International Journal of Scientific Research in Physics and Applied Sciences
Vol.8, Issue.6, pp.01-05, December (2020)
Research Paper
E-ISSN: 2348-3423

Selection of Anti-Cancer Agent based on Radionuclide Cross Sectional Area used in Nuclear Therapy Technology

S.H. Dhobi

Department of Physics, Tribhuvan University, Kathmandu-44600, Nepal
Robotics Academy of Nepal, Lalitpur-44700, Nepal
Innovative Ghar Nepal, Lalitpur-44700, Nepal

Author's Mail Id: saddam@ran.edu.np

Available online at: www.isroset.org

Received: 09/Nov/2020, Accepted: 11/Dec/2020, Online: 31/Dec/2020

Abstract—Study the selection of cross sectional areas of radionuclide and its implementation in the medical field like nuclear therapy is the main objective of this work. For the selection of radionuclide cross section, two nuclear reactions (p, n) and (d, 2n) of Rh and Pd were taken. The observation shows the cross sectional area of (d, 2n) is higher than (p, n) during the reaction. Therefore this observation is beneficial for the selection and treatment of infected areas with more safety and accuracy.

Keywords— Radionuclide, Cross Sectional Area, Infected Surface, Healthy Cell, Technology, Therapy, etc.

I. INTRODUCTION

The development of technologies and their safety and preciseness has equally important in the medical field. As for this work, nuclear reaction importance in the medical field for the treatment of cancer is considered. Therefore the detailed knowledge for using the technology with the nuclear reaction for diagnosis, therapy, imaging, and others is necessary. For detailed knowledge one of the major parts is knowledge of nuclear cross section area of radionuclide used in treatment.

With the knowledge of the cross sectional area of radionuclide, the purity of radionuclide is also important. This is for the control of unnecessary nuclear reactions during the treatment of patients because the unnecessary reaction may damage the healthy cell that surrounds the infected cell. For the nuclear reaction in the medical field nuclear technology like cyclotrons, nuclear reactors, or radioisotope generators, and others are used [1]. For the purity of radionuclide varieties of analytical techniques such as liquid chromatography, paper chromatography, and thin-layer chromatography [2].

This nuclear technology causes a nuclear reaction with the production of the daughter radionuclides from the parent's radionuclide. In our work, our main focus is on Rh and Pd, which involved reaction as their appropriate properties for anti-cancer treatment, active against malaria, leishmaniosis, trypanosomes, bacteria, and algae, treatment of leishmaniosis, and so on.

To compare the cross section area of the nuclide, the reaction chosen in this work is inelastic scattering between neutrons is isotropic,

$$\frac{\Delta M}{M_0} = \sigma_i \frac{d^2NB}{2(1+A)} \sum T \frac{b}{r_1^2 r_2^2}(1 + A\cos^2\theta) \ldots\ldots\ldots (1)$$

Here summation represents over all elements in the scattered, N is the number of scattering nuclei per unit volume $, A = 0.5, B$ is an area of the cross section $, \sigma_i$ is inelastic scattering cross section of the scattered, T is the probability that a neutron will undergo no process in its passage through the scattered other than a single inelastic collision in the volume element concerned and σ_i can be written as,

$$\sigma_i = \frac{F_1\left(\frac{\Delta R}{R}\right)\left(\frac{E_1}{E_0}\right)\left(\frac{s_0}{s_1}\right)}{\frac{d^2N}{2(1+A)}\Sigma T \frac{b}{r_1^2 r_2^2}(1 + A\cos^2\theta)} \ldots\ldots\ldots\ldots (2)$$

This expression helps to determine the cross-section value of compound nuclide i.e. ^{103}Rh (p, n) ^{103Pd} and ^{103}Rh (d, 2n) ^{103Pd} [3].

II. RELATED WORK

Some of the radionuclide therapy used in the medical field

For radionuclide therapy iodine (I-131) is used for thyroid disease, thyroid cancer, and skeletal disease. Since the shape and size of the infected area are irregular therefore the knowledge of cross section areas is important for more precious and safe therapy [4, 5]. Proton and deuteron induced activation cross section products up to 40 and 50 MeV used clinically and commercially available as radionuclide of ^{103}Pd. Rhodium and rhodium alloys are used in fusion, fission technology, and nuclear transmutation, where secondary high energy protons are induced [6].

Induced neutron for activation of cross-sections governs the rate of production of isomers and radioactive isotopes. The cross-sections area is of immediate interest in estimating radiation levels or concentration during the treatment. The decay heat of materials that have been exposed to radiation fields with a strong neutron component.

The nuclear reaction ^{127}I (n, γ) ^{128}I and ^{129}I (n, 2n) ^{128}I reactions for isotopes of iodine and instance the ^{96}Mo (n, p) ^{96}Nb and ^{97}Mo(n, x)^{96}Nb reactions for isotopes of molybdenum are an example of neutron-induced activation cross-sections that govern the rate of production of isomers and radioactive isotopes[7]. The Neutron induced fission reaction produced neutrons by using a radionuclide and used neutron sources with limited in number [8]. The medically-related radioisotopes like ^{104}Ag, ^{101}Rh, ^{103}Pd and the activation cross sections of the proton, deuteron, ^{3}He, and alpha-particle are used for therapy. Very few works on (p, n) reactions were found in the literature [9].

