Proton Single-Particle States in 209Bi via the 208Pb(d, n)209Bi Reaction

著者	Terakawa A., Tohei T., Nakagawa T., Narita A., Hosomi K., Orihara H., Ishii K., Ohura M., Hosaka M., Jon G. C., Miura K., Ohnuma H.
journal or publication title	CYRIC annual report
volume	1991
page range	38-43
year	1991
URL	http://hdl.handle.net/10097/49629

I. 8. Proton Single-Particle States in ^{209}Bi via the ^{208}Pb(d, n)^{209}Bi Reaction

Terakawa A., Tohei T., Nakagawa T., Narita A., Hosomi K., Orihara H., Ishii K.*, Ohura M.** Hosaka M.*, Jon G. C. *, Miura K.*** and Ohnuma H.*****

Department of Physics, Faculty of Science, Tohoku University
*Cyclotron and Radioisotope Center, Tohoku University**
*The Institute of Physical and Chemical Research (RIKEN)***
*Tohoku Institute of Technology****
*Department of Physics, Tokyo Institute of Technology*****

The doubly magic nucleus ^{208}Pb has played important roles in the study of the nuclear structure and reaction. The single-proton stripping reactions on ^{208}Pb [1-4] have shown six strong transitions for each single-particle orbit in the Z = 82 - 126 proton shell, indicating the single-particle motion around the ^{208}Pb core.

The spectroscopic factors of these proton single-particle states in ^{209}Bi are expected to be close to unity. On the other hand, the previous investigations for these states through the (^{3}He, d) reaction [1,2] have shown that the DWBA analysis with the usual Thomas spin-orbit strength $\lambda = 25$ gives the larger spectroscopic factors than the sum rule limit, and that the reasonable values result from the analysis with $\lambda = 6$.

In this situation for ^{208}Pb, we attempt to deduce the spectroscopic factors through the ^{208}Pb(d, n)^{209}Bi reaction at $E_d = 25$ MeV. The (d, n) data on ^{208}Pb have not so far been reported. In addition, the (d, n) reaction at the sufficiently high incident energy may be a powerful spectroscopic tool for probing the single-particle property of nuclei since the theoretical treatment for this reaction is more straightforward than that for other proton stripping reactions. Therefore, the spectroscopic factors through the (d, n) reaction on ^{208}Pb are highly desired.

In this report, we present the result of a study of the ^{208}Pb(d, n)^{209}Bi reaction at E_d = 25 MeV. The obtained data have been analyzed with the adiabatic deuteron breakup approximation (ADBA) calculation [6], where s-wave deuteron breakup effects have been included, as well as the conventional DWBA calculation.

The experiment was performed at the Cyclotron and Radioisotope Center (CYRIC), Tohoku University. A 25 MeV deuteron beam was obtained from the K = 50 MeV AVF-Cyclotron. The targets used were self-supporting ^{208}Pb foils isotopically enriched to 99.6 %. The target thicknesses were 14.4 and 20.7 mg/cm^2. The emitted neutrons were detected with twelve neutron detectors containing liquid-scintillator NE213. The neutron energies were measured using the TOF facility with a 44 m flight path. The solid angle in the experimental setup was 0.23 msr. The angular distributions of the neutrons were measured with a beam swinger system in the angular range of θ_L = 10° - 60° in 3° intervals for $\theta_L \leq$ 36° and in 5° intervals for $\theta_L \geq$ 40°. The details of the facilities have been described elsewhere 7).

A typical excitation energy spectrum is shown in Fig. 1. Overall energy resolution was 215 keV (FWHM) for the neutrons leading to the low lying states in the residual nucleus. Errors in the absolute magnitude of the cross section have been estimated to be less than 15 %.

The angular distributions of the differential cross sections for the proton single-particle states in ^{209}Bi were analyzed with both the DWBA and ADBA analyses. The calculations were performed with the code DWUCK4 8). Finite range and non locality corrections were included in the calculation. The finite range parameter was 0.695 fm, while the non locality parameters for a deuteron were 0.54 fm in the DWBA treatment and 0.425 fm in the ADBA treatment, and that for a neutron 0.85 fm. The deuteron optical potential parameters in the DWBA calculation were taken from the global sets of Daehnick et al.9). The adiabatic deuteron potential was derived from the sets of the nucleon parameters at $E_p = E_n = 1/2E_d$, which have been given by Becchetti and Greenlees 10). The single particle wave function for the transferred proton was generated from the Woods-Saxon potential with the usual parameters (r_0 = 1.25 fm, a = 0.65 fm and λ = 25).

