**Compilation of Experimental Nuclear Reaction Data Measured in Central Asia**

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The Institutes of Nuclear Physics (INP) in Almaty and Tashkent been active in measurements of nuclear reaction data (**Fig. 1**). The charged-particle induced reaction data measured by the cyclotrons of the INP Almaty and Tashkent as well as the neutron-induced reaction data measured at the research reactor of the INP Almaty have been the major contributors to the current EXFOR library from these countries. The cyclotron of the INP Almaty is active, and the cyclotron of the INP Tashkent currently used for isotope production is planned to be back to nuclear reaction experiments in the near future. All experimental works from these countries and compiled in EXFOR are listed in **Appendices 1** and **2**, and have been utilized by EXFOR users. For example, proton and alpha induced reaction activation cross sections measured by V.N. Levkovskij [1] are known to show good agreements with later experimental data sets (if the original data are renormalized due to change in the monitor cross section), and it is one of the most frequently cited experimental nuclear data from Kazakhstan.

Recently the IAEA Nuclear Data Section has performed checking of EXFOR completeness for radioisotope production cross sections by using the reference lists in Landolt-Börnstein compilation [2], and found some experimental works from Kazakhstan and Uzbekistan are missing in EXFOR. All of them are published in domestic journals (Izvestiya Akademii Nauk Kazakhskii SSR Seriya Fizika i Matematiches, Izvestiya Akademii Nauk Uzbekiskoi SSR Seriya Fizika i Matematiches). Especially there is no EXFOR entry compiled from the latter journal, and the situation may indicate that systematic scanning of articles for EXFOR compilation have not been performed for these journals though it is not easy to find these journals in libraries outside these countries. Furthermore, it was mentioned during this workshop (The 4th Asian Nuclear Reaction Database Development Workshop, Almaty, Kazakhstan, 23-25 October 2013) that about half of experimental works from INP Almaty are still missing in EXFOR [3]. Appendices 1 and 2 show that digitized data are sometimes compiled instead of the original data provided by authors from Kazakhstan and Uzbekistan even for the experimental works published recently.

**Fig. 1.** Cumulative numbers of EXFOR entries for charged-particle (cp) and neutron (n) induced reactions measured in Kazakhstan (Kaz) and Uzbekistan (Uz).

The Institute of Experimental and Theoretical Physics, Al-Farabi Kazakh National University organized a three-days workshop from 28 to 30 October 2013 for young researchers from Kazakhstan and Uzbekistan in order to improve the above mentioned situation. Following some lectures on access to EXFOR and preparation of EXFOR entries, the participants searched some EXFOR entries by themselves, and also learned EXFOR compilation by using an editor (HENDEL) [4] and digitizer (GSYS) [5]. The participants finalized one new EXFOR entry for the 19F(α,n)22Na excitation function measured at INP Almaty [6], and the entry was accepted by the IAEA Nuclear Data Section for transmission to other data centres. Note that there have been only two EXFOR entries reporting this (α,n) excitation function. Both of them were measured by detection of neutrons while the Kazakh experiment reports data by activation.

After the workshop, the participants finalized three more EXFOR entries for radioisotope production cross sections measured at INP Almaty [7] and Tashkent [8-9]. All Kazakh and Uzbek data identified as missing in EXFOR by checking against Landolt-Börnstein compilation will be included in EXFOR in the near future. After finalization of these entries, a new article published by researchers of Kazakh National University [10] was also compiled by us with the numerical data received from the authors. It must be also mentioned that one of us (M.T.) compiled another new article reporting data from INP Almaty [11] under supervision of JCPRG prior to the workshop in Almaty. The IAEA Nuclear Data Section plans to continue this training to investigate if the Kazakhstan-Uzbekistan group is capable to continue EXFOR compilation activity for data from these countries on a stable basis.

