Assessment of the $^{12}C(d,p)^{13}C$ cross sections

A. Gurbich

Institute of Physics and Power Engineering

Obninsk, Russia

No significant problems for the $^{12}C(d,p)^{13}C$ cross section was found. Recent results obtained by Kokkoris et al. are in a reasonable agreement with the data acquired many years ago. Thanks to Kokkoris' detailed measurements the cross section for ^{12}C+d is known both for transitions to ground and excited states in a sufficiently wide interval of angles. The quality of the available experimental data is illustrated by Fig. 1, where different data sets are compared for 165°. Some uncertainty is seen in the peak locations and in the magnitude of the broad peak near 1200 keV. A substantial discrepancy is observed only in the energy region above 1900 keV indicated by a circle. It worth noting that for the 1200 keV peak the data obtained by Kashy and Balin are in excellent agreement (the absolute value reported by Balin et al. is 102±6.7 mb/sr) whereas Kokkoris' points lie a little bit lower. The data by Phillips reproduced in the LA-2014 report are erroneously normalized (see Fig. 2) by factor ~2.

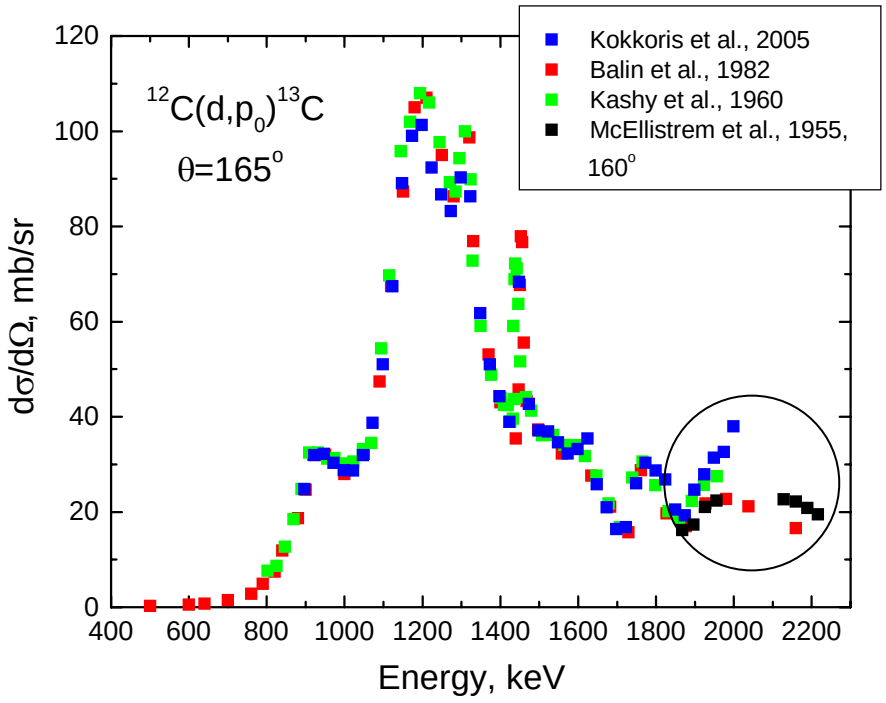


Fig. 1. Comparison of different experimental data for 165°.