Figure 2 shows the angular distributions of the differential cross sections for the proton single-particle states, and the results of the ADBA (solid lines) and DWBA (dashed lines) calculations. The angular distribution shapes have well been reproduced by the ADBA calculation, while poor agreements with the data at forward angles have been obtained in the case of the DWBA treatment.

The spectroscopic factors obtained in the present analysis are listed in Table 1 together with those of the previous works 1-4) . The results of this analysis have shown the strong dependence of the spectroscopic factor on the deuteron potential. It is noted that the spectroscopic factor for the ground state transition exceeds the sum rule limit for the $1h_{9/2}$ transfer by 56 % in the case of the ADBA calculation.

On the other hand, it is well known that the spectroscopic factor also depends on assumed geometrical parameters of the bound potential. The surface localization of the hadronic reaction makes its cross section sensitive to the asymptotic behavior of the single-particle wave function of the transferred nucleon. For example, a change of 1 % in the radius of the bound potential results in that of about 12 % in the spectroscopic factor ($12\ \Delta r/r \sim \Delta S/S$) in the present case. Therefore, we should treat the bound potential carefully.

In the recent analyses 11,12) of the proton transfer reaction in the lead region, the bound potential parameters (r_0 = 1.2675 fm, a = 0.810 fm) obtained from the detailed analysis for the nuclear matter distribution of ^{208}Pb 13) have been used. If we choice these parameters in the present analysis, the reasonable spectroscopic factors are obtained, as is shown in Table 1. Furthermore, the results are in good agreement with those of the (α, t) reaction at E_α = 80 MeV, where the bound potential parameters are close to those for the nuclear matter distribution.

In conclusion, the strong dependence of the spectroscopic factor on both the optical potential and geometry of the bound potential has been shown from the analyses of the ^{208}Pb(d, n)^{209}Bi reaction at E_d = 25 MeV. For the ground state transition, the spectroscopic factor have exceeded the sum rule limit by 56 % in the case of the ADBA analysis with the usual bound potential parameters, while the use of the parameters obtained from the analysis of the nuclear matter distribution [13) has given the reasonable spectroscopic factors in all cases. The influence from these uncertainties in the analysis may make the absolute value of the spectroscopic factor unreliable, leading to the difficulty in the precise determination of the nuclear properties, such as the occupation probability and energy of the single-particle orbit.

References

1) Wildenthal B. H. et al., Phys Rev. Lett. **19** (1967) 960.
2) Bardwick J. and Tickle R., Phys. Rev. **171** (1968) 1305.
3) Grolean R. et al., Phys. Rev. **C22** (1980) 440.
4) Gales S. et al., Phys. Rev. **C31** (1985) 94.
5) Martin M. J., Nuclear Data Sheets **63** (1991)723.
6) Wales G. L. and Johnson R. C., Nucl. Phys. **A247** (1976) 168.
7) Orihara H. et al., Nucl. Instru. and Meth. **188** (1981) 15 ; *ibid* **A257** (1987) 189.
8) Kunz P. D., The code DWUCK4, unpublished.
9) Daehnick W. W. et al., Phys. Rev. **C21** (1980) 2253.
10) Becchetti F. D. and Greenlees G. W., Phys. Rev. **182** (1969) 1190.
11) Radhakrishna M. C. et al., Phys. Rev. **C37** (1988) 66.
12) Grabmayr P. et al., Nucl. Phys. **A494** (1989) 244
13) Streets J. et al., J. of Phys., **G8** (1982)2253.

Table 1. Experimental spectroscopic factors in ^{209}Bi.

			Spectroscopic factor (C^2S)							
			(d,n), E_d=25 MeV				(^{3}He,d), E_h=51.26 MeV[d]	(^{3}He,d), E_h=44.2 MeV[e]	(^{3}He,d), E_h=30 MeV[f]	(α,t), E_α=80 MeV[g]
			Usual[b]		NMD[c]		$\lambda = 6$	$\lambda = 6$	$\lambda = 6$	$\lambda = 25$
E_x(MeV)[a]	J^π[a]	$n\ell j$	ADBA	DWBA	ADBA	DWBA				
g.s.	$9/2^-$	$1h_{9/2}$	1.56	0.84	1.02	0.70	1.00	0.95	1.00	0.80
0.986	$7/2^-$	$2f_{7/2}$	1.05	0.77	0.62	0.59	1.12	1.18	1.38	0.76
1.608	$13/2^+$	$1i_{13/2}$	0.84	0.89	0.58	0.66	0.94	0.88	0.85	0.74
2.822	$5/2^-$	$2f_{5/2}$	0.93	0.62	0.53	0.48	1.14	1.15	0.87	0.57
3.118	$3/2^-$	$3p_{3/2}$	0.72	0.64	0.42	0.47	1.08	1.03	0.98	0.44
3.633	$1/2^-$	$3p_{1/2}$	0.62	0.57	0.35	0.42	(0.7 - 0.9)	0.63	0.54	0.20

a) Reference 5.

