Calculation of Neutron Production in (α, n) Reactions with SOURCES4 and ONYSC

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Introduction

The (α, n) reactions are processes in which a nuclide absorbs an alpha particle and emits a neutron. The atomic number therefore increases by two and the mass number increases by three. An example of such reaction is $^{10}B + \alpha \rightarrow ^{13} N + n$. This can be abbreviated as $^{10}B(\alpha, n)^{13}N$.

A quantitative understanding of all significant neutron sources is paramount in underground experiments, nuclear medicine, energy generation and other areas. (α, n) reactions are an important neutron source and as such require a comprehensive study.

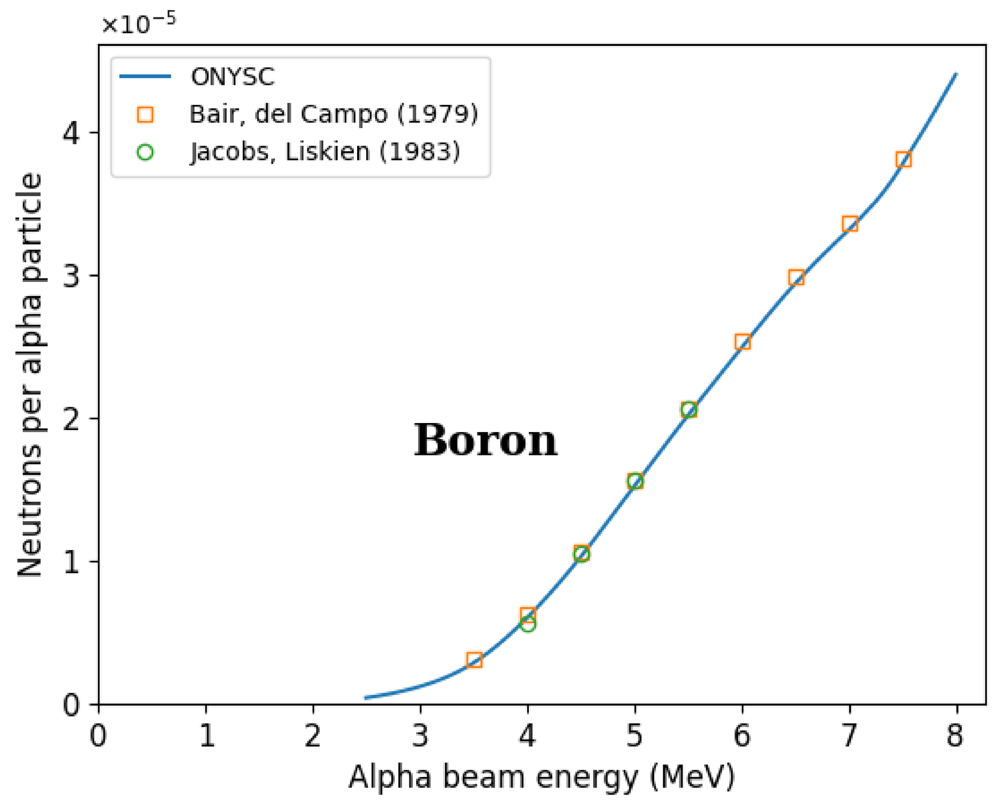

Figure 1: $B(\alpha, n)N$ neutron yield as a function of alpha energy. (Calculated with ONYSC). The experimental data is from [1] and [2].

