Low energy nuclear reaction studies at Atomki for the astrophysical $\gamma$-process

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My first encounter with γ-process (20 years ago)

Sr (nasty)

Sm (nasty, too)

missing student’s name
1997

- α-induced reactions
- p-induced reactions
2000

- α-induced reactions
- p-induced reactions
2001

- α-induced reactions
- p-induced reactions
2002

- α-induced reactions
- p-induced reactions
2004

- α-induced reactions
- p-induced reactions
2008

- **α-induced reactions**
- **p-induced reactions**
2011

α-induced reactions

p-induced reactions
Experiments in Debrecen

- Alpha-induced reactions: 5-15 MeV
  ⇒ Cyclotron

- Proton-induced reactions: 1-4 MeV
  ⇒ Tandetron, (Van de Graaff)

ERC Starting Grant
„Nuclear reaction studies relevant to the astrophysical p-process nucleosynthesis“
The activation method for cross section measurements in nuclear astrophysics

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Abstract. The primary aim of experimental nuclear astrophysics is to determine the rates of nuclear reactions taking place in stars in various astrophysical conditions. These reactions are an important ingredient for understanding the elemental abundance distribution in our solar system and the galaxy. The reaction rates are determined from the cross sections which need to be measured at energies as close to the astrophysically relevant one as possible. In many cases the final nucleus of an astrophysically important reaction is radioactive which allows the cross section to be determined based on the off-line measurement of the number of produced isotopes. In general, this technique is referred to as the activation method, which often has substantial advantages over the in-beam particle- or γ-detection measurements. In this paper the activation method is reviewed from the viewpoint of nuclear astrophysics. Important aspects of the activation method are exemplified through several reaction studies for charged particle, neutron and γ-induced reactions. Various techniques for the measurement of the produced activity are detailed. As a special case of activation, the technique of Accelerator Mass Spectrometry in cross section measurements is also reviewed.
Technical and methodological developments

X-ray detection based activation

Thin window gas cell for activation: $^{124}\text{Xe}(\alpha,\gamma)^{128}\text{Ba}$ $^{3}\text{He}(\alpha,\gamma)^{7}\text{Be}$

Thick target yield measurements

$^{32}\text{Mo}(p,\gamma)^{32}\text{Tc}$

$^{124}\text{Xe}(\alpha,\gamma)^{128}\text{Ba}$

$^{3}\text{He}(\alpha,\gamma)^{7}\text{Be}$

$^{64}\text{Zn}(p,\alpha)^{61}\text{Cu}$

$\alpha$-OMP studied in a $(p,\alpha)$ reaction
A typical result

$^{121}\text{Sb}(\alpha,\gamma)^{125}\text{I}$

Nuclear input to be improved: alpha-nucleus optical potential

\[ \text{McF potential 1966} \]

\[ ^{191}\text{Ir}(\alpha,n)^{194}\text{Au} \]

\[ ^{193}\text{Ir}(\alpha,n)^{196}\text{Au} \]

New optical potential constructed

- Based on scattering data
- Surface WS imaginary + double folding real part
- Present version: ATOMKI V1
- to be continued
Elastic alpha scattering experiments and the alpha-nucleus optical potential at low energies

P. Mohr\textsuperscript{a,b}, G.G. Kiss\textsuperscript{a}, Zs. Fülöp\textsuperscript{a}, D. Galaviz\textsuperscript{c}, Gy. Gyürky\textsuperscript{a}, E. Somorjai\textsuperscript{a}
Good performance of the new potential
Never use independent methods...!*

\[ ^{124}\text{Xe}(p,\gamma)^{125}\text{Cs} \]

Atomki, gas cell, activation

GSI, storage ring
Something completely different...

See the talk of István Rajta
$^{17}\text{O}(p,\gamma)^{18}\text{F}$: the first completed scientific project on the Tandetron

Solar composition problem: contradiction between

- Helioseismology (high precision)
- Solar model, supported by neutrino detection (high precision)

More precise reaction cross sections needed!
$^{14}\text{N}(p,\gamma)^{15}\text{O}$ measurement with activation
Thank you for your attention!

Atomki nuclear astrophysics group:
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