Comments and Addenda

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Charge-Exchange Threshold Effect in ^{93}Nb(d, p)^{94}Nb†

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A charge-exchange threshold cusp is observed in the summed 160° excitation curve for ^{93}Nb(d,p)^{94}Nb(6^+, g.s.-2^+, 0.31 MeV) at ~7.1 MeV, the threshold of the analogous ^{93}Nb(d,n)-^{94}Mo^A(6^+, 13.2 MeV-2^+, 13.5 MeV) reaction. As predicted by theory, it is essentially identical in shape to the excitation curve previously measured for ^{90}Zr(d,p)^{91}Zr($d_{5/2}$, g.s.) in the same energy region.

Charge-exchange cusps were originally noticed by Moore *et al.*,[1] in the ^{90}Zr(d,p)^{91}Zr($d_{5/2}$, g.s.) excitation curve at 160°, in the vicinity of E_d = 7.05 MeV, the threshold of the analogous reaction ^{90}Zr(d,n)^{91}Nb^A($d_{5/2}$, 9.48 MeV). A number of reports of such cusps have since been made for (d,p) and (p,d) reactions on ^{91,92,94,96}Zr,[2-4] ^{92,94}Mo,[3] ^{89}Y,[5] and ^{88}Sr.[6] A theoretical description of the process based on the Lane model has been shown to give good agreement with ^{90}Zr and ^{92}Mo data.[7]

However, tests of the theory have so far been *post facto*. It is useful to check a straightforward prediction, and we report here on such a check.

A simple incorporation of the Lane model into the distorted-wave Born approximation[7,8] leads to the prediction that the cusp will be very similar in appearance for any two (d,p) reactions in the same mass region, involving the same jls transfer, such that $4Q-\Delta_C$ is positive and approximately the same for both nuclei. Equivalently, the analog resonances excited in the analogous (d,n) reactions should have comparable proton widths and resonance energies. Here Q is the (d,p) Q value, Δ_C the Coulomb displacement energy of a proton in the residual nucleus. It is important that the appearance of the cusp will not depend on the nature of the residual nuclear state except indirectly through the proton decay width of its isobaric analog. The reaction ^{93}Nb(d,p)^{94}Nb is therefore of interest. For ^{90}Zr(d,p)^{91}Zr($d_{5/2}$, g.s.), $4Q-\Delta_C=8.0$ MeV, while for ^{93}Nb(d,p)^{94}Nb(6^+, g.s.), $4Q-\Delta_C$ = 8.0 MeV. The ^{93}Nb(d,n)^{94}Mo^A(6^+, 13.2 MeV) threshold occurs at 7.1 MeV, about the same deuteron energy as the ^{90}Zr(d,n)^{91}Nb^A($d_{5/2}$, 9.5 MeV) threshold (7.05 MeV). The ^{93}Nb(d,p)^{94}Nb excitation curve should therefore be practically identical in shape to the ^{90}Zr(d,p) excitation curve at the same angle.

An excitation curve was obtained using a 1.0-μA deuteron beam in 0.2–0.5-MeV steps from 5.0 to 10.0 MeV, on a self-supporting rolled ^{93}Nb foil of 0.39-mg/cm^2 thickness. Protons were observed with three Si(Li) counters, cooled to dry-ice temperature and fixed at 120, 140, and 160°. The cluster of six states in ^{94}Nb in the interval 0.0 to 0.31 MeV in excitation were summed as a single state, since they all share in the $d_{5/2}$ strength.[9] This has the effect of energy-averaging the ^{93}Nb(d,p)^{94}Nb(6^+, g.s.) excitation curve over 300 keV, since the excitation curves for all six $l=2$ transitions should have similar shapes with thresholds differing by 300 keV for highest and lowest states. This averaging will not wash out the cusp, which in ^{90}Zr(d,p) is ~1 MeV broad.

In Fig. 1 is shown a comparison of the ^{93}Nb(d,p) data with the ^{90}Zr(d,p)^{91}Zr($d_{5/2}$, g.s.) excitation curve at 155° from Ref. 4 (dashed line), and the ^{90}Zr(d,p)^{91}Zr excitation curve averaged over 300

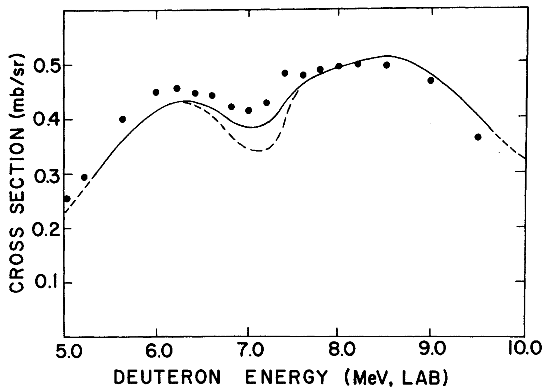

FIG. 1. Comparison of the $^{93}Nb(d,p)^{94}Nb$(g.s. to 0.31 MeV) cross section at 160° with the $^{90}Zr(d,p)^{91}Zr$(g.s.) cross section at 155° (from Ref. 4). The solid line is the $^{90}Zr(d,p)$ cross section averaged over 0.3 MeV, the dashed line the unaveraged cross section. The ^{93}Nb data are arbitrarily normalized, for display purposes, to the absolute ^{90}Zr cross section at 8.0 MeV.

keV (solid line). The averaging of the data was performed numerically by computing

$$\left(\frac{d\sigma(E)}{d\Omega}\right)_{\text{avg}} = \frac{1}{\Delta}\int_{E-\Delta/2}^{E+\Delta/2} \rho(E')\left(\frac{d\sigma(E')}{d\Omega}\right)_{\text{exp}} dE' ,$$

where $\rho(E)$ is a Lorentzian weighting function and $[d\sigma(E)/d\Omega]$ are the data of Ref. 4. The ^{93}Nb data have been arbitrarily normalized to the ^{90}Zr absolute cross section at 8.0 MeV. The agreement is seen to be reasonable.

The experimental $^{93}Nb(d,n)$ cross section is seen to fall off slightly more rapidly with energy above 9 MeV than the $^{90}Zr(d,p)$ averaged data. This effect may be similar to that observed by Moore[2] in comparing $^{91}Zr(d,p)^{92}Zr(4^+$, 1.49 MeV) and $^{90}Zr(d,p)^{91}Zr(d_{5/2}$, g.s.) excitation curves. It seems to represent a genuine difference in the energy dependence of the (d,p) cross sections, unrelated to the threshold effect.

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Lifetimes of Ir^{193} Levels*

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Using new information concerning the decay modes of the 460-, 557-, and 559-keV levels in Ir^{193}, previous resonance-fluorescence data have been reevaluated in terms of the mean lives of these levels.

Recently, several attempts have been made to determine the mean lives of the 460-, 557-, and 559-keV excited states of Ir^{193} with the delayed-coincidence technique.[1-3] In many instances it was only possible to establish lower limits, because these lifetimes are close to the useful range of that technique. Earlier resonance-fluorescence experiments[4] in which these levels had been excited gave only tentative values for the mean lives of the 557- and 559-keV levels, because detailed information concerning their decay modes was not available. Recent studies[5,6] have provided some of the needed spectroscopic information, and it is the purpose of this note to report what conclusions