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DETERMINATION OF THE ENERGY RANGE FOR THE PRODUCTION OF PURE FORM OF IODINE AND BISMUTH.

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ABSTRACT

In this work, the energy range at which Iodine and Bismuth is produced in its purest form was checked for the production of ^{127}Iodine and ^{208}Bi isotopes using EXIFON code in the energy range of 0 - 40 MeV. The use of EXIFON code in this work is based on an analytical model for statistical multistep direct and multistep compound reactions (SMD/SMC model). The result obtained showed that the energy range for producing the purest form of Iodine is 21.6 MeV and the 16.7 MeV for Bismuth respectively. It is therefore concluded that, EXIFON code is a good tool for investigation of nuclear reaction cross section and is useful in the production of the radioisotopes Iodine and Bismuth of high purity and in an efficient manner. These isotopes have potential application in the field of medical science especially for diagnostics and therapeutic purposes.

***Keyword**: Iodine, Bismuth, Exifon code, SMD/SMC model*

1. INTRODUTION

A nuclear reaction occurs when a nucleon or a nucleus collides with another nucleon or nucleus (Kettern, *et al.*, 2009). In other words, nuclear reaction is said to occur when a nuclear particle comes into close contact with another during which there is an exchange of energy and momentum (the product of mass and velocity) (Klopries, *et al.*, 1997). Nuclear reactions are characterized by the incoming nuclei and the outgoing reaction products. Thus after the reaction, the product nuclei which are the residual nucleus and the ejectile leave the point of contact in different directions (Basu, *et al.*, 2013). Besides the incoming nuclei and the outgoing reaction products, other properties of interest are the incident and outgoing particle energies as well as the scattering angles. The changes produced in a nuclear reaction usually involve strong nuclear force (Basu, *et al.*, 2013).

Radioactive isotopes play an important role in the field of medical science in terms of beneficial applications in both diagnosis and therapy purposes (Hauser, W., & Feshbach, H. 1952). In radioisotope production programmers, nuclear reactions data are mainly needed for optimization of production routes (Nicholas, 2002). The cross section data for different nuclide was intensively investigated and up to now, the nuclear databases are accessible online (Akovali, 2004).

Therefore, this radionuclide again, plays an important role in medical applications and research. For example, Gamma-emitted short-lived ^{123}I and long live ^{124}I isotopes can be used as the diagnostic image in SPECT and PET (Srivastava, 1996). Besides, the ^{124}I allows for studying of important organs such as brain and heart. The long-lived ^{125}I isotope is used as a source for internal radiotherapy, bone dosimetry and a biological tracer (Srivastava, 1971).Nuclear reaction by neutron interactions on bismuth-208 was studied for the production of lead isotopes and thallium isotopes (Hauser, W., & Feshbach, H. 1952).

Over the years, the concept of statistical multistep processes has become more and more important for the understanding of nuclear reaction mechanism, especially above 20 MeV (Probst, *et al.*, 1976). An analytical model for both statistical multistep direct (SMD) and statistical multistep compound (SMC) processes was applied for describing nuclear reactions up to 30 MeV (Filatenkov, *et al.*, 2000). This can be generalized in several respects:

The extension to higher energies is performed including s-step direct processes for s = 1 up to 5 (Filatenkov, *et al.*, 2000).

Thus, there is no reference to the optical model (OM) reaction cross section. The OM cross section for charged particles was used to simulate coulomb effects in the threshold region only. α and γ-Processes are included Spin-isospin conservation during the two-body collision is considered (Audi, *et al.*, 2003).

The calculation of Multiple Particle Emission (MPE) is generalized. Up to three decays of the compound nucleus are considered (Nicholas, 2002). This model is formulated in detail for predicting emission spectra for neutrons, protons, alphas and photons including equilibrium, pre-equilibrium, direct as well as MPE processes in a consistent way (Aslam, M. N., & Qaim, S. M. 2014).

In this research, EXIFON code was used to calculate particle induced cross sections of some reactions of interest (Bismuth and Iodine), in energy range of 0 – 40 MeV which is a major gap that was found in the huge number of literatures that were reviewed.

2. MATERIALS AND METHOD

MATERIALS

The Unit and source of the materials used is this research work is summarized in Table 2.1

Table 2.1: Materials Used

Material	Unit/Language	Source
Bismuth crystals	$5gcm^{-3}$	International Atomic Energy Agency
Iodine Crystals	$5g\,cm^{-3}$	International Atomic Energy Agency
Exifon Code	Version 2.0	International Atomic Energy Agency
Enrichments	-	International Atomic Energy Agency
Computer Hardware	IBM PC	ML Tech
Computer Software	Fortran Version 2.42	International Atomic Energy Agency
Coding Language	(POO3O51PCXTO1)	International Atomic Energy Agency

METHOD

In this research EXIFON code was used which is computer program package for computational nuclear Data physics, which is based on an analytical model for statistical multistep direct and multistep compound reactions (SMD/SMC model). It predicts emission spectra, angular distributions, and activation cross sections for neutrons, protons, alpha particles, and photons. Multiple particle emissions are considered for up to three decays of the compound system.