b) Present work. The bound potential parameters of $r_0 = 1.25$ fm, $a = 0.65$ fm and $\lambda = 25$ were used.

c) Present work. The bound potential parameters from the analysis of the nuclear matter distribution ($r_0 = 1.2675$ fm, $a = 0.810$ fm and $\lambda = 25$) were used.

d) Reference 1. The bound potential parameters of $r_0 = 1.24$ fm and $a = 0.65$ fm were used.

e) Reference 2. The bound potential parameters of $r_0 = 1.24$ fm and $a = 0.65$ fm were used.

f) Reference 3. The bound potential parameters of $r_0 = 1.24$ fm and $a = 0.65$ fm were used. The spectroscopic factor was normalized to unity for the ground state transition.

g) Reference 4. The bound potential parameters of $r_0 = 1.28$ fm, $a = 0.76$ fm , $r_{so} = 1.09$ fm and $a_{so} = 0.60$ fm were used.

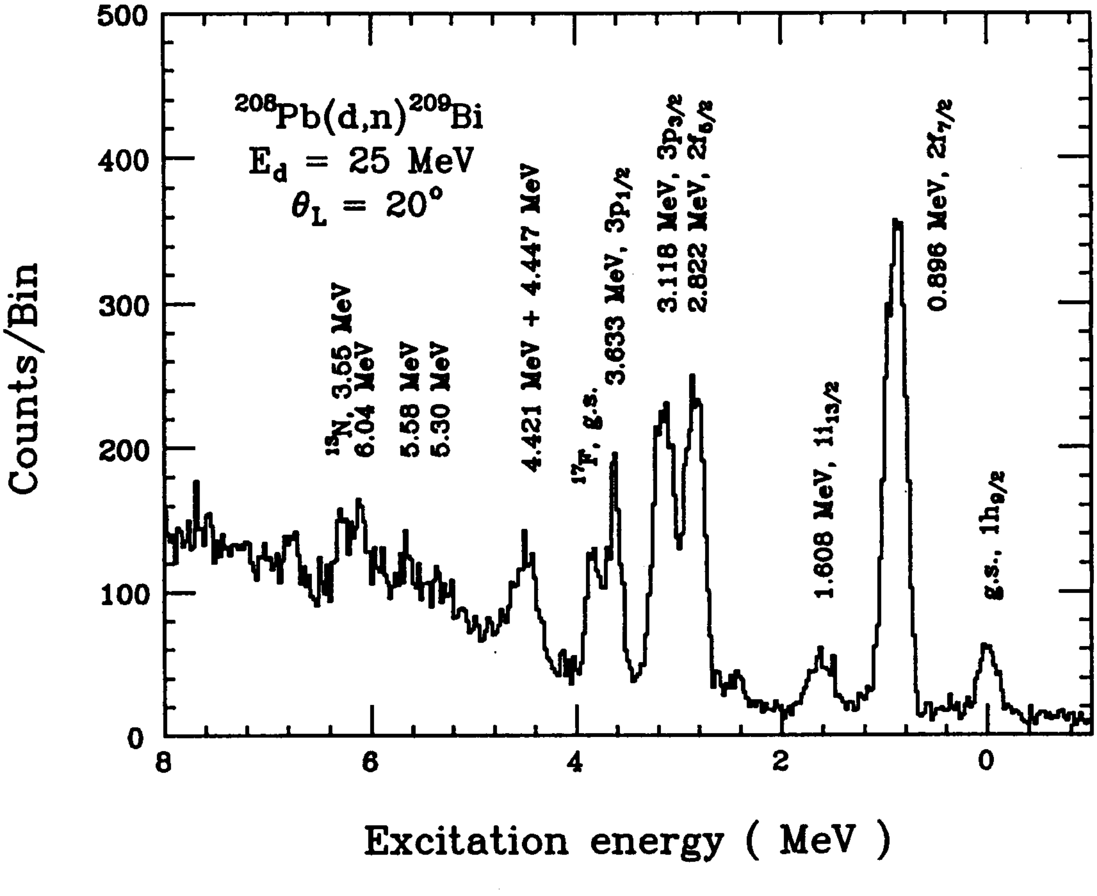

Fig. 1. Energy spectrum of the ^{208}Pb(d, n)^{209}Bi reaction at $\theta_L = 20^{\circ}$.

