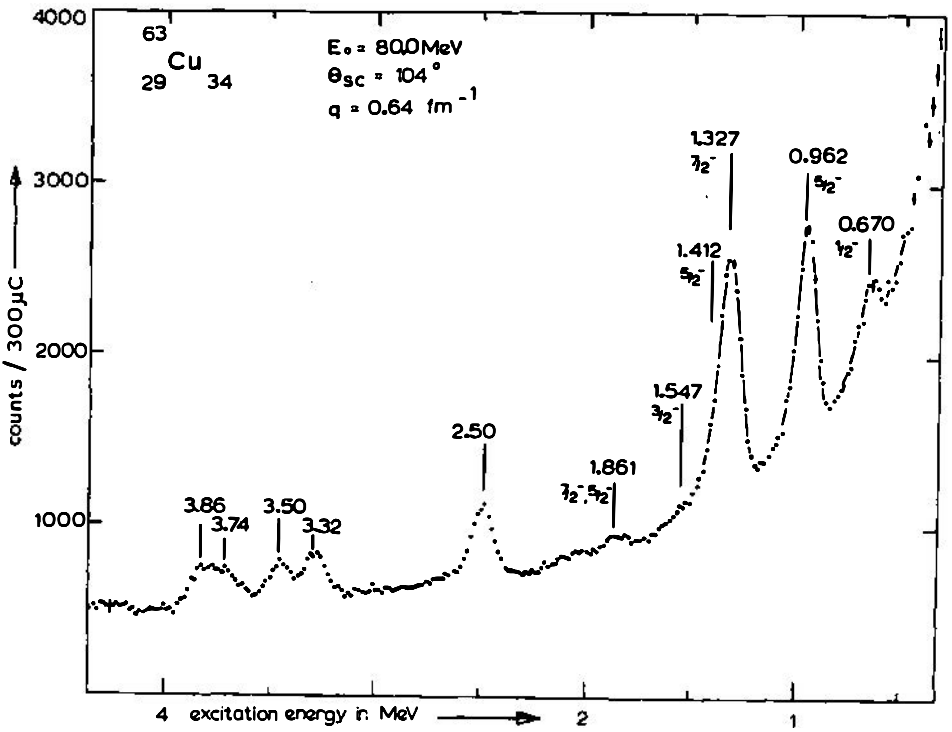

Fig.2. Spectrum of electrons inelastically scattered from ^{63}Cu.

of dipole-dipole and quadrupole-quadrupole terms.

In the quasi-particle scheme one quasi-proton is coupled to quasi-bosons or to two quasi-neutrons |16|.

All these authors (except Beres) confined themselves to lower-lying negative-parity levels in ^{63}Cu and to E2 and M1 transitions. Although several interesting features emerged from the rich amount of theoretical predictions, mainly concerning the $3/2_2$ and $5/2_2$ levels, and although the electron-scattering measurements yielded several decisive aspects in this field, this short note is limited to octupole transitions.

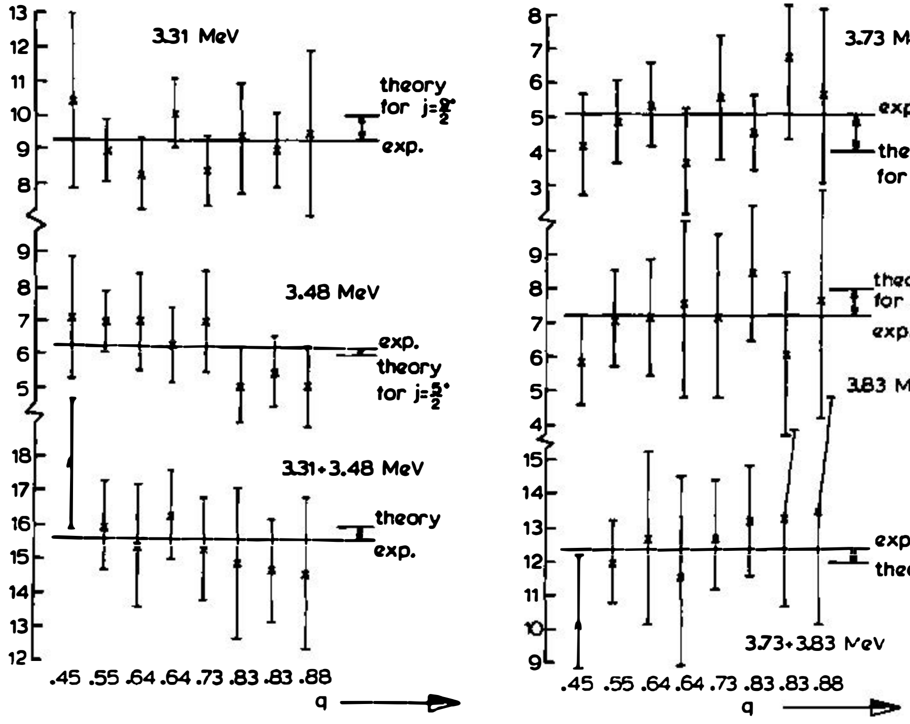

Fig.3. Relative peak areas for the 3.5 MeV quartet excited in the ^{63}Cu(e,e´) measurements. The total area of the quartet is normalized to 28 units. Left: the area of the 3.31 and 3.48 MeV peaks and their sum versus momentum transfer. Right: the area of the 3.73 and 3.83 MeV peaks and their sum.