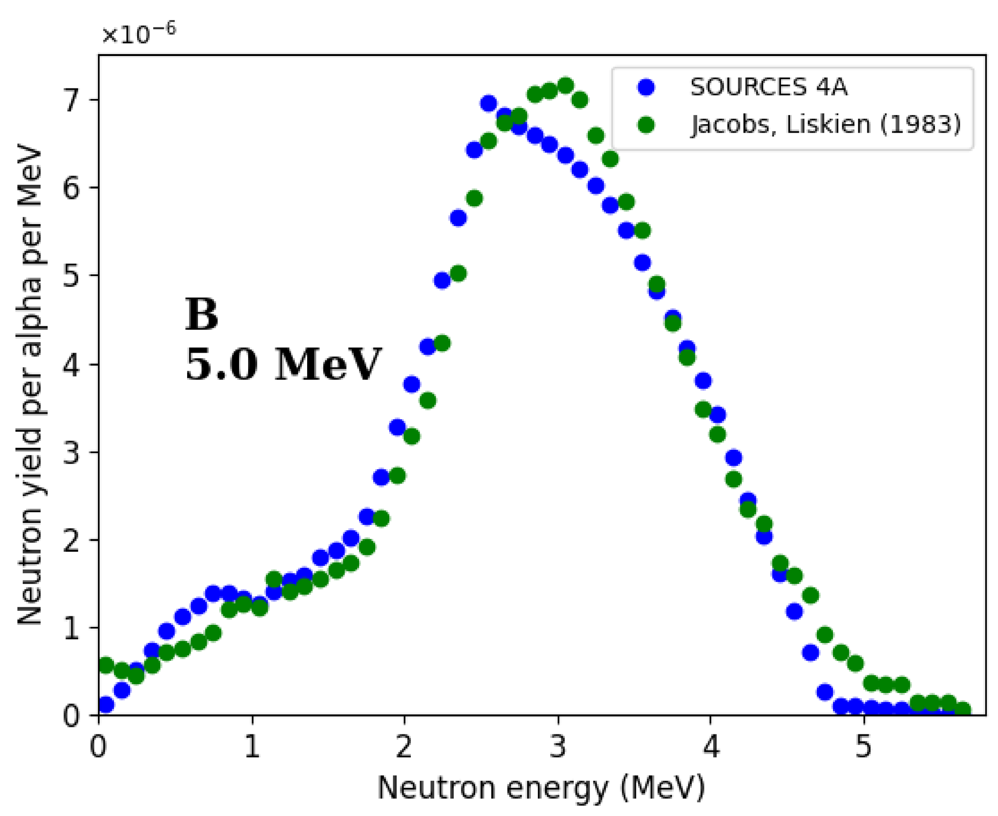

Figure 2: $B(\alpha, n)N$ neutron spectrum for 5.0 MeV alphas. (Calculated with SOURCES4). The experimental data is from [2].

Methodology

Two codes were used to calculate neutron production in these reactions for energies not exceeding around 10 MeV. Boron (Figure 1 and Figure 2) and fluorine (Figure 3, 4 and 5) were selected as examples. ONYSC (Open Neutron Yield and Spectra Calculator) was used to evaluate neutron yields as a function of the alpha energy. SOURCES4 [3] was used to calculate the spectra using updated libraries [5].

In both codes, stopping cross-sections are used to determine the energy losses as the alpha particle travels through matter. Together with the (α, n) cross-section database, total yields are integrated. The branching ratios database is used to generate the spectra. SOURCES4 can also use radioactive isotopes as alpha sources.

Conclusions

The agreement with the measurements varies greatly depending on the target and energy. The scarcity of empirical data results in the difficulty of reliably estimating the accuracy of the calculations. The yields match quite well, usually within a few per cent. Spectra can vary by as much as 20% but there is only one available study [2] which itself has uncertainties around 5%-10%.

The ONYSC code (written in C++) was based on SOURCES4 (Fortran) and the former is meant to eventually replace the latter, with improved functionality and free license. The work is ongoing and hopefully will be finished within the next few months.

