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First g-factor measurement using a radioactive ^{76}Kr beam

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Abstract. The g factor of the first 2_1^+ state of radioactive ^{76}Kr ($T_{1/2} = 14.8$ h) has been measured using projectile Coulomb excitation in inverse kinematics combined with the transient magnetic-field technique. The ^{76}Kr beam was produced and accelerated in batch mode (re-cyclotron method) at the Lawrence Berkeley National Laboratory 88-Inch Cyclotron. The g factor $g(^{76}\mathrm{Kr}; 2_1^+) = +0.37(11)$ was obtained.

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1 Introduction

The variation of magnetic moments of excited nuclear states as a function of spin and energy, or across a range of N or Z can provide significant information on the microscopic structure of nuclei. Recently, new methods have been developed which use the transient field technique and Coulomb excitation of a beam by a light target in inverse kinematics. These methods are particularly suited to measurements of nuclei that can only be produced in the form of *radioactive beams*.

This paper describes the production of a beam of ^{76}Kr ($T_{1/2} = 14.8$ h and the procedure used to measure, for the first time, the g factor of the 2_1^+ state. The details have been reported in refs. [1,2,3] and references therein.

2 Experimental technique

2.1 Production of ^{76}Kr

The ^{76}Kr radioactive ions were produced and accelerated using a batch mode method involving only one accelerator and therefore was named the "re-cyclotron method" [2].

Approximately 10^{14} ^{76}Kr nuclei were produced in the reaction ^{74}Se(α, 2n)^{76}Kr during a 17-hour production period using a 38 MeV, 6 particle-μA ^{4}He, beam on a 165 mg/cm^2 thick metallic ^{74}Se target. After irradiation the selenium was melted to release the krypton, which was transferred via a He gas flow to a cryogenic trap. After release from the trap into the Advanced Electron Cyclotron Resonance-U ion source(AECR-U) the 88-Inch Cyclotron accelerated ^{76}Kr^{+15} ions to 230 MeV producing currents as high as 3×10^8 particles per second and yielding an average current of 4×10^7 particles per second for two hours on target.

Three batches were produced. For comparison with radioactive beam facilities providing a continuous beam, a total intensity of 8×10^{11} of ^{76}Kr was obtained, equivalent to a constant beam of 1.6×10^6 particles per second for five days.

2.2 g-factor measurement

The transient field technique in inverse kinematics was used. The target was a layered structure of ^{26}Mg, gadolinium and copper.

Four Clover detectors were used to detect the γ rays, and a solar cell detector was used to detect the Mg ions. The radioactive beam exiting from the target was stopped in a moving tape mounted behind the target.

Figure 1 shows the γ-ray spectra obtained from the activity accumulated in the copper layer of the target and the coincidence particle-γ-ray spectra from which all contaminant radiations were removed.

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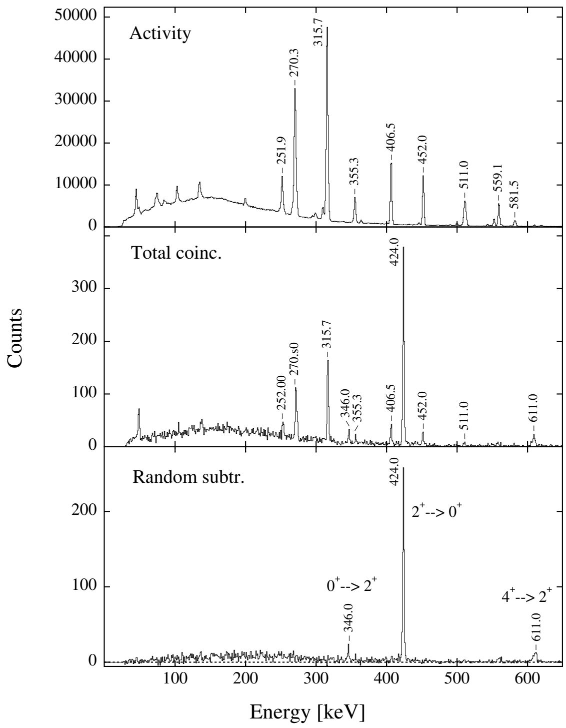

Fig. 1. Top: a background spectrum taken after the end of a ^{76}Kr beam batch cycle. Middle: a γ-ray spectrum taken in coincidence with particles. Bottom: the same Clover spectrum as shown in the middle panel with random coincidences subtracted. Only the ^{76}Kr γ-ray lines remain.