Between 2 and 4 MeV five important E3 transitions are seen in the spectrum of electrons scattered from ^{63}Cu. (These transitions are also seen in α, α´ measurements |17|.) The five octupole transitions have the following properties:

1) The form factors can all be fitted with the shape of the form factor of the $0^{+}\rightarrow 3_{1}^{-}$ transition in

^{62}Ni, suggesting, on first sight, collective-type transitions.

2) The sum of the cross sections of the transitions to the 3.5 MeV quartet is only 8% less than the cross section of the $0^+ \rightarrow 3^-_1$ transition in ^{62}Ni, indicating an almost saturated sum rule.

3) The energy center-of-gravity of the quartet is 3.56 MeV, while weak-coupling predictions |18,19| give 3.75 MeV (the energy of the 3^- octupole state in ^{62}Ni).

All these arguments seem to lead to the conclusion that the quartet of levels at 3.5 MeV is due to the coupling of a $p_{3/2}$ proton to the 3^- octupole one-phonon state of the ^{62}Ni core. Moreover, if one assigns to the total strength of the quartet 28 units (4(2J+1)), then the individual strengths of the members at 3.31, 3.48, 3.73, and 3.83 MeV are 9.3, 6.3, 5.1 and 7.2 units, respectively. The simplest weak-coupling model would predict for these strengths 10,6,4 and 8 units ($\sim$(2j+1)). Therefore, in this framework a spin assignment of 9/2, 5/2, 3/2, and 7/2 (see fig. 3) can be given to these levels. The 2.5 MeV transition can then be explained as a $p_{3/2} \rightarrow g_{9/2}$ transition. As particle-transfer reactions give $\ell=4$ to this level |20|, a spin assignment 9/2, 7/2 can be made. The preference for 9/2 is a result from the fact that the $g_{9/2}$ shell-model state is much lower in energy than the $g_{7/2}$ state.

This simple picture may not be completely correct. Several problems are left unexplained. For instance, the fact that the shape of the form factor looks so very much like that of the collective E3 transition in ^{62}Ni needs an explanation. Moreover, the effective proton charge for the $p_{3/2} \rightarrow g_{9/2}$ transition needs to be looked at. Finally, in the framework of the particle-core coupling models, it is difficult to explain how the two 9/2 levels can be so close.

Hence, further work is required from experimentalists to establish the spins of these positive-parity states, and from theoreticians, to put octupole transitions and positive-parity states into their calculational schemes.

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REFERENCES

|1| P.J.T. Bruinsma, J.G. Noomen and C. de Vries, Nucl. Instr. & Meth. 74 (1969) 1 a.f. articles.

|2| A.A.C. Klaasse and P.F.A. Goudsmit, Z. Physik 266 (1974) 75.

|3| S.S.M. Wong, Nucl. Phys. A159 (1970) 235.

|4| J.E. Koops, to be published.

|5| M. Bouten and P. v. Leuven, Nucl. Phys. 32 (1962) 499; Nucl.Phys. 76 (1966) 479.

|6| L. Simons and T. Sundius, Soc.Sci.Comm.Phys.-Math. 34 (1969) 67.

|7| V. Paar, Nucl.Phys.A147 (1970) 369.

|8| T. Paradellis and S. Hontzeas,Can.J.Phys. 49 (1971) 1750.

|9| J.M.G. Gomez, Nucl. Phys. A173 (1971) 537.

|10| B. Castel, I.P. Johnstone, B.P. Singh and K.W.C. Stewart,Can.J.Phys. 50 (1972) 1630.

|11| J.L. de Jager and E. Boeker, Nucl.Phys. A186 (1972) 393.

|12| J.L. de Jager and E. Boeker, Nucl.Phys. A216 (1973) 349.

|13| V.K. Thankappan and W.W. True, Phys.Rev. 137 (1965) B793.

|14| D. Larner, Phys.Rev. C2 (1970) 522.

|15| R.G. Markham and H.W. Fulbright, Nucl.Phys. A203 (1973) 244; Univ. of Rochester Intern. Report UR-NSRL-41 (1971).

|16| W.P. Beres, Nucl.Phys. 75 (1966) 255.

|17| B.G. Harvey, J.R. Meriwether, A. Bussière and D.J. Horen, Nucl.Phys. 70 (1965) 305.

|18| R.D. Lawson and J.L. Uretsky, Phys.Rev. 108 (1957) 1300.

|19| A. de-Shalit, Phys.Rev. 122 (1961) 1530.

|20| A.G. Blair, Phys.Rev. 140 (1965) B648.