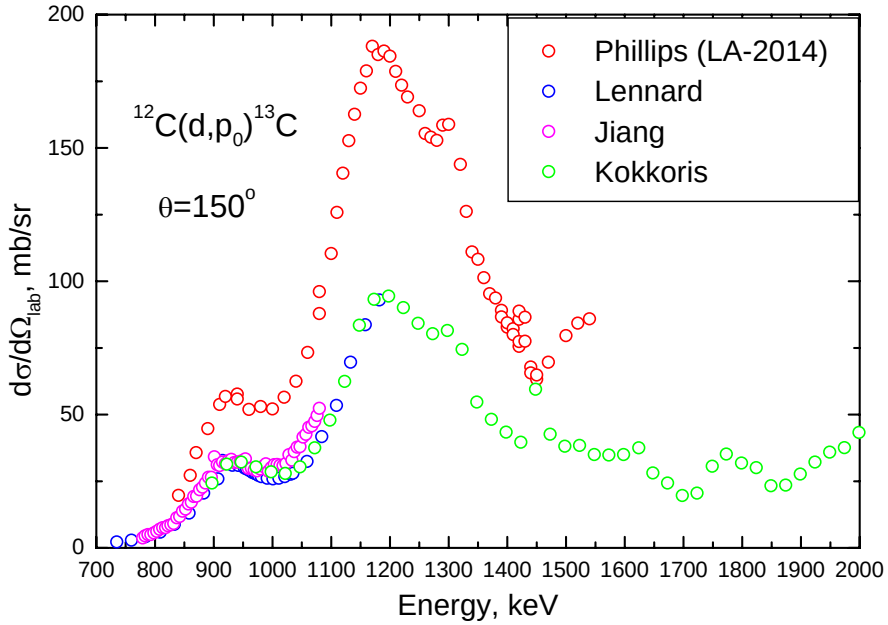


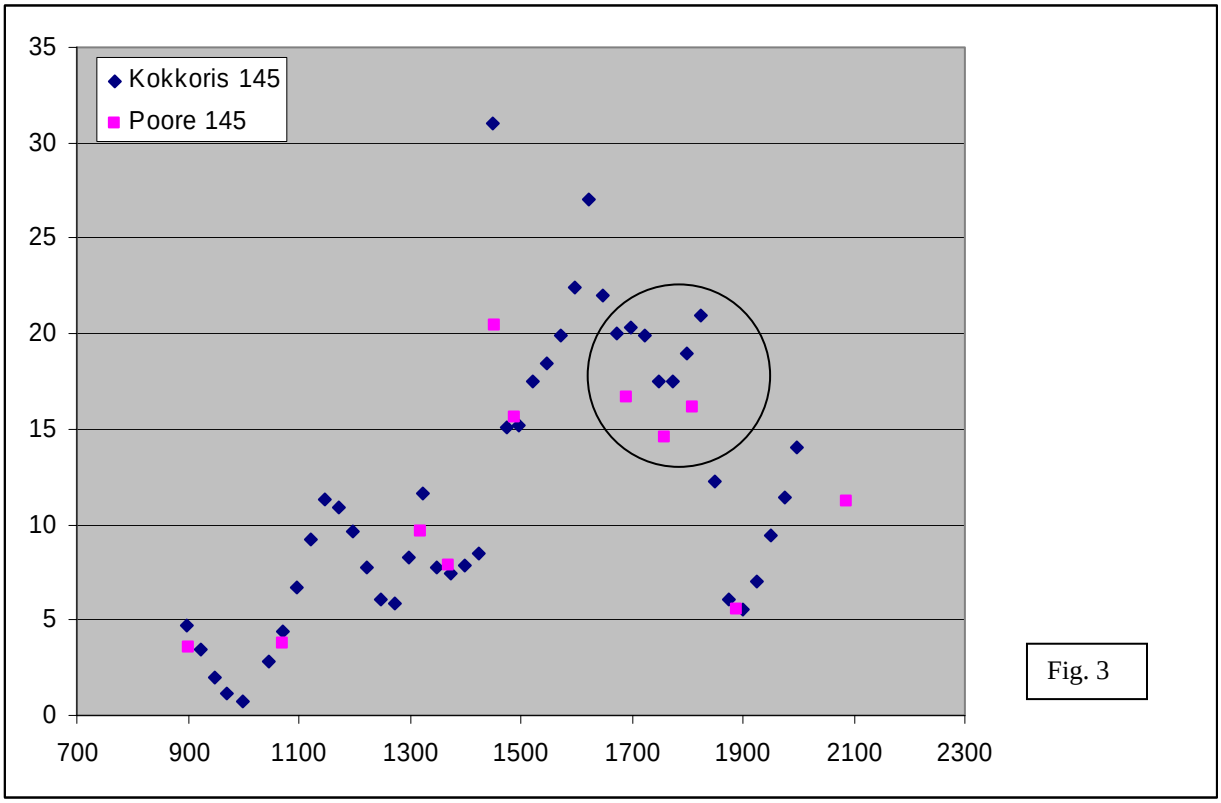
Fig. 2. Comparison of different experimental data for 150°.

Special efforts were applied for absolute calibration of the $^{12}C(d,p_0)^{13}C$ cross section at the 900-1000 keV plateau. The obtained results along with Jiang's tabulated data are compared in Table 1. Again, the agreement between values reported by different authors is good.