NUCLEAR MODEL CALCULATIONS

Theoretical calculations of cross-section were performed by nuclear model code EXIFON the program was run and the input and output directory were defined, and then the target nucleus is specified. The incident particle and target nucleus were selected and excitation function in the general options section for this calculation was chosen.

The number of incident energy was specified followed by the first incident energy, and then the incident energy step is also specified. The Cross-section correspond to each particular energy was obtained.

The output data (OUTEXI) for the calculation was then stored in the set out- put directory. Also, DAT file name is stored in the set output directory.

Secondly, the option without shell effect is also used for each target nucleus, also an output data (OUTEXI) for the calculat ion is then stored in the set output directory. Also, DAT file is stored in the set output directory.

CROSS SECTION CALCULATIONS

The program was run and the input and output directory were defined that is; Iodine and Bismuth as the input and the incident energy as the output respectively, and then the target nucleus is specified. The neutron was chosen as incident particle followed by selecting the target nucleus and excitation function in the general option section for this calculation.

The number of incident energy was specified followed by the first incident energy, and then the incident energy step is also specified. The cross section correspond to each particular energy was obtained.

3. RESULT AND ANALYSIS

This research clearly shows the analysis of the results of the energy range at which pure form of iodine and bismuth are produced in their distinct reactions, the calculated reaction cross section, the excitation functions of Iodine – 127 and Bismuth – 208 interactions with different emission spectra and the effect of shell structure on the reaction cross section.

ENERGY RANGE FOR PRODUCTING PURE FORM OF IODINE

Figure 3.2 shows the plot of Excitation function of Iodine-124 and Tellurium-124 reactions. In the Figure, the y-axis represents the cross section which is measured in Milli Barn (mb) while the x-axis represents the particle energy which is measured in Mega Electron Volt (MeV). An observation from the Figure reveals that the optimum energy range for the production of ^{123}I (pure form of Iodine) is Ep = 25.0 —> 18.0 MeV, it also showed that it was not possible to eliminate the ^{124}I impurity from the ^{123}I because the ^{124}I is being made at the same energy. All that can be done is to minimize the ^{124}I impurity by choosing an energy where the production of ^{124}I is near a minimum. In this case, proton energies higher than about 20 MeV will give a minimum of ^{124}I impurity.

