



Development of a Reference Database for Particle-Induced Gamma-ray Emission spectroscopy



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ABSTRACT

Particle-Induced Gamma-ray Emission (PIGE) is a powerful analytical technique that exploits the interactions of rapid charged particles with nuclei located near a sample surface to determine the composition and structure of the surface regions of solids by measurement of characteristic prompt γ rays. The potential for depth profiling of this technique has long been recognized, however, the implementation has been limited owing to insufficient knowledge of the physical data and lack of suitable user-friendly computer codes for the applications. Although a considerable body of published data exists in the nuclear physics literature for nuclear reaction cross sections with γ rays in the exit channel, there is no up-to-date, comprehensive compilation specifically dedicated to IBA applications. A number of PIGE cross-section data had already been uploaded to the Ion Beam Analysis Nuclear Data Library (IBANDL) (<http://www-nds.iaea.org/ibandl>) by members of the IBA community by 2011, however a preliminary survey of this body of unevaluated experimental data has revealed numerous discrepancies beyond the uncertainty limits reported by the authors. Using the resources and coordination provided by the IAEA, a concerted effort to improve the situation was made within the Coordinated Research Project on the Development of a Reference Database for PIGE spectroscopy, from 2011 to 2015. The aim of the CRP was to create a data library for Ion Beam Analysis that contains reliable and usable data on charged particle γ -ray emission cross sections that would be made freely available to the user community. As the CRP has reached its completion, we shall present its main achievements, including the results of nuclear cross-section evaluations and the development of a computer code that will become available to the public allowing for the implementation of a standardless PIGE technique.

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1. Introduction

Among the various accelerator-based Ion Beam Analysis techniques used for material characterization, Particle-Induced Gamma-ray Emission spectroscopy (PIGE) is one of the most

powerful ones. PIGE uses the interactions of rapid (several MeV) charged particles with matter to determine the composition and the depth profile of constituting elements near the surface (from 0 to 500 μm) by measuring the energy spectra of prompt γ rays. This technique has been used since the early 1960's in different fields of applications ranging from analysis of fission reactor materials to biomedicine, environment, cultural heritage, and more recently, fusion reactor materials. Its potential for depth profiling

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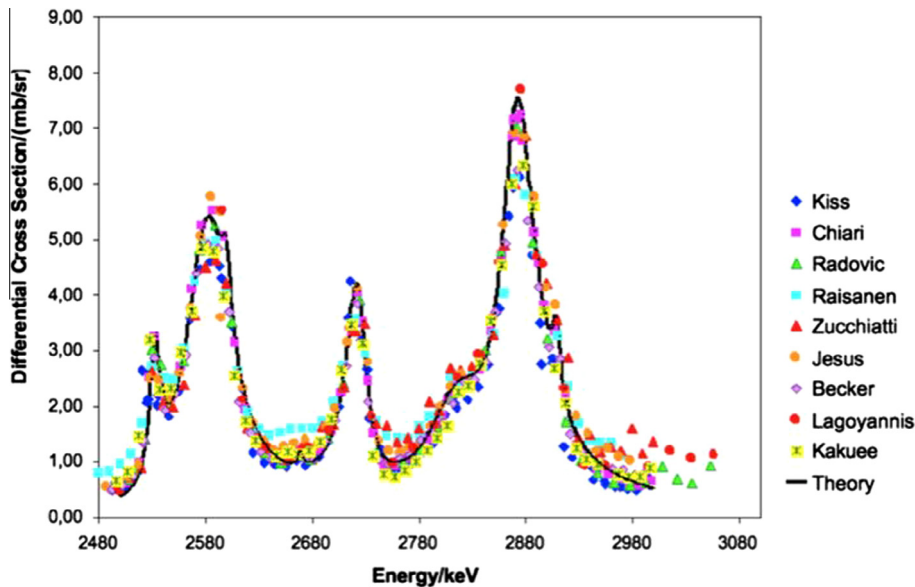


Fig. 1. Differential cross sections of the $^{27}\text{Al}(p,p')^{27}\text{Al}$, $E_\gamma = 844$ keV (isotropic line), at energies ranging from 2.5 to 3 MeV, as measured by the different laboratories shown in the legend. The solid line corresponds to the evaluated cross section [16].