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**References**

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8. A. Vasidov, G. Vakilova, S. Mukhammedov, Izv. A.N. UzSSR Ser Fis.-Mat. 1981 No.3 (1981) 93. EXFOR D0726.
9. S. Mukhammedov, E. Pardayev, Izv. A.N. UzSSR Ser Fis.-Mat. 1985 No.5 (1985) 81. EXFOR D0727.
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**Appendix 1**

Nuclear reaction data measured in Kazakhstan and compiled in EXFOR before this workshop (Italicized EXFOR entry numbers indicate inclusion of data digitized from figures.)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **EXFOR**  | **1st Author**  | **Year**  | **Lab.**  | **Quantity measured**  |
| 40016 | V.N. Levkovskiy  | 1963 | INP (linac?)  | (n,p) and (n,α) cross section at 14 MeV  |
| 40009 | G.P. Vinitskaya  | 1967 | INP (linac)  | (n,p) and (n,α) cross section at 14 MeV  |
| *F1184* | V.Yu. Gonchar  | 1967 | INP (cyclotron)  | α scattering angular distribution  |
| 40223 | V.N. Levkovskiy  | 1968 | INP (CCW)  | (n,p) and (n,α) cross section at 14 MeV  |
| *F0668* | V.Yu. Gonchar  | 1968 | INP (cyclotron)  | 24Mg+α scattering angular distribution  |
| *F1168* | V.Yu. Gonchar  | 1968 | INP (cyclotron)  | Ni, Pb+α scattering angular distribution  |
| 40226 | V.N. Levkovskiy  | 1969 | INP (VdG?)  | (n,p) and (n,α) cross section at 14 MeV  |
| A0647 | O.A. Zhukova  | 1970 | INP (cyclotron)  | (α,n) cross section excitation function  |
| 40029 | V.N. Levkovskiy  | 1971 | INP (VdG?)  | (n,p) and (n,α) cross section at 14 MeV  |
| 40125 | K.E. Volodin  | 1972 | INP (reactor)  | 249Cf(n,f) fragment kinetic energy  |
| A0644 | O.A. Zhukova  | 1972 | INP (cyclotron)  | Co(α,x) cross section excitation function  |
| A0695 | B.G. Kiselev  | 1974 | INP (cyclotron)  | 93Nb+p cross section excitation function  |
| O0627 | V.N. Okolovich  | 1974 | INP (cyclotron)  | (p,f) cross section excitation function  |
| *F0865* | K.B. Baktybaev  | 1975 | INP (cyclotron)  | Zn+α elastic scattering ang. distribution  |
| *F0868* | N.T. Burtebaev  | 1975 | INP (cyclotron)  | 7Li(α,p)10Be angular distribution  |
| *F1145* | A.D. Duisebaev  | 1975 | INP (cyclotron)  | 27Al,59Co(α,t+x) double diff. cross section  |
| *F0672* | N.N. Pavlova  | 1976 | INP (cyclotron)  | α elastic scattering angular distribution  |
| *F1142* | A.D. Duisebaev  | 1977 | INP (cyclotron)  | Al, Co, Sn(3He,α) energy spectrum  |
| *F1160* | N.N. Pavlova  | 1977 | INP (cyclotron)  | Fe+α elastic scattering ang. distribution  |
| *F0670* | N.N. Pavlova  | 1979 | INP (cyclotron)  | α elastic scattering angular distribution  |
| 41321 | O.I. Artem’ev  | 1980 | INP (VdG)  | (n,p) and (n,α) cross section at 14 MeV  |
| *F0940* | N.T. Burtebaev  | 1982 | INP (cyclotron)  | (3He,cp+x) double diff. cross section  |
| 40698 | E.Z. Akhmetov  | 1983 | INP (reactor)  | Cold neutron total cross sections  |
| *F0570* | N.T. Burtebaev  | 1984 | INP (cyclotorn)  | (α,p) double differential cross section  |
| 40904 | G.A. Dostemesova  | 1985 | INP (reactor)  | 70Ge(n,n’+γ)70Ge gamma spectrum  |
| 40905 | Yu.G. Kosyak  | 1985 | INP (reactor)  | 74Ge(n,n’+γ)74Ge gamma spectrum  |
| 40939 | G.A. Dostemesova  | 1986 | INP (reactor)  | 78Se(n,n’+γ)78Ge gamma spectrum  |
