Ain Shams University
Women's College for Arts,
Science and Education
Physics Department

Investigation of Charged Particles Induced Nuclear Reactions on Some Medium Weight Nuclei

Thesis submitted for the partial fulfillment of Master Degree in Physics (Nuclear Physics)

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Approval Sheet

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

ٱلرَّحْمَٰنُ ﴿١﴾ عَلَّمَ ٱلْقُرْءَانَ ﴿٢﴾

خَلَقَ ٱلْإِنسَٰنَ ﴿٣﴾ عَلَّمَهُ ٱلْبَيَانَ ﴿٤﴾

﴿ سُورة الرَّحمَنُ ﴾

ABSTRACT

The atomic age is associated not only with electric power plants and nuclear weapons, but also with the applications of radioactive isotopes in medicine, agriculture, industry and science. Studies of excitation functions of charged particles induced reactions play an important role in many practical applications in medicine, industry. Also charged particle induced nuclear reactions on metals are of considerable significance for evaluating their potential use as monitor reactions for determining the energy and intensity of the bombarding beam especially in small cyclotrons, and for optimization of the beam parameters in the Thin Layer Activation technique (TLA) used for wear, corrosion or erosion measurements. Knowledge of the various excitation functions especially near the reaction thresholds helps in the optimization of the production process at small cyclotrons.

Iron is one of the most important elements in radiation field since this element is one of the main accelerator components especially in the beam lines. So studying deuteron irradiation of a natural iron target is useful for shielding designs, radioactivity estimation, and for the production of ^{55,57}Co which are important isotopes in industry, medicine and nuclear research fields.

The excitation functions were measured for nuclear reactions induced by deuterons on natural iron in the energy range from threshold energy up to 10 MeV leading to the production of ^{52g,54}Mn and ^{55,56,57,58g}Co radionuclides. Full excitation function curve for ^{nat}Fe(d,x)^{57}Co was obtained in the used energy range, and it reaches its maximum ($\sigma \sim 270$ mb) at deuteron energy $E_d \sim 6.3$ MeV.

The measured data were compared with previous measured data and also with the results of theoretical calculations using the default parameters of codes ALICE-IPPE, EMPIRE-3.0 & TALYS.

Theoretical calculations using ALICE-IPPE did not give any results for the production cross sections of ^{55,56,57,58g}Co radionuclides, there was disagreement with EMPIRE-3.0 calculations but with TALYS there was partial agreement in most reactions.

The coulomb barriers B_c for the iron target were calculated and the excitation curves were discussed taking in consideration the deuteron breakup and pre-equilibrium emission processes.

The integral yield of ^{55}Co, ^{56}Co, ^{57}Co & ^{58g}Co were calculated as a function of deuteron energy. The average values of integral yields were estimated in the energy range E_d = 6- 10 MeV and they were 1.1 MBq/µAh for ^{55}Co, 0.0042 MBq/µAh for ^{56}Co, 0.1 MBq/µAh for ^{57}Co and 0.0092 MBq/µAh for ^{58g}Co. Also the radionuclidic impurity levels were discussed.

The integral yield of ^{52g}Mn and ^{54}Mn were measured. Both have nearly the same values in the used energy region, the average values of integral yields were estimated in the energy range Ed = 6- 10 MeV and for ^{52g}Mn it was 0.00972 MBq/µAh and for ^{54}Mn it was 0.00798 MBq/µAh

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Chapter (1)

INTRODUCTION AND LITERATURE REVIEW

1.1. RADIONUCLIDES

Radionuclides are often referred to by chemists and biologists as radioactive isotopes or radioisotopes, and they play an important part in the technologies that provide us with food, water, and good health. Radionuclides may occur naturally, but they can also be artificially produced. More than 1,500 radionuclides are known today. Some occur in nature, but most are produced artificially. However, only 10% are important and are applied in practice. The main factor that decides the importance and application of radionuclides is their half-life. The majority of the important radionuclides applicable in science, technology, and industry have a sufficiently long half-life (months, years, tens of years, and even more) allowing long-term application, especially in the form of so-called closed radio-emitters. Short-lived radionuclides used in nuclear medicine can be applied in radionuclide diagnosis and therapy in the form of open radio emitters. These are called radiopharmaceuticals and are administered to the organism directly (in most cases intravenously or orally).

Apart from stable chemical elements, very low concentrations of radioactive elements occur naturally in the environment. We can divide these natural radionuclides into three categories according to their origin and formation: primordial radionuclides, secondary radionuclides, and cosmogenic radionuclides. For the demands of present science and technology, industry, and health services, these few radionuclides of natural origin are far from sufficient. Therefore we must produce radionuclides artificially**.**

Artificial radionuclides can be produced by nuclear reactors, by particle accelerators, or by radionuclide generators [**Michael and Leo, 2007**].

The most common methods of producing radioisotopes are by adding or removing a proton or a neutron during the nuclear reaction. In practice, the effect of adding a thermal neutron or removing a proton can be achieved through reactions available via a reactor (e.g. (n,x γ) or (n,xp), where x = 1, 2,...) - giving rise to a family of radioisotopes, which are described as neutron-rich isotopes. On the other hand, the effects of adding a proton or removing a neutron, leading to the proton-rich isotopes, are usually produced with an energetic proton accelerator, such as a linac or a cyclotron (e.g. (p,xn), where x = 1, 2,…) **[Daniela, 2002]**.

1.1.1) Radionuclide Generators

Generators are units that contain a radioactive **"parent" nuclide** with a relatively long half-life that decays to a short-lived **"daughter" nuclide**. The most commonly used generator is the technetium-99m (^{99m}Tc) generator (Figure 1-1), which consists of a heavily shielded column with molybdenum-99 (^{99}Mo; parent) bound to the alumina of the column. The ^{99m}Tc (daughter) is "milked" (eluted) by drawing sterile saline through the column into the vacuum vial. The parent ^{99}Mo (small grey circles) remains on the column, but the daughter ^{99m}Tc (white circles) is washed away in the saline **[Thormod and David, 2005]**.