# Coulomb excitations of open-shell nuclei



2009 J. Phys. A: Math. Theor. 42 214047

(http://iopscience.iop.org/1751-8121/42/21/214047)

IOP Publishing — Journal of Physics A: Mathematical and Theoretical

J. Phys. A: Math. Theor. **42** (2009) 214047 (3pp) doi:10.1088/1751-8113/42/21/214047

# Coulomb excitations of open-shell nuclei

**R A Radhi**

Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq

E-mail: raadradhi@yahoo.com

Received 13 October 2008, in final form 26 February 2009
Published 8 May 2009
Online at stacks.iop.org/JPhysA/42/214047

**Abstract**

Coulomb excitations of open sd-shell nuclei are investigated. Microscopic theory is employed to calculate the C2 form factors for the first two $2^+$ states in $^{22}$Ne, $^{26}$Mg and $^{30}$Si. These collective transitions are discussed taking into account core-polarization effects. Remarkable agreements are obtained between the measured and calculated form factors for the first $2^+$ states. No strong conclusion can be drawn for the second $2^+$ states.

PACS numbers: 25.30.Dh, 21.60.Cs, 27.30.+t

## 1. Introduction

Comparisons between calculated and measured Coulomb electron scattering form factors have long been used as stringent tests of models of the nuclear structure. In the nuclear shell model, the sd shell is an interesting region for nuclear structure investigation by inelastic electron scattering. Experimental data, such as transition rates or electron scattering form factors in the sd-shell region, cannot be explained by the simple shell model, when few nucleons are allowed to be distributed over the sd-shell orbits, outside a closed $^{16}$O core. Inadequacies in the shell-model wavefunctions are revealed by the need to scale the matrix elements of the one-body operators by state-and-mass-independent effective charges to match the experimental data [1]. The effective charges may yield the same reduced transition probabilities yet differ substantially in the radial dependence of transition matrix elements. It is clear that either the $q$ dependence of effective charges or a large model space must be considered explicitly [2]. A quite successful alternative is to consider excitation of particles from the core, usually taken to be $^{16}$O, in the case of sd-shell nuclei. These particle–hole (p–h) excitations of the $^{16}$O core are referred to as core polarization (cp).

A microscopic model has been used [3] to study the C2 and C4 longitudinal form factors of the stable even–even $N = Z$ sd-shell nuclei. Their results gave a remarkably good agreement with the measured data.

The purpose of the present work is to consider the particle–hole excitations of $^{16}$O for the C2 transition in the open-shell nuclei $^{22}$Ne, $^{26}$Mg and $^{30}$Si.

  

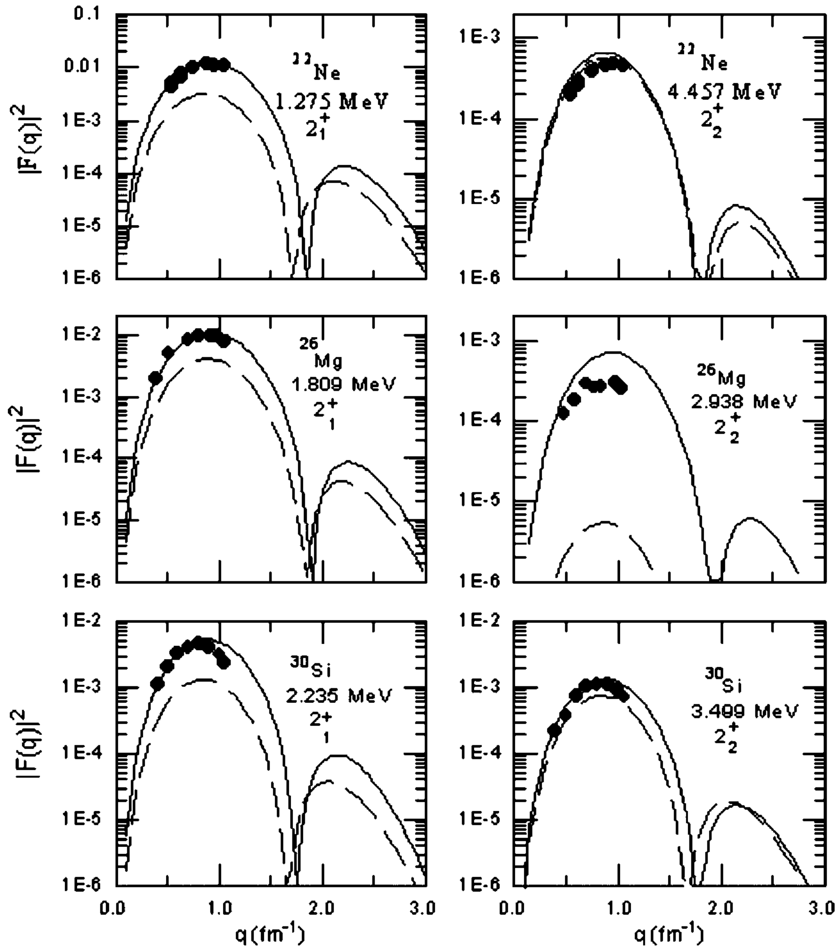


**Figure 1.** The Coulomb C2 form factors for the transitions to the $2^+$ 1 states in $^{22}$Ne, $^{26}$Mg and $^{30}$Si. The data are taken from [7], [8] and [9], respectively.