| 40941 | L.V. Chekushina  | 1986 | INP (reactor)  | 80Se(n,n’+γ)80Se gamma spectrum  |
| *F0777* | V.N. Gragin  | 1986 | INP (cyclotron)  | α scattering angular distribution  |
| *O1277* | N.I. Zaika  | 1988 | INP (cyclotron)  | (3He,f) angular distribution  |
| 41043 | Yu.G. Kosyak  | 1989 | INP (reactor)  | Ni(n,n’+γ)Ni gamma ang. Distribution  |
| 41146 | Ga. Dostemesova  | 1989 | INP (reactor)  | Se(n,n’+γ)Se gamma ang. dist.  |
| *F0497* | S.Ya. Aisina  | 1989 | INP (cyclotron)  | α scattering angular distribution  |
| 41106 | Yu.G. Kosyak  | 1990 | INP (reactor)  | 73Ge(n,n’+γ)73Ge gamma spectrum  |
| A0510 | V.N. Levkovskiy  | 1991 | INP (cyclotron)  | p-, α- cross section excitation function  |
| 41136 | Yu.G. Kosyak  | 1992 | INP (reactor)  | 52Cr(n,n’+γ)52Cr gamma spectra  |
| 41140 | Yu.G. Kosyak  | 1993 | INP (reactor)  | 48Ti(n,n’+γ)48Ti gamma spectra  |
| 41176 | Yu.G. Kosyak  | 1994 | INP (reactor)  | 46Ti(n,n’+γ)46Ti gamma spectra  |
| 41408 | Yu.G. Kosyak  | 1998 | INP (reactor)  | 82Se(n,n’+γ)82Se gamma spectra  |
| 41411 | Yu.G. Kosyak  | 1999 | INP (reactor)  | 80Se(n,n’+γ)80Se gamma spectra  |
| 41412 | Yu.G. Kosyak  | 2000 | INP (reactor)  | 65Cu(n,n’+γ)65Cu gamma spectra  |
| *F0775* | N. Burtebaev  | 2000 | INP (cycloron)  | 13C+3He elastic scattering ang. dist.  |
| O1145 | A.M.Blechman  | 2000 | INP (cyclotron)  | 197Au(α,3He+x) doub. diff. cross section  |
| 41413 | Yu.G. Kosyak  | 2001 | INP (reactor)  | 65Cu(n,n’+γ)65Cu gamma spectra  |
| F0560 | K.A. Kuterbekov  | 2001 | INP (cyclotron)  | 120,124Sn+α scattering ang. distribution  |
| F0561 | A.D. Duisebaev  | 2001 | INP (cyclotron)  | 90,94Zr+α scattering ang. distribution  |
| 41486 | Yu.G. Kosyak  | 2002 | INP (reactor)  | 72Ge(n,n’+γ)72Ge gamma spectra  |
| F0758 | N. Burtebaev  | 2002 | INP (cyclotron)  | 10B(α,3He), 11B(d,3He) ang. distribution  |
| F0759 | N. Burtebaev  | 2002 | INP (cyclotron)  | 9Be+α elastic angular distribution  |
| *F0766* | M.K. Baktybaev  | 2003 | INP (cyclotron)  | 28Si+α total reaction cross section  |
| *F0767* | N. Burtebaev  | 2003 | INP (cyclotron)  | 13C(3He,t) angular distribution  |
| O1060 | A. Duisebayev  | 2003 | INP (cyclotron)  | 90Zr(p,p,d+x) double diff. cross section  |
| *A0851* | V.Yu. Ugryumov  | 2004 | INP (cyclotron)  | 28Si+α total reaction cross section  |
| F0763 | N.T. Burtebaev  | 2004 | INP (VdG)  | 14N(p,γ)15O angular distribution  |
| 41451 | Yu.G. Kosyak  | 2005 | INP (reactor)  | 74Ge(n,n’+γ)74Ge gamma spectra  |
| F0772 | N. Burtebaev  | 2005 | INP (cyclotron)  | 11B+α scattering angular distribution  |
| O1307 | A. Duisebayev  | 2005 | INP (cyclotron)  | 56Fe(p,p,α+x) double diff. cross section  |
| *A0819* | N. Burtebaev  | 2008 | INP (cyclotron)  | 12C(p,γ)13N angular distribution  |
| A0867 | N. Burtebaev  | 2010 | INP (cyclotron)  | 6Li+d elastic scat. angular distribution  |
| A0886 | Sh. Hamada  | 2011 | Astana (cyclotron)  | 12C+16O elastic scat. ang. distribution  |
| A0899 | S.V. Artemov  | 2011 | INP (cyclotron)  | 10B(d,t) and (d,3He) ang. distribution  |
| *A0907* | S.B. Dubovichenko  | 2011 | INP (Tandem)  | 6Li+p elastic ang. distribution  |
| F1189 | V.V. Dyachkov  | 2012 | INP (cyclotron)  | Mg, C+d elastic angular distribution  |

