Ain Shams University
Faculty of Science
Physics Department

Light Charged Particles Induced Nuclear Reactions on some Medium Weight Nuclei for Practical Applications

Thesis Submitted for the Partial Fulfillment of Master Degree of Science (Nuclear Physics)

By

Bahaa Mohamed Ali Mohamed Mohsena

B.Sc. in Physics 2004
(Physics Department- Faculty of Science- Al Azhar University)

To

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Ain Shams University

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2011

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Approval Sheet

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Degree: Master of Science (Nuclear Physics).

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كـليـــــة العـلـــــوم
قســـم الفيـزيــاء

التفاعلات النووية المستحثة بالجسيمات الخفيفة المشحونة علي بعض الأنوية متوسطة الوزن للتطبيقات العملية

رسالة مقدمة من

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للحصول علي درجة الماجستير في العلوم
(الفيزياء النووية)

الي

قسم الفيزياء- كلية العلوم
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٢٠١١

جامعــة عيــن شمـــــس
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كليـــــة العلـــــوم
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صفحة الموافقة علي الرسالة

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- الدرجة العلمية : ماجستير العلوم في الفيزياء (فيزياء نووية)
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ABSTRACT

The radioisotopes of indium, cadmium and tin have many practical and medical applications. Their standard routes for production are proton or deuteron induced reactions on natural or enriched cadmium or tin. The production via ^{3}He induced reactions on natural or enriched cadmium was rarely discussed.

In this study ^{3}He induced reactions on natural cadmium were measured utilizing the stacked-foil technique. The primary incident beam energy was 27 MeV extracted from the MGC-20E cyclotron, Debrecen, Hungary. The excitation functions for the reactions ^{nat}Cd(^{3}He,x)^{115g,111m}Cd, ^{117m,g,116m,115m,114m,113m,111g,110m,g,109g,108g,107g}In and ^{117m,113g,111,110}Sn were evaluated. The data were compared with the available literature data.

Different theoretical nuclear reaction models were also used to predict the cross sections for those reactions. The used models were ALICE-IPPE, TALYS-1.2 and EMPIRE-03. The experimental data were compared also to the theoretical model calculations. The theoretical models did not describe most of the experimental results.

The isomeric cross section ratios for the isomeric pairs ^{117m,g}In and ^{110m,g}In were calculated. The isomeric cross section ratio depends on the spins of the states of the interested isomeric pair. The calculated isomeric ratios helped to identify the mechanisms of the reactions involved.

The integral yields for some medically relevant isotopes were calculated using the excitation function curves.

CONTENTS

1.1. RADIOACTIVITY

Nuclear physics as a subject distinct from atomic physics could be said to date from 1896, the year that Henri Becquerel observed that photographic plates were being fogged by an unknown radiation emanating from uranium ores. He had accidentally discovered radioactivity: the fact that some nuclei are unstable and spontaneously decay **[Martin, 2006]**. Rutherford started working with these newly discovered uranium rays believing that they were similar to the X-rays discovered by Röntgen [**Joseph Magill and Jean Galy, 2005**]. In the years that followed, the phenomenon was extensively investigated, notably by the husband and wife team of Pierre and Marie Curie and by Ernest Rutherford and his collaborators and it was established that there were three distinct types of radiation involved: these were named (by Rutherford) α, β and γ rays. In 1897 J. J. Thomson was the first to identify the cathode ray -that had been observed to occur when an electric field was established between electrodes in an evacuated glass tube- to be free electrons (the name 'electron' had been coined in 1894 by Stoney) **[Martin, 2006]**. In 1900 Becquerel identified that β rays consists of electrons. And in the same year Villard and Becquerel propose that γ radiation is of electromagnetic nature; finally proven in 1914 by Rutherford and Andrade. In 1903 Rutherford proved that α radiation is shown to be ionized helium atoms. The rate of radioactive decay per unit weight was found to be fixed for any specific radioelement, no matter what its chemical or physical state was, though this rate differed greatly for different radioelements. Radioactive decay is a random process. Among the atoms in a sample undergoing decay it is not possible to identify which specific atom will be the next to decay **[Gregory et al., 2002]**. The activity (A) is the number of disintegrations per unit time and is proportional to the number of radioactive atoms

$$A = -\frac{dN}{dt} = \lambda t \qquad (1-1)$$

where (λ) is the decay constant and (N) is the number of nuclei at any time (t). Using simple mathematical treatment, the well known decay low can be obtained,

$$A = A_0 e^{-\lambda t} \qquad (1-2)$$

1.2. ISOTOPES

In 1913, Fajans and Soddy independently stated that each element could have atoms of different weight and with different radioactive properties, and Soddy introduced in 1914 the name isotope for different atomic species of an element. In 1913 Thomson discovered that an accelerated beam of neon atoms is divided into two beams, corresponding to atoms having a mass number 20 and 22, when it passed through a crossed electric and magnetic field. After World War I, Aston resumed Thomson's work and developed mass spectrometers that could be used to measure very precisely the mass of atoms as well as their relative abundance for individual elements. He demonstrated that most elements have more than one isotope **[Gregory et al., 2002]**. The explanation of isotopes had to wait 20 years until a classic discovery by Chadwick in 1932. He discovered the neutron and in so doing had produced almost the final ingredient for understanding nuclei **[Martin, 2006]**. A nuclear species, or nuclide, is defined by (N), the number of neutrons, and (Z), the number of protons. The mass number (A) is the total number of nucleons, i.e. A = N + Z. Thus the isotopes of an element have the same number of protons i.e. same charge but different number of neutrons i.e. the same atomic number but different mass number. From this point, the isotopes have different nuclear properties but practically have identical chemical properties, since these arise from the (Z) electrons around the nucleus **[Basdevant et al., 2005]**. It is possible for nuclei to have the same mass number but different number of protons and different number of neutrons. Such nuclei are called isobars. Others have the same number of neutrons and different number of protons. They are called isotones. It is convenient also to identify Isomers as, the same nuclide (same Z and A) in which the nucleus is in different long lived excited states. For example, an isomer of (Tc) is (^{99m}Tc) where the (m) denotes the longest-lived excited state (i.e., a state in which the nucleons in the nucleus are not in the lowest energy state).

1.2.1. PRODUCTION OF ISOTOPES

Stable isotopes, as their name suggests, do not undergo radioactive decay. Radioactive isotopes, or radioisotopes, are available with a great variety of half lives, types of radiation, and energy **[Raymond, 2009]**. Of the nuclei found on Earth, the vast majority is stable. This is so because almost all short-lived radioactive nuclei have decayed during the history