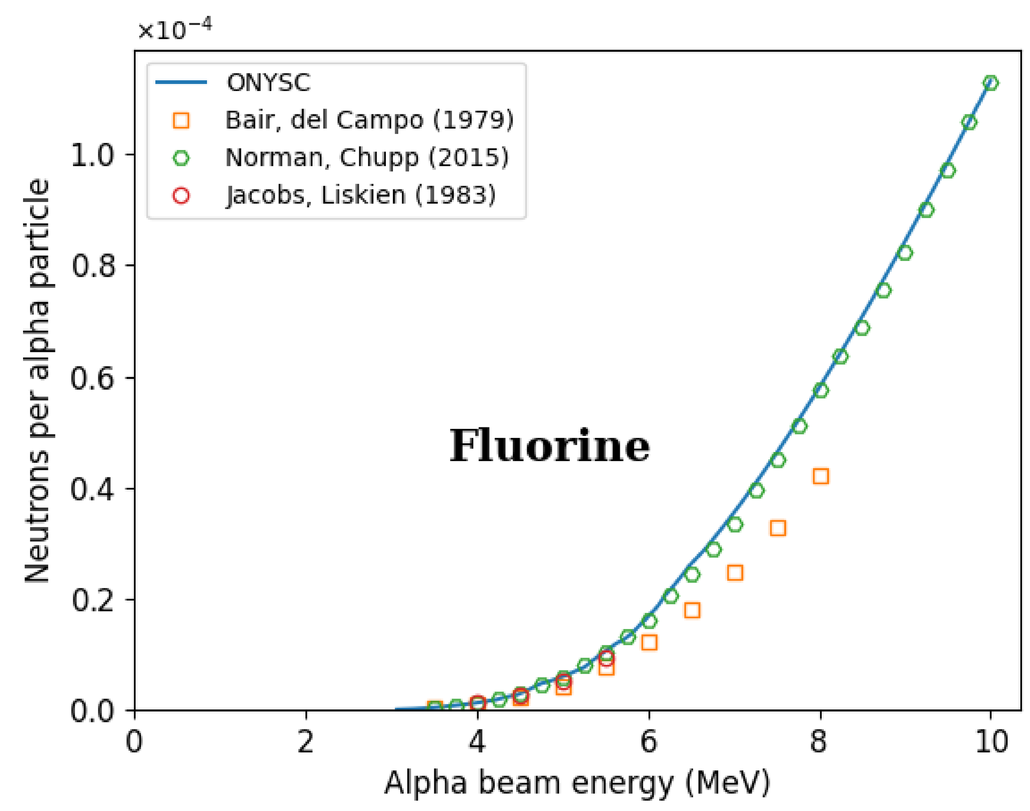

Figure 3: $F(\alpha, n)Na$ neutron yield as a function of alpha energy. (Calculated with ONYSC). The y-axis is linear. The experimental data is from [1] and [4] [2]