**Appendix 2**: Nuclear reaction data measured in Uzbekistan and compiled in EXFOR before this workshop (Italicized EXFOR entry numbers indicate inclusion of data digitized from figures.)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **EXFOR** | **1st Author**  | **Year**  | **Lab.**  | **Quantity measured**  |
| *A1482* | U.R. Arifkhanov | 1974 | INP (cyclotron)  | (p,n) angular distribution  |
| *A1127* | S.A. Azimov | 1975 | INP (cyclotron)  | (d,n) angular distribution  |
| 40541 | S. Arynov | 1977 | INP (reactor)  | (n,γ) gamma spectra  |
| *A1194* | M.P. Gold’berg | 1978 | INP (cyclotron)  | D(p,p)np DDX  |
| *F1140* | S.V. Artemov | 1978 | INP (cyclotron)  | 24Mg+p scattering excitation function  |
| A0075 | L.Ya. Arifov | 1980 | INP (cyclotron)  | 92Mo(p,γ) isomeric ratio  |
| A0085 | A.V. Muminov | 1980 | INP (cyclotron)  | (p,n) thick target isotope yield  |
| A0104 | L.Ya. Arifov | 1981 | INP (cyclotron)  | 92Mo(d,n) isomeric ratio  |
| *F0892* | S.V. Artemov | 1981 | INP (cyclotron)  | 27Al+p scattering excitation function  |
| A0211 | G. Vakilova  | 1983 | INP (cyclotron)  | (p,n) thick target isotope yield  |
| A0212 | S. Mukhammedov | 1984 | INP (cyclotron)  | (p,x) (d,x) thick target isotope yield  |
| *F1181* | R.B. Begzhanov  | 1985 | INP (cyclotorn)  | (p,d) angular distribution  |
| *A0331* | S. Mukhammedov  | 1986 | INP (cyclotron)  | (d,x) thick target isotope yield  |
| *F0403* | F. Kadirov  | 1987 | INP (cyclotron)  | (d,n) angular distribution  |
| *F1171* | G.S. Valiev  | 1987 | INP (cyclotron)  | (p,d) angular distribution  |
| *A1301* | M.A. Kayumov  | 1988 | INP (cyclotron)  | (d,n) and (p,n) angular distribution  |
| F0222 | S.A. Goncharov  | 1988 | INP (cyclotron)  | (d,t) angular distribution  |
| 41047 | A.D. Belyaev  | 1989 | INP (reactor)  | 241Pu(n,f) fission yields FY(A,E)  |
| A0621 | R.B. Begyanov  | 1990 | INP (cyclotron)  | 66Zn(α,n)68Ge excitation function  |
| *F0071* | I.R. Gulamov  | 1990 | INP (cyclotron)  | (d,t) angular distribution  |
| F0821 | S.V. Artemov  | 1996 | INP (cyclotron)  | (3He,d) angular distribution  |
| *M0749* | S.R. Palvanov  | 1998 | NUU (betatron)  | 89Y(γ,2n)87Y isomeric ratio  |
| M0766 | S.R. Palvanov  | 1999 | NUU (betatron)  | (γ,n) (γ,p) isomeric ratio  |
| *F0698* | S.V. Artemov  | 2000 | INP (cyclotron)  | (3He,d) angular distribution  |
| *F0780* | S.V. Artemov  | 2001 | INP (cyclotron)  | 12,13C+α scat. angular distribution  |
| *41465* | V.P. Pikul  | 2005 | INP (reactor)  | 235U(n,f) fission yields FY(A,E)  |
| 41493 | Yu.N. Koblik  | 2006 | INP (reactor)  | 239Pu(n,f) Fission yields FY(A,E)  |
| *M0743* | S.R. Palvanov  | 2007 | NUU (betatron)  | 142Nd(γ,n)141Nd isomeric ratio  |
| 41563 | S.R. Palvanov  | 2011 | INP (VdG?) | (n,2n) and (γ,n) isomeric ratio  |
| *M0812* | NUU (betatron)  |
| A0945 | S.V. Artemov  | 2012 | INP (cyclotron)  | 14N(p,γ)15O angular distribution  |