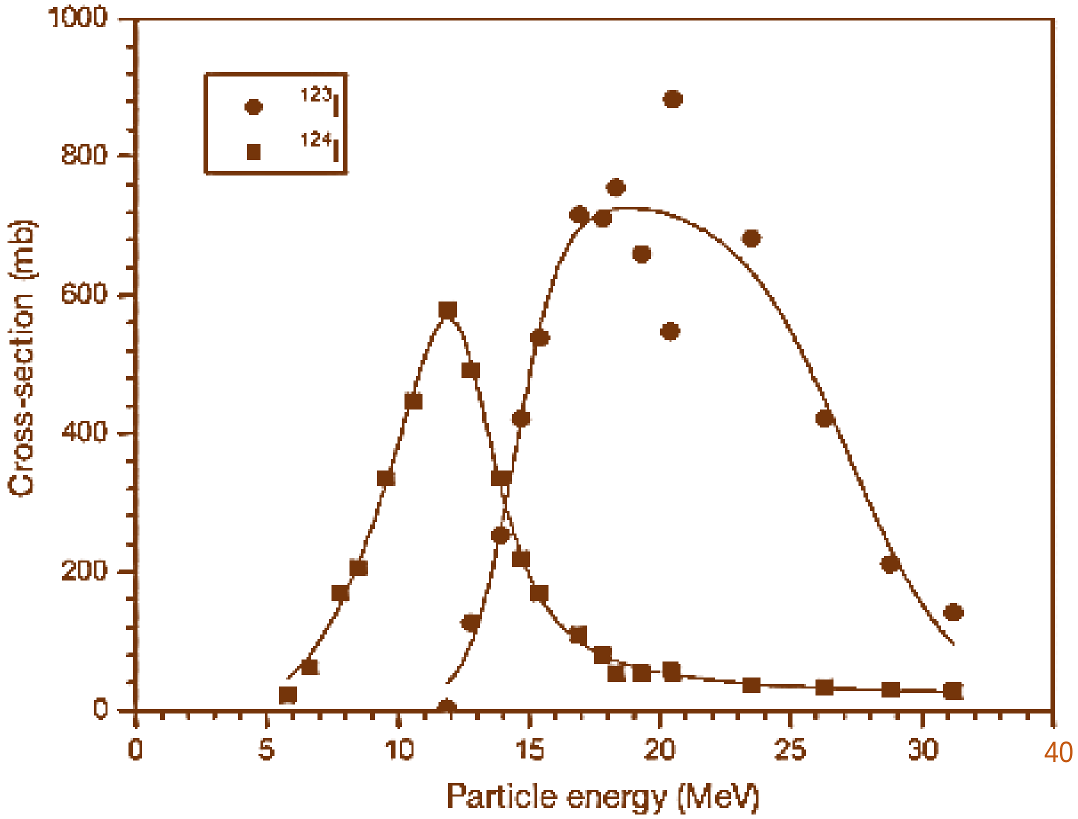
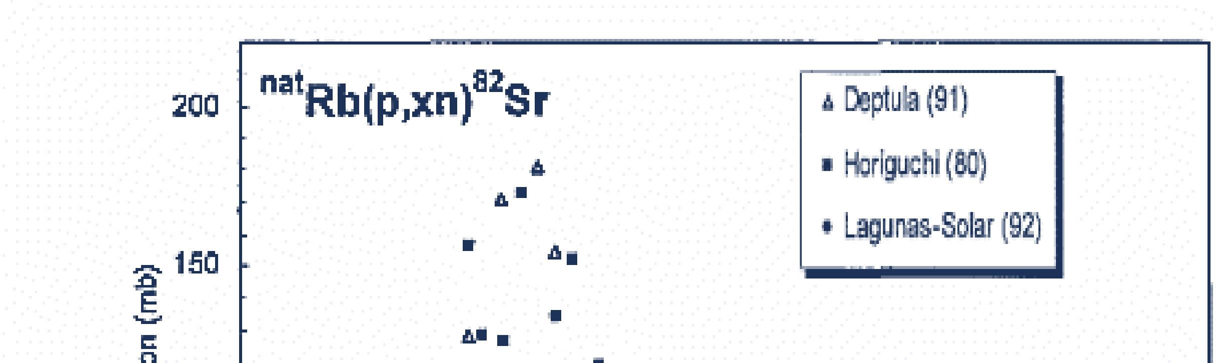


Figure 3.1 Excitation functions *of* $^{124}Te(p,n)^{124}I$ and $^{124}Te(p,2n)^{124}I$ reactions.

ENERGY RANGE FOR PRODUCTING PURE FORM OF BISMUTH

Figure 3.1 shows the plot of Excitation function of Astatine-211, Astatine-212, and Bismuth-207 and Bismuth-208 reactions. In the figure, the y-axis represents the cross section which is measured in Milli Barn (mb) while the x-axis represents the particle energy which is measured in Mega Electron Volt (MeV). A close observation from the Figure shows that the optimum energy range for the production of ^{208}Bi (pure form of Bismuth) is Ep = 16.5 —> 14.0 MeV, it also showed that it was not possible to eliminate the ^{207}Bi and ^{204}Bi impurities from the ^{208}Bi because the ^{204}Bi and ^{207}Bi is being made at almost the same energy. All that can be done is to minimize the ^{207}Bi and ^{204}Bi impurities is by choosing an energy where the production of ^{204}Bi and ^{207}Bi is near a minimum. In such case, proton energies higher than about 15 MeV will give a minimum of ^{207}Bi impurity for long- lived radiation dose. While for short-lived radiation dose the optimum energy range for producing pure form of Bismuth is 25 MeV upwards.



208 Bi

207 Bi

Figure 3.2 Excitation functions *of* $^{211}At(p,n)^{207}Bi$ and $^{212}At(p,2n)^{208}Bi$ reactions.

4. DISCUSION

In this work, the energy range at which pure form of Bismuth and Iodine is produced in their distinct reaction was checked. The result in Figure 1.1, showed that the optimum energy range for the production of ^{123}I (pure form of Iodine) is Ep = 25.0 —> 18.0 MeV and the result in Figure 1.2, showed that the optimum energy range for the production of ^{208}Bi (pure form of Bismuth) is Ep = 16.5 —> 14.0 MeV respectively. This observation is consistent with the findings of Firouzbakht *et al.* (1993), Hupf *et al.* (1968) and Hassan *et al.* (2006) except that none of their work reported what could be done with the radioactive impurities that is produced in the same energy range as that of the produced pure radioactive substances. This work demonstrates that all that could be done with the impurities is by choosing an energy range where the impurities is near minimum.

5. CONCLUSION

In conclusion, the determination of the energy range at which the pure form of Bismuth and Iodine have been identified using EXIFON code and the result revealed accurate cross section of the excitation function of reactions data that will lead to maximum production yield of radioactive substances of high purity.

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