Table 1. Absolute values for the $^{12}C(d,p_0)^{13}C$ cross section at 150°

Energy, keV	Cross section, mb/sr	Target	Reference
968	29.5±1.2	Polystyrene	Quillet
970	27.9±1.4	Frozen gas	Lennard91
970	25.5±0.8	Frozen CO_2	Davies80
969	29.25±1.2	C/Glass	Jiang

Scarce information is available for the cross sections of the reaction leading to excite states of the residual nucleus. In order to make a comparison excitation functions for the $^{12}C(d,p_1)^{13}C$ reaction were derived from the angular distributions presented in [1] (see Figs. 2-4). As is seen from the figures the discrepancy is observed in the 1700-1800 keV energy region for 145° and 150° and good agreement is for 165°. It should be noted that the cross section behavior in the vicinity of the sharp resonance at the energy slightly less than 1500 keV was measured in insufficient detail.


Kokkoris 145
Poore 145
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2300

Fig. 3

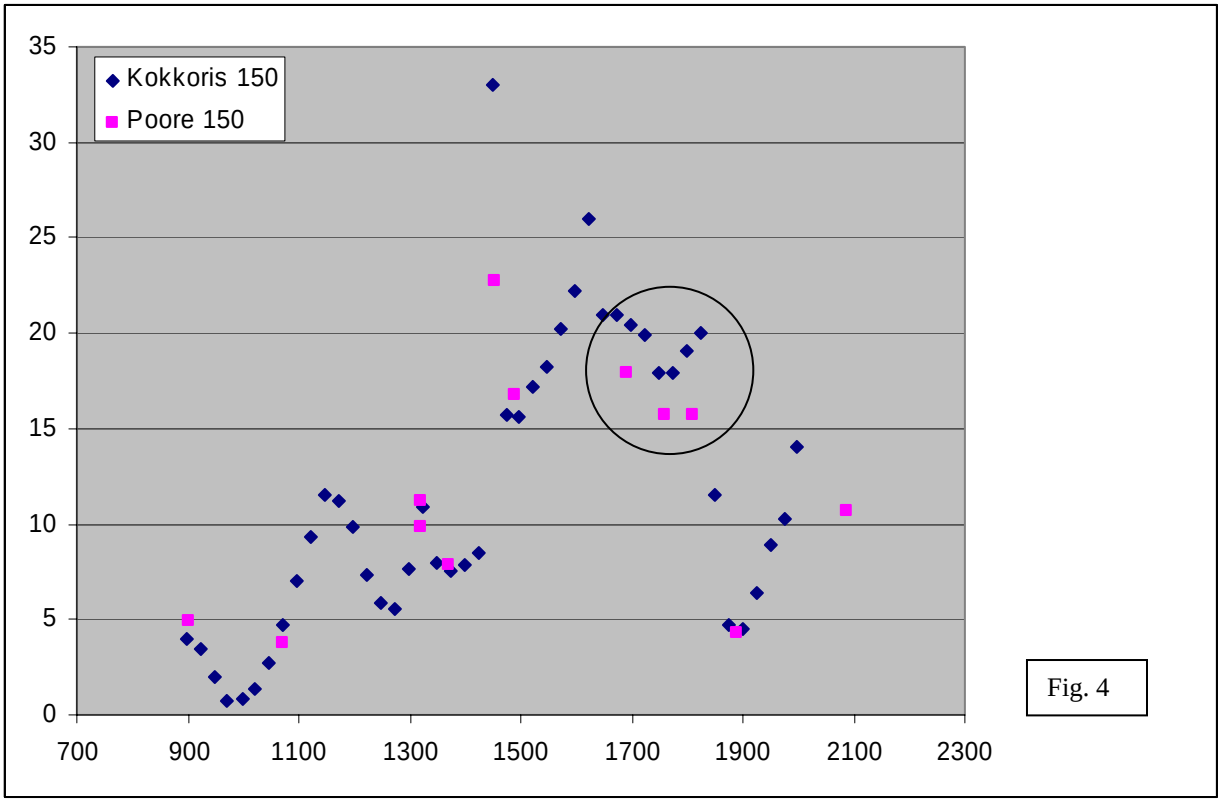
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Fig. 4