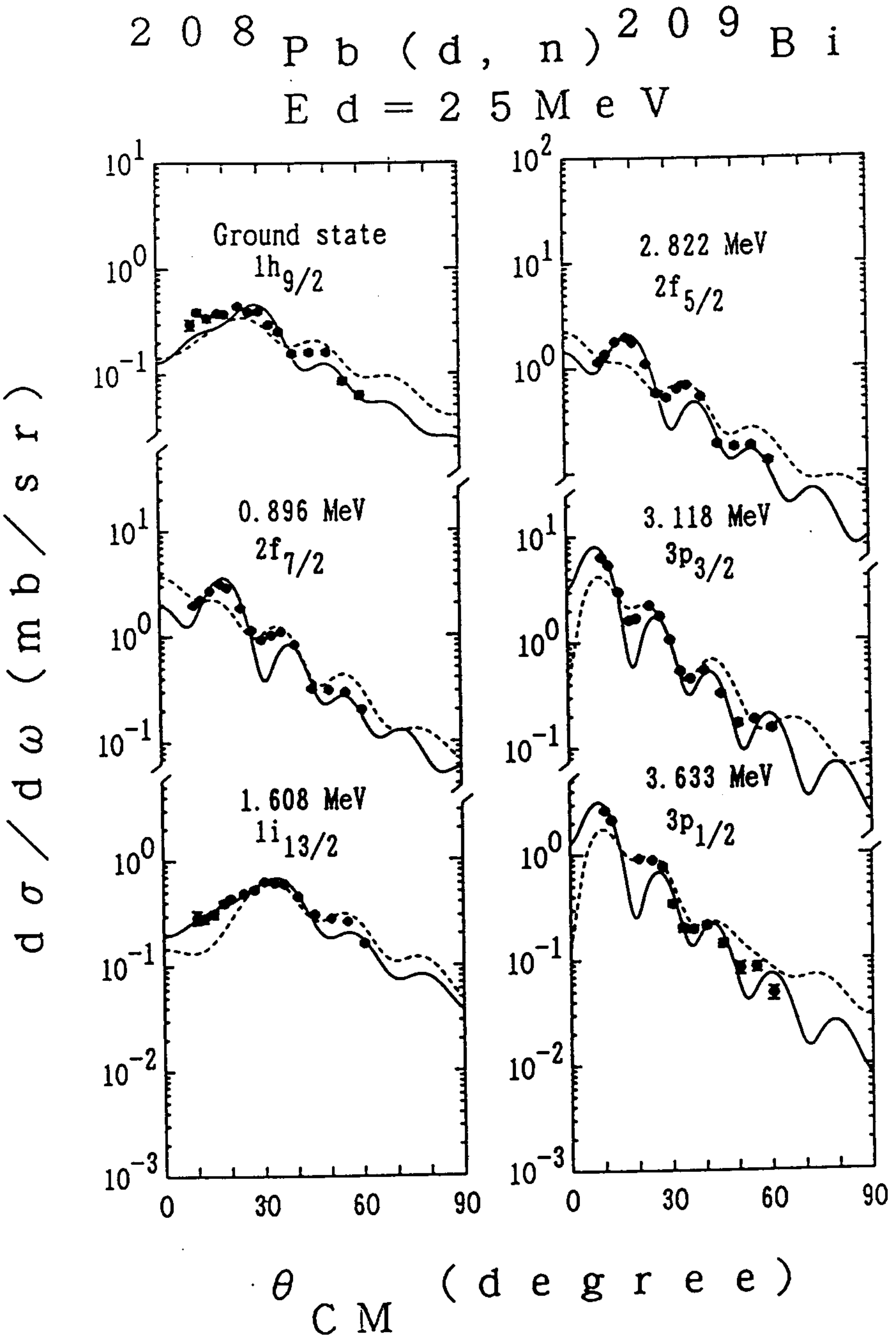

Fig. 2 Angular distributions of the differential cross sections for the proton single-particle states in ^{209}Bi. The solid lines represent the results of the ADBA calculations and the dashed lines those of the DWBA calculations.