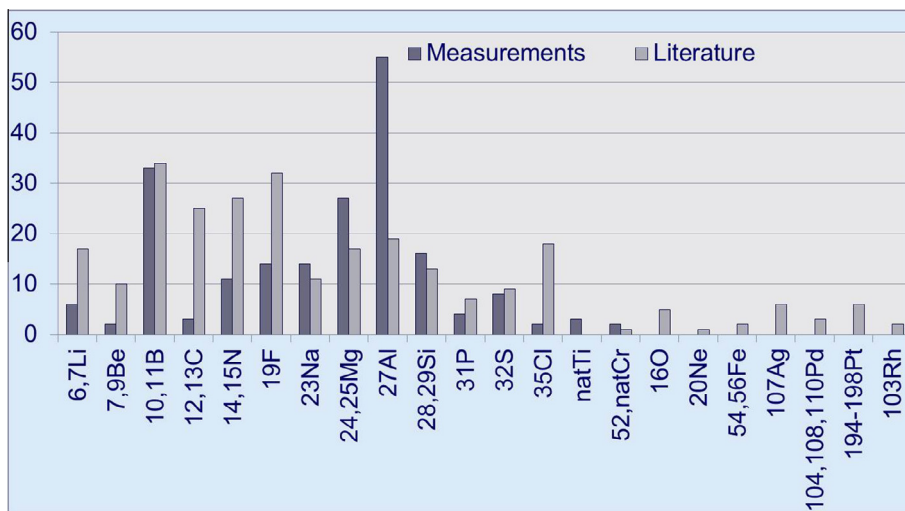


Fig. 2. Number of PIGE datasets available on IBANDL during the course of the PIGE CRP.

with better resolution than the other IBA techniques was recognized early on.

As with all IBA methods including backscattering spectroscopy and nuclear reaction analysis, PIGE relies strongly on differential cross-section data, the lack of which has significantly hindered progress in the implementation of IBA techniques in general. In an attempt to address the IBA data needs, the Nuclear Data Section (NDS) of the International Atomic Energy Agency (IAEA) held a Coordinated Research Project (CRP) on the Development of a Reference Database for Ion Beam Analysis [1] from 2005 to 2010. The CRP produced a comprehensive and reliable database of cross-section data relevant for elastic backscattering (EBS) and nuclear reaction analysis (NRA) techniques primarily, including evaluated cross sections. The experimental cross-section data were made available on the Ion Beam Analysis Nuclear Data Library (IBANDL) [2] while the evaluated cross sections are available through the online calculator SigmaCalc [3]. While this first CRP catered for the data needs of the EBS and NRA techniques, the situation for

PIGE was far from satisfactory. Although there existed a considerable body of published data in the nuclear physics literature, there was no up-to-date and comprehensive compilation dedicated to IBA purposes. Although a number of PIGE cross-section data had already been uploaded to IBANDL by members of the IBA community, a preliminary survey of this data revealed numerous discrepancies showing that there was an urgent need for compilation, assessment and evaluation of the PIGE cross-sections.

In response to the request of the IBA community, NDS organized a consultant's meeting to assess the data needs for PIGE and propose actions for improving the quality and availability of nuclear cross-section data for PIGE. The meeting was held in 2010 [4] and recommended a CRP with the goal to develop a Reference Database for PIGE data that would be freely available to the community of practice. The IAEA CRP ran from 2011 to 2015 with the participation of ten laboratories from ten different countries with active IBA research and applications programmes. Three Research Coordination Meetings (RCM) were held [5–7] during the course

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