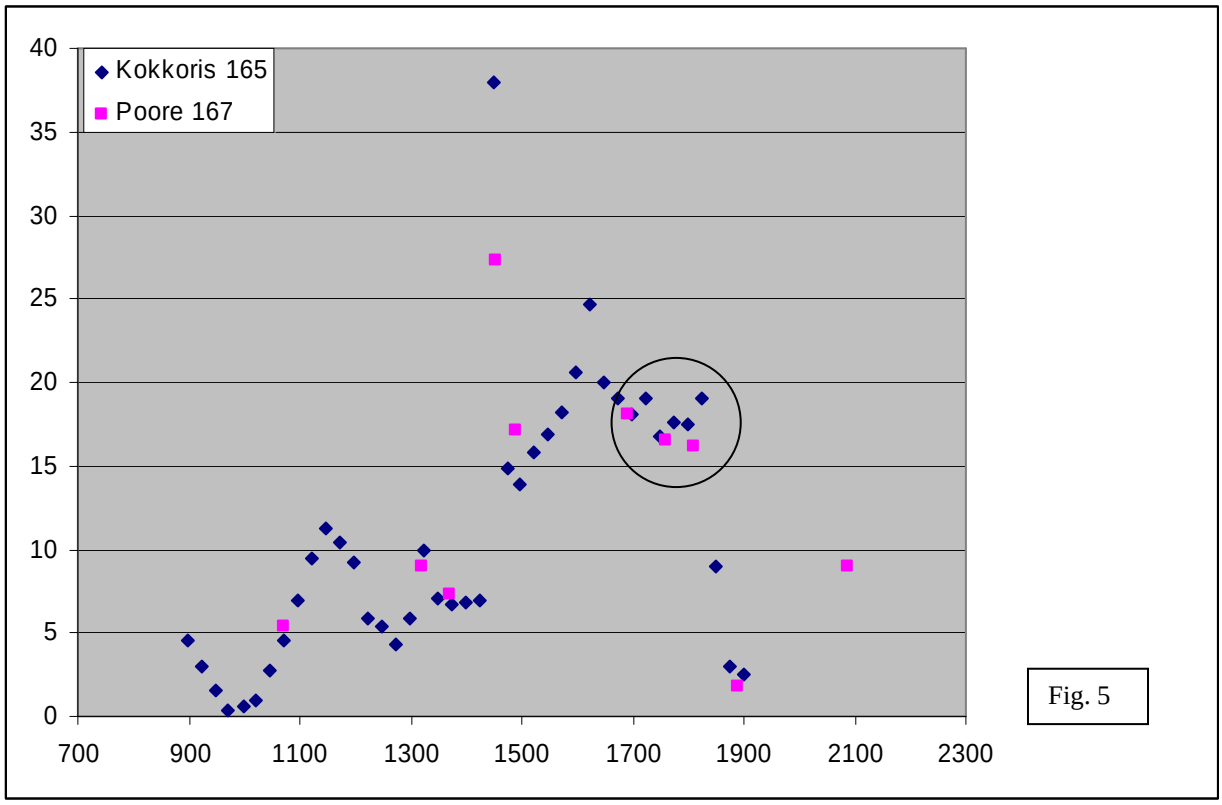

Fig. 5

Cumulative information on the studied cross sections is presented in Table 2. The comparison of different presentations of Kashy's data for 165° (EXFOR vs IBANDL) shown in Fig. 5 demonstrates good agreement. Nevertheless, a decision should be made which of the data sets should be accepted in order the data bases have identical data for the same paper.

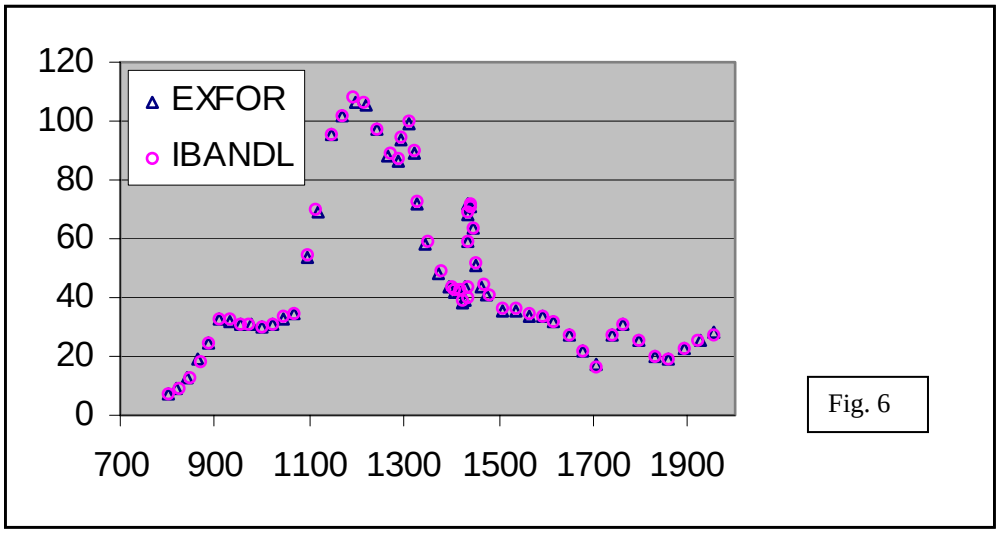

Fig. 6

Table 2. Cumulative information on the deuteron induced reactions for ^{12}C.