A survey conducted by the IAEA for radiopharmaceuticals shows that small amounts of radioactive isotopes are used for the diagnosis and management of some cancers, and chronic diseases (IAEA, 2020). Radioactive isotopes have a variety of applications like effective tracers because their radioactivity is easy to detect.

III. METHODOLOGY

One of the challenges to the selection of an optimal radionuclide for therapy for both the clinician and the patient is the current issue. This is because the treatment of various cancers depends on the need for interstitial versus intracavitary implants, in the required part of our body. The sources used in nuclides are either used as sealed or unsealed on the part of the body where it necessary. After filling or surface polished with radionuclide of required surface for treating sources of energy particle emitted on such surface for therapeutic.

This phenomenon of therapeutic with radionuclide may damage the healthy cell surrounded unhealthy example cancer cells. The damage of the cell is uncontrolled due to the unknown of cross sectional area of radionuclide used in treatment. This is because upon incidence of energy particle on radionuclide sample increases the cross section area of the radionuclide implement or polished or filled in cavitary.

The different radionuclides have different therapeutic effects that conduct to a selection of radiation therapy should necessary, in this work, the focusing on ^{103}Rh (p, n) ^{103Pd} and ^{103}Rh (d, 2n) ^{103Pd} for biochemical characteristics and others. Since the focus is only on the cross sectional area of radionuclide in this research work. Therefore the other characteristic and the unrelated cross sectional area are not taken into account in this work.

For the selection of the nuclear reaction based on the cross sectional area in the medical field, the data are taken from IAEA and some past work done by different researchers in a related field. The most commonly used nuclear process for the production of ^{103}Pd is the ^{103}Rh (p, n)^{103}Pd reaction was measurement with the help of emitted neutron spectroscopy as well as by characterization of the activation product.

Blaser reported in 1951, 10 data cross-section points up to 7MeV with error, about 10%. Albert reported in 1959, 7 data cross-section point up to 9 MeV with 2% accuracy. The neutrons emitted from this target were measured with error, about 10%. Johnson reported in 1960, 27 data cross-section values between 2 and 6 MeV with van de Graaff accelerator with the uncertainty of about 10%. Harper reported in 1961, data radio-chemically up to 22MeV, with uncertainty up to 15%.

Similarly, Hansen reported in 1962, 6 cross-section values up to 10 MeV. Hermane reported in 2000, the production of ^{103}Pd and characterized the possible contaminants during proton irradiation of 99.9% pure ^{103}Rh up to 28 MeV. Seven stacks of the target material and monitor foils were irradiated with 14.7, 22.5, and 29.4 MeV proton beams. Sudar in 2002 reported 26 values of the reaction cross-section up to 40 MeV.

Some measurement on the formation of ^{103}Pd via this reaction was done only by Hermane in 2002 using the stacked-foil technique with total uncertainties up to 10%, for the (d, 2n) reaction. The recommended sets of data were generated, upper and lower 95% confidence limits were determined for the best estimation of uncertainty in the recommended values with visualization in

Radiotherapeutics phenomena and radionuclide (p, n) and (d, 2n) reaction for Rh and Pd

Nuclear reaction and cross section area of ^{103}Rh (d, n) ^{103Pd} nuclide

When target Rhodium bombard with incident particle proton (p) a transition nuclide is formed with Palladium and neutron is formed. The represent of reaction and visualized are below with the help of figure 1.

Target nuclei (Rh) + Incident Particle (P) → Pladium Nuclei (Pd) + Neutron

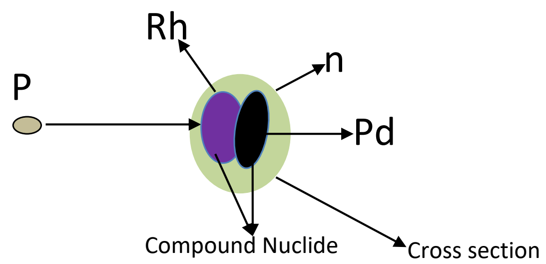

Figure 1: Phenomena of production of the neutron (n) with the incidence of the proton (p)

The above figure 1, shows that the formation of the compound nuclide with help of proton, rhodium, neutron, and palladium, with the incidence of suitable energy proton. On the incidence of the proton to Rhodium element another element palladium nuclei and neutron form, where neutron leaves the radionuclide sample used for treatment. The compound nuclide has maximum cross-section value at bound state, here bounded state means a state at which maximum neutron emitted with suitable energy incidence or overcome nucleon binding energy. After receiving the energy from the incidence particle nucleus absorbed the energy and vibrate which causes an increase in the resultant cross sectional area of the nuclide. In this way reaction and cross section area of nuclide change with incidence particles.

Nuclear reaction and cross section area of ^{103}Rh (d, 2n) ^{103Pd} nuclide

When target nuclei (Rhodium) bombard with incident particle deuterium (d) a nuclide with Palladium and two neutrons are formed. The visualization and representation of the reaction are shown in figure 2.

