# Nuclear Spin of Gallium-68†

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The atomic-beam magnetic resonance method has been used to measure the nuclear angular momentum of 68-minute gallium-68. It is found that $I=1$.

## INTRODUCTION

THIS paper presents the results of measurements performed to determine the ground-state nuclear angular momentum of gallium-68. These measurements are a portion of a program to determine the nuclear properties of the long-lived radioactive gallium isotopes (half-life>30 minutes). Prior work on the nuclear properties of gallium-66 and gallium-67 has been reported elsewhere.[1,2]

## ISOTOPE PRODUCTION

Production of gallium-68 is via the reaction $Cu^{65}(\alpha,n)Ga^{68}$ and takes place in the Berkeley 60-inch cyclotron. Ordinary 10-mil commercial sheet copper is used as a target in the bombardment. It is impossible to entirely suppress the simultaneous production of $Ga^{64}$, $Ga^{65}$, $Ga^{66}$, and $Ga^{67}$. However, use of a $\frac{1}{2}$- or 1-hour bombardment enhances the ratio of $Ga^{68}$ to the longer-lived $Ga^{66}$ and $Ga^{67}$. Enhancement over the 15-minute $Ga^{65}$ component is accomplished partially by using 20-Mev alpha particles and partially by the fact that there is about a 1-hour delay from the time of removal of the target from the cyclotron to the time of insertion of the gallium into the atomic-beam apparatus. For this latter reason, no measurable $Ga^{64}$ component is present in the beam.

## GALLIUM SEPARATION AND BEAM PRODUCTION

In order to produce a satisfactory beam of gallium, it is first necessary to separate the gallium from the copper target. Chemistry is performed conveniently by using diethyl ether to extract the radioactive gallium from the copper target in a $6N$ solution of HCl. The gallium chloride is extracted from the ether with $H_2O$ and the gallium is then precipitated as $Ga(OH)_3$ by adding NaOH until the $p$H is about 5.5. The precipitate is then dissolved in the smallest possible amount of NaOH and the gallium is electroplated out of this solution onto a 4-mil platinum wire. In this way it is found that essentially 100% separation is obtainable, with recovery of approximately 50% of the available gallium. A higher recovery would be made possible by use of an electroplating period longer than the 15 minutes used in this work. This technique is a modification of a method first developed by Swift in 1924.[3]

The first attempt to produce a beam of gallium was by distillation of the material directly from the copper target. This failed, for the activity coefficient of Ga in copper is about $10^{-3}$, making a vapor-pressure separation, such as that used for thallium,[4] impossible. Similar results were obtained in a subsequent attempt to distill the gallium from a platinum foil onto which the material had been electroplated. A usable beam was obtained only when the chemistry procedure described above was used, and when the electroplated gallium was placed in a carbon oven. Ovens made of iron and tantalum were found to be unsatisfactory owing to interaction with the gallium at beam temperatures. This effect has been observed also by Renzetti in work on the stable gallium isotopes.[5]

The oven is introduced into the apparatus with negligible disturbance to the apparatus vacuum by means of an oven loader. The typical beam temperatures of 1100–1300°C are reached by using electron bombardment. Heating the oven is most efficiently accomplished if tantalum foil is placed around the carbon oven, so as to minimize heat losses due to radiation.

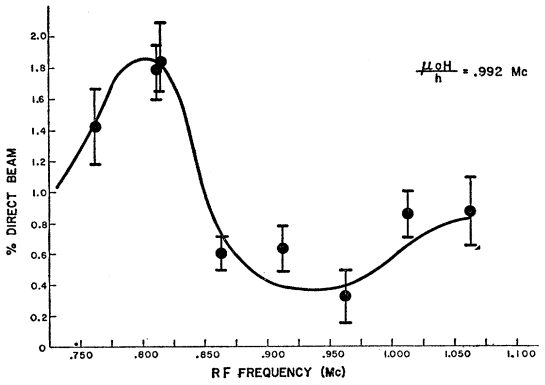


FIG. 1. Observed transitions in the $^2P_{\frac{1}{2}}$ level of $Ga^{68}$ in a field of 0.709 gauss.

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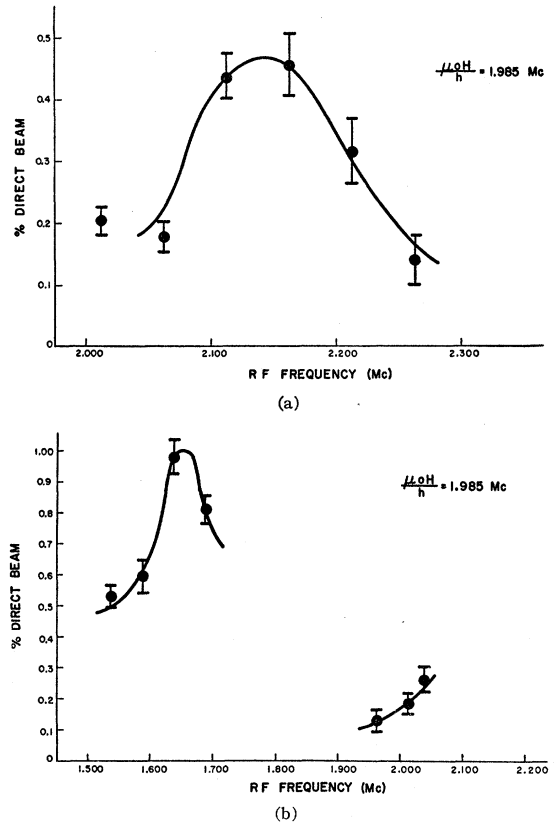


FIG. 2. (a) $F=\frac{3}{2}$ resonance in the $^2P_{\frac{3}{2}}$ level of $Ga^{68}$ at a $C$ field of 1.418 gauss. (b) $F=\frac{5}{2}$ resonance in the $^2P_{\frac{3}{2}}$ level of $Ga^{68}$ at a $C$ field of 1.418 gauss.

## EXPERIMENTAL METHOD AND OBSERVATIONS

For a given electronic state, the possible Zeeman frequencies are, in general, unique functions of the nuclear spin. Hence a determination of the nuclear spin involves observation of the transition frequencies for an atom in a known electronic state. The electronic ground-state term of gallium is $^2P$, with a fine-structure separation of 826 $cm^{-1}$. Both the $^2P_{\frac{1}{2}}$ and $^2P_{\frac{3}{2}}$ levels are therefore appreciably populated at the normal beam temperature of 1200°C. Observations on atoms in the $^2P_{\frac{3}{2}}$ level were made at a $C$ field of 0.709 gauss. Resonances were observed (Fig. 1) at frequencies corresponding to the transitions in the hyperfine-structure levels $F=\frac{3}{2}$ and $F=\frac{5}{2}$, with a nuclear spin of 1. These transitions have been verified at higher fields (Fig. 2). However, a frequency shift is observed at these fields, which is characteristic of a low hyperfine structure. Further experiments are being conducted to more precisely determine the hyperfine-structure separations. Isotope identification is performed by following the decay of a resonance button. The observed half-life (67±15 min) is in good agreement with published values for $Ga^{68}$.[6]

## DISCUSSION

On the simple shell-model picture,[7] the odd proton in gallium-68 is in a $p_{\frac{3}{2}}$ level, and the odd neutron is in an $f_{\frac{5}{2}}$ level. According to Nordheim's strong rule,[8] these particles couple to a ground-state angular momentum of 1.

The measured spin is in agreement with an assignment made from beta-ray spectroscopy.[9]

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