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NUCLEAR-TRANSFER SPECTROSCOPY USING RADIOACTIVE TARGETS[†]

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Abstract

The feasibility and techniques for carrying out transfer spectroscopic experiments with radioactive targets having half lives down to a fraction of a year are reviewed. The use of such radioactive targets is illustrated by recent studies of the spectroscopy of ^{149}Sm , ^{174}Lu and ^{247}Bk using (p,t) transfer spectroscopy.

1. Introduction

The specificity of charged particle transfer spectroscopy applied to shorter lived isotopic targets affords many interesting possibilities for detailed examination of the structure of nuclei lying off the stability line. Two developments make possible such experimental investigations: first, the availability of high flux reactors or the high current beams at the meson factories and second, the development of the highly efficient thermal ion sources used to prepare the isotopic targets. The latter technology has been particularly developed by Johnson's group¹⁾ at the Livermore National Laboratory and by Raiko²⁾ and his collaborators at Dubna.

The activity levels involved in such investigations are not prohibitive. For example, a 2 microgram target occupying dimensions 5 mm x 2 mm corresponds to a thickness of 20 $\mu\text{g}/\text{cm}^2$, a target thickness quite adequate for precision nuclear spectroscopy using current apparatus.

If one considers the disintegration rate for such a 2 microgram quantity of a pure isotope with mass 150, one finds the activity levels are quite acceptable from the point of view of preparation and manipulation at the spectrograph as shown in the table below.

Half Life (years)	Activity Level (millicurie)
10^3 years	5×10^{-3}
1 year	5
1/3 year	15

With the availability of such radioactive targets numerous interesting prospects unfold among which are the investigations of the level structures of transuranium nuclei, odd-odd nuclei using two nucleon transfer spectroscopy and the structure of nuclei in the vicinity of shell closures such as occur near ^{54}Ni , ^{82}Zn or ^{146}Gd .

To illustrate some of these we have chosen three studies completed at the Princeton University Q30 Spectrograph.

The first figure shows the identification of the rotational band based on the Nilsson $7/2^+ [633]$ proton state in Berkelium 247 using the (p,t) reaction with 320 day Berkelium 249 as a target.

Fig. 1 Levels in $^{247}\text{Bk}_{152}$ from the (p,t) reaction on 320 day $^{249}\text{Bk}_{154}$.

The latter is exceptional among the odd A Berkelium isotopes in having a $7/2^+$ ground state. This ground state has been previously assigned as the $[633]$ state. We observe the (p,t) reaction specifically populates 5 members of the rotational band in Berkelium 247 which corresponds to the ground state of Berkelium 249. The specificity of the (p,t) reaction and the close similarity of the $7/2^+ [633]$ states in both Berkelium 247 and 249 is shown by the absence of evidence for population of any other states in ^{247}Bk .

Figure 2 displays the triton spectra observed in the (p,t) reaction on a target of 90 year Samarium 151, a nucleus lying in the shape transition region with 89 neutrons.

Fig. 2 Levels in ^{149}Sm from the ^{151}Sm (p,t) reaction.

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The possibility of employing radioactive odd-odd nuclei as targets is particularly intriguing both because of the scarcity of these nuclei among the naturally occurring species and also because the specificity of certain transfer reactions permits the relationship of states occurring in two nearby odd-odd nuclei to be established.

One rotational band (with rotational members at 715, 922 and 1142 keV) is populated; the prominent 7-2 quasiparticle band head is located by these studies at 523 keV. On the basis of the $L = 0$ angular distribution and the intensity observed for the 523 keV state we are able to assign this band in lutetium 174 as the two neutron hole analog of the ground state band known in lutetium 176 having the same two quasiparticle configuration for the odd neutron and proton in both product and target. The relatively strong population observed for the second 7-state at 320 keV, however, indicates that, in the case of the (p,t) reaction in odd-odd nuclei less perfect overlap occurs between the ground state of the target and the product.

stability line which cannot be achieved using other techniques presently available.

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