Energy range (MeV)	Reaction	Target	The energy (MeV) of angular distribution measurement	The angle of excitation function measurement	Error	Data presentation	Notes	Ref.
0.9-2.1	(d,p_1)	Thin self-supporting ^{12}C targets made from a suspension of graphite in alcohol	0.9, 1.07, 1.32, 1.37, 1.452, 1.49, 1.69, 1.76, 1.809, 1.89, 2.088			Graph	EXFOR F0334002 Excitation function for 145°, 150°, 167° derived from angular distributions are shown in Figs. 2-4	Poore
0.968	(d,p_0)	Polystyrene film		150	4%	Value		Quillet
0.970	(d,p_0)	Frozen CO_2		150	2%	Value	Added to IBANDL	Davies
0.74-1.18	(d,p_0)	Frozen gas		150	5%	Table	Added to IBANDL	Lennard
0.8-1.1	(d,p_0)	C/Glass		150	4%	Table, Graph	Added to IBANDL	Jiang
0.5-3.0	(d,p_0)	Carbon foil		135	12%	Graph	Jarjis' data are presented in IBANDL	Debras
0.75-1.98	(d,d), (d,p_0), (d,p_1)	Carbon foil	0.92, 1.19, 1.31, 1.61, 1.76	47.6, 80.5, 158.4, 165.0	8%	Graph	Cross section for 158.4° was added to IBANDL (EXFOR 1007003). Data for (d,p_1) are presented only for 80.5°.	Kashy
0.78-1.55	(d,p_0)	Cracking benzene vapor on silver foils	0.75, 0.91, 0.99, 1.09, 1.16, 1.286, 1.30, 1.32	0, 90, 150		Graph	Data from LA-2014 report are presented in IBANDL	Phillips

Table 2, continued

0.5-2.16	(d,p_0)	Carbon foil		165	7%	Graph	Data supplied by the authors are presented in IBANDL	Balin
1.87-3.51	(d,p_0)	Gas		160, 168.7…	5%	Graph	Cross section for 160° was added to IBANDL (EXFOR C0993006 converted to lab.)	McEllistrem
0.8-1.5	(d,p_0)	Thick target		165		Graph		Barit
0.9 – 2.0	(d,p_{0-3})	Carbon foils		145, 150, 155, 160, 165, 170		Graph, Table	Added to IBANDL	Kokkoris

References

1. R.V. Poore, P.E. Shearin, D.R. Tilley, R.M. Willamson, Nucl. Phys. A 92 (1967) 97.
2. V. Quillet, F. Abel, M. Schott, Nucl. Instr. and Meth. B 83 (1993) 47.
3. J.A. Davies, P.R. Norton, Nucl. Instr. and Meth. 168 (1980) 611.
4. W. Jiang, V. Shutthanandan, S. Thevuthasan, D.E. McCready, W.J. Weber, Nucl. Instr. and Meth. B 222 (2004) 538; B 227 (2005) 450 (Erratum).
5. W.N. Lennard, G.R. Massoumi, P.F.A. Alkemade, I.V. Mitchell, S.Y. Tong, Nucl. Instr. and Meth. B61 (1991) 1.
6. G. Debras and G. Deconnink, J. Rad. Chem. 38 (1977)193 (reproduced by Jarjis).
7. V.G.Balin, A.F.Gurbich, V.S.Shorin, Preprint FEI-1341, Obninsk (1982).
8. E. Kashy, R.R. Perry, J.R. Risser, Phys.Rev. 117 (1960) 1289.
9. G.C. Phillips, Phys. Rev. 80 (1950) 164 (reproduced by N.Jarmie and J.D.Seagrove in Los Alamos Report LA-2014 (1957)).
10. M.T. McEllistrem, K.W. Jones, Ren Chiba, R.A.Douglas, D.F. Herring, E.A.Silverstein, Phys.Rev. 104 (1956) 1008.
11. I.Ya. Barit, D.L. Kogan, L.E. Kuzmin et al. Short Communications in Physics PHIAS, No.7 (1986) 29 (in Russian).
12. M. Kokkoris, P. Misaelides, A. Kontos, A. Lagoyannis, S. Harissopulos, R. Vlastou, C.T. Papadopoulos, to be published (two papers).
13. D.G. Gerke et al. Nucl. Phys. 75 (1966) 609. (angular distributions (d,p), (p,p) ^{13}C(p,p)).