Target nuclei (Rh) + Incident Particle (d) → Pladium Nuclei (Pd) + 2 Neutron (2n)

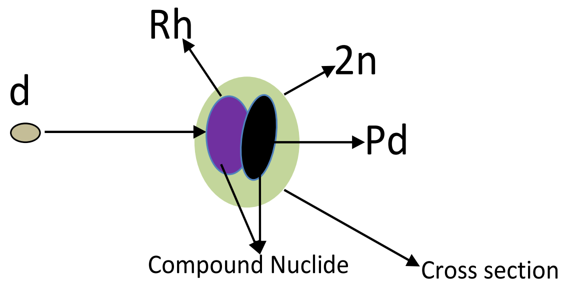

Figure 2: Phenomena of production of 2n with the incidence of deuterium

Here, for our study, we represent d, Rh, Pd, and 2n are deuteriums, Rhodium element, Palladium element, and two neutrons respectively. Upon incidence of deuterium with suitable energy form nuclide and emit two neutrons from the radionuclide sample instantaneously. The increase and decreasing phenomena of cross sectional area similar as described for Rh (p, n) Pd nuclide reaction.

Relevant details should be given including experimental design and the technique (s) used along with appropriate statistical methods used clearly along with the year of experimentation (field and laboratory).

IV. RESULTS AND DISCUSSION

On plotting cross sectional area of Rh(d, 2n)Pad nuclide, using data from, IAEA, it is found that cross-section area goes increase with increases in incidence particle energy, and at a certain value of incidence energy, the maximum cross section area of nuclide area maximum for ^{103}Rh(d,2n)^{103}Pd is also observed.

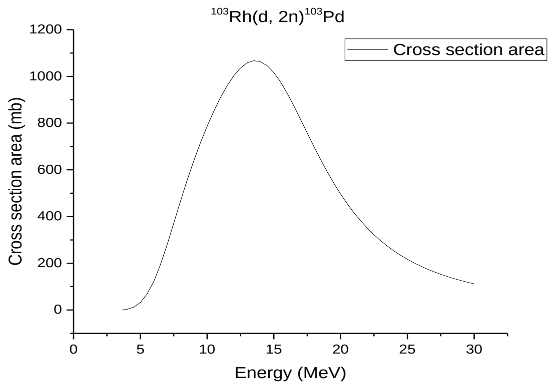

Figure 3: Energy of incidence particles vs cross section of nuclide (d, 2n), (Data Sources: IAEA, 2020)

The obtained graph is quite an asymmetry above 400mb and in energy in travel 10MeV to 20MeV. The peak or resonance takes place at 15MeV about 1100mb because this energy is suitable for the reaction. This amount of incidence particle for Rh target causes vibration with maximum resonance and emits neutron, the vibration is due to absorption of incidence proton energy.

In case of low energy particle incidence on the sample, the emission of neutron low with less vibration but the vibration of nuclide overcome the cross sectional emitted neutron and result are increased in the cross sectional area which is both proton and vibration. Since the proton, the cross section area of the proton is considered throughout the reaction, therefore proton cross section area although not described here but taken into consideration.

Hence with low energy proton incidence for reaction, emitted less neutron and vibration is less, and resultant cross sectional area increases with the increase of energy of incidence. Ongoing increasing with the energy of incidence particles proton vibration is maximum and result in a maximum cross sectional area with cross-ponding energy, at this point a large number of neutrons are also emitted. But later on, increase the energy of the particle, cross sectional area of nuclide goes decrease this is because the number of neutrons is emitted and leave the nuclide and this causes the decrees the cross sectional area although vibration and proton cross sectional area are considered.

Therefore, with increase energy of incidence proton cross sectional area goes increase due to vibration and vibration overcomes until peak point or resonance are obtained but after resonance decreasing in cross sectional area take place due to emission of the neutron, in this the resultant cross sectional area is less and can't overcome the emitted neutron cross sectional area so, although vibration is high but can't fulfill the cross sectional area reduce due to emitted neuron, up to the peak in past.

The plot of 30 data points up to 30MeV is shown in the above graph and the maximum cross section for this nuclide is approximately 1100mb. Cross-section value is negligible at 5MeV and below this, no nuclear reaction took place for this nuclide. The maximum cross-section at 15 MeV which is the resonance energy needed for maximum cross section area is absorbed by nuclide.

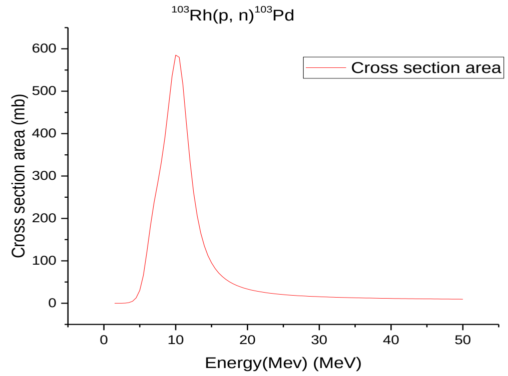