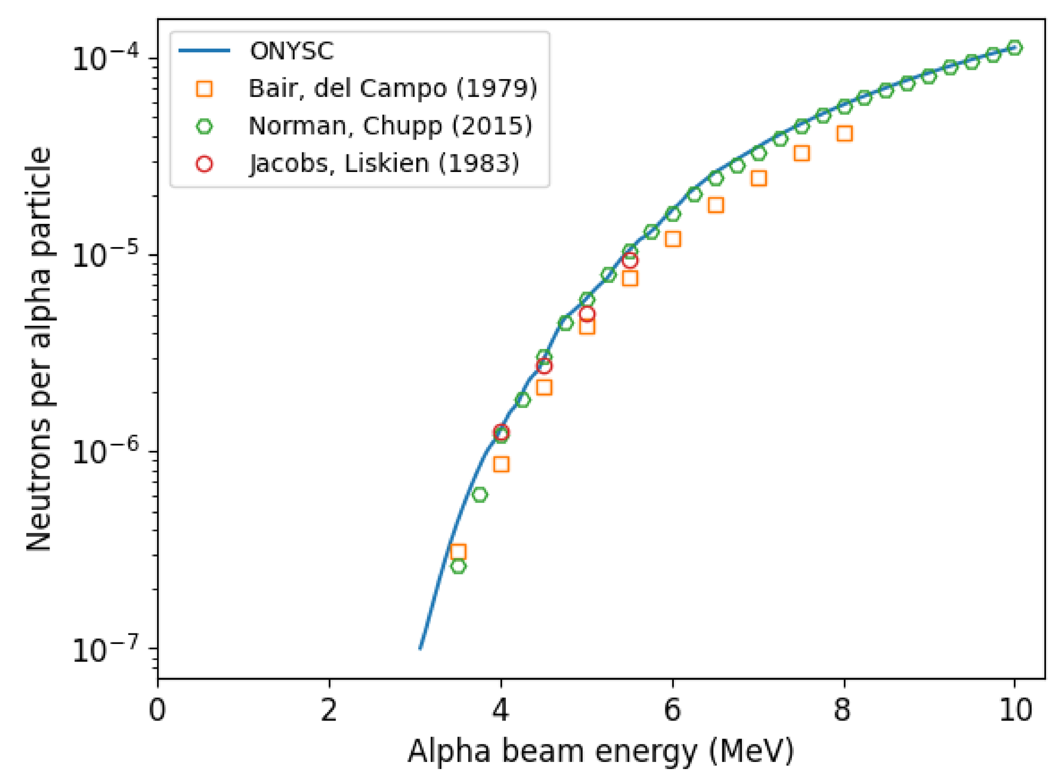

Figure 4: $F(\alpha, n)Na$ neutron yield as a function of alpha energy. (Calculated with ONYSC). The y-axis is logarithmic. The experimental data is from [1], [4] and [2].

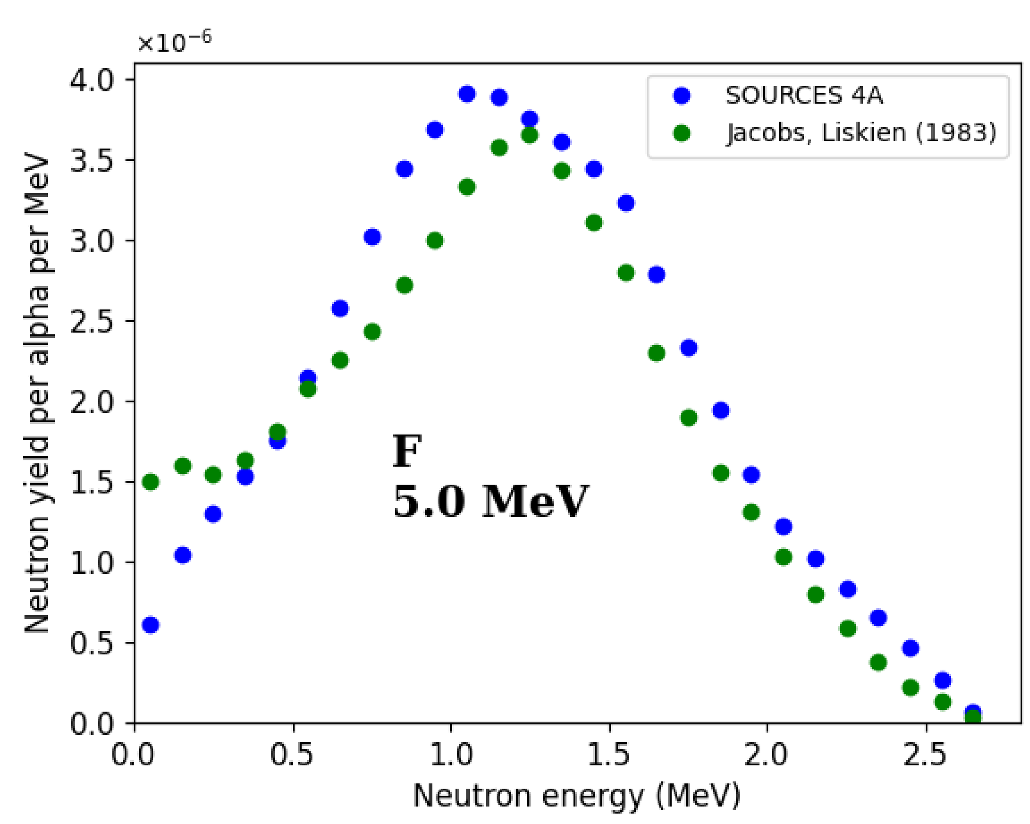

Figure 5: $F(\alpha, n)Na$ neutron spectrum for 5.0 MeV alphas. (Calculated with SOURCES4). The experimental data is from [2].

References

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