## 2. Results and discussion

We will discuss the core-polarization effects on the Coulomb C2 form factors for the first and second $2^+$ states in the open-shell nuclei $^{22}$Ne, $^{26}$Mg and $^{30}$Si. The core-polarization effect on the form factor is based on microscopic theory, which combines shell-model wavefunctions and configurations with higher energy. These higher configurations can be calculated by perturbation theory as described in [3]. We adopt the USDB interaction [4] to generate the zero-order (sd-model space) matrix elements, using the shell model code OXBASH [5]. The effects of virtual excitations of nucleons from 1s and 1p core orbits into higher allowed orbits and also from the 2s1d orbits into higher allowed orbits are considered up to 10 $\hbar\omega$ excitations, where a sufficient convergence is obtained in the Coulomb matrix elements. The M3Y interactions of Bertsch *et al* [6] between the core nucleons and the valence nucleons are assumed.

The Coulomb C2 form factors for the transitions to the $2^+$ 1 states in $^{22}$Ne, $^{26}$Mg and $^{30}$Si are shown in figure 1. The dashed lines give the calculations of the sd-shell model space (without cp), while the solid lines give those which include cp. The core-polarization effects enhance the form factors for the C2 transitions to the first $2^+$ 1 states in these nuclei and the measured experimental data are well reproduced. The experimental data for the second $2^+$ state in $^{22}$Ne are well described by the sd-shell model, and the cp effect enhances the form factor by about a factor of 1.5. The form factor for the $2_2^+$ 1 state in $^{26}$Mg is mostly determined by the cp form factor. The sd-shell contribution is small. The data are slightly overestimated when the cp effect is included. The core plays the major role for this transition in $^{26}$Mg. The measured form factor for the $2_2^+$ 1 state in $^{30}$Si is well reproduced when the cp effect is included.

## 3. Conclusions

As demonstrated by our core-polarization calculations, it is the p–h excitations that are responsible for obtaining a reasonable agreement between the measured and theoretical form factors for the $2_1^+$ states in the nuclei that are considered in the present work. The $2_2^+$ states are less affected by core-polarization effects for $^{22}$Ne and $^{30}$Si. For $^{26}$Mg, this state is enhanced appreciably by core polarization, and needs more theoretical efforts to understand this behavior. The calculated form factor becomes closer to the experimental data than the model space form factor.

More and better experimental measurements are necessary, when the $q$ values extend beyond 1 fm$^{-1}$, to see the $q$-dependent core-polarization effects, and to support the conclusion of previous studies that the $q$-independent effective charges cannot be considered as an accurate alternative of the core-polarization effect.

## Acknowledgment

The author would like to express his thanks to Professor B A Brown of the National Superconducting Cyclotron Laboratory, Michigan State University, for providing him the computer code OXBASH.

## References

[1] Brown B A, Radhi R and Wildenthal B H 1983 *Phys. Rep.* **101** 313
[2] Yokoyama A and Ogawa K 1989 *Phys. Rev.* C **39** 2458
[3] Radhi R A and Bouchebak A 2003 *Nucl. Phys.* A **716** 87
[4] Brown B A and Richter W A 2006 *Phys. Rev* C **74** 034315
[5] Brown B A, Etchegoyen A, Godwin N S, Rae W D M, Richter W A, Ormand W E, Warburton E K, Winfield J S, Zhao L and Zimmerman C H *MSU-NSCL Report Number 1289*
[6] Bertsch G, Borysowicz J, McManus H and Love W G 1977 *Nucl. Phys.* A **284** 399
[7] Maruyama X K, Kline F J, Lightbody J W Jr, Penner S, Briscoe W J, Lunnon M and Crannell H 1979 *Phys. Rev.* C **19** 1624
[8] Lees E W, Johnston A, Brain S W, Curran C S, Gillespie W A and Singhal R P 1974 *J. Phys. A: Math. Nucl. Gen.* **7** 936
[9] Brain S W, Johnston A, Gillespie W A, Lees E W and Singhal R P 1977 *J. Phys* G **3** 821