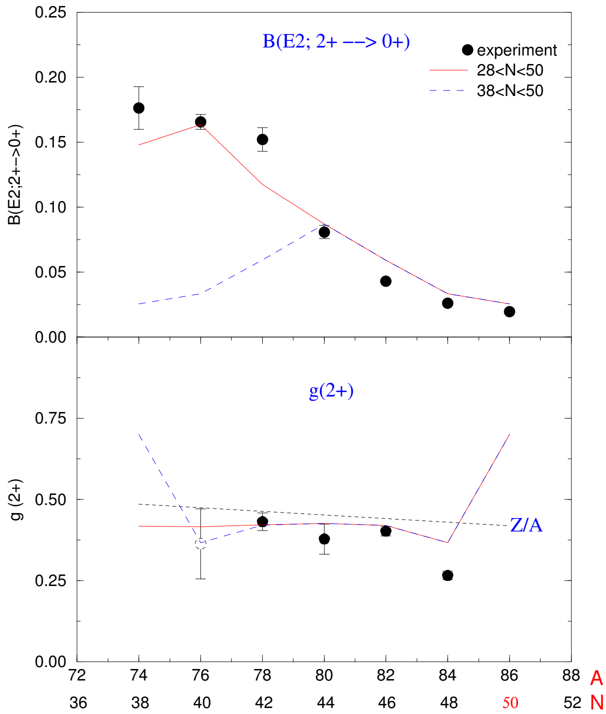

Fig. 2. $B(E2)$ values in e^2b^2 and g factors for even Kr isotopes. The curves are IBA-II calculations as described in ref. [1] and the g factor for ^{76}Kr is from this work.

The extraction of a g factor requires a knowledge of the particle–γ-ray angular correlation. However, since the angular correlation should be very similar to that obtained under the same kinematic conditions with a stable beam of a neighbouring isotope, and in view of the similarity between the energy level structure of ^{76}Kr and ^{78}Kr, angular correlation and precession measurements were carried out with a ^{78}Kr beam.

In six hours, 800 events/Clover in the photopeak of the ^{76}Kr, $2_1^+ \to 0_1^+$ transition, were recorded for each field direction. In 2.5 h, 7×10^4 counts/Clover and field direction were recorded for the ^{78}Kr, $2_1^+ \to 0_1^+$ transition.

The g factor of the 2_1^+ state in ^{76}Kr can be directly written in terms of the known g factor of the 2_1^+ state in ^{78}Kr, $g(^{76}\mathrm{Kr}; 2_1^+) = g(^{78}\mathrm{Kr}; 2_1^+) \times \frac{\epsilon(^{76}\mathrm{Kr})}{\epsilon(^{78}\mathrm{Kr})} = +0.37(11)$, where ϵ is related to the change in counting rate observed when the external magnetizing field is changed from the up to the down direction with respect to the γ-ray detection plane.

3 Discussion

The g factors of the 2_1^+ states in the Kr isotopes have been measured across the region from the semi-magic ^{86}Kr to the lightest, radioactive ^{76}Kr and are summarized in fig. 2.

Semi-magic $^{86}_{50}$Kr has a large positive $g(2_1^+)$ factor of +1.12(14) (off scale in fig. 2) a clear indication of proton excitations. The two $g_{9/2}$ neutron holes in ^{84}Kr are responsible for the smaller g factor for the 2_1^+ state. However, as more neutrons are removed, the g factors of the 2_1^+ states increase progressively toward the collective value of Z/A. At the same time, the g factors of the 4_1^+ and 2_2^+ states also tend to be equal to the nominal Z/A value [1].

Calculations based on the interacting boson model IBA-II, a "pairing-corrected" collective model and the shell model are described in refs. [1,4].

In summary, this experiment provided the first measurement of a g factor carried out by the Coulomb excitation/transient field technique on a radioactive beam and supports the applicability of the method to the measurements of magnetic moments on radioactive beams. The result confirms the collective nature of the structure of the 2_1^+ state of ^{76}Kr.

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References

1. T.J. Mertzimekis *et al.*, Phys. Rev. C **64**, 024314 (2001).
2. J.R. Cooper *et al.*, Nucl. Instrum. Methods Phys. Res. A **253**, 287 (2004).
3. G. Kumbartzki *et al.*, Phys. Lett. B **591**, 213 (2004).
4. T.J. Mertzimekis, A.E. Stuchbery, N. Benczer-Koller, M.J. Taylor, Phys. Rev. C **68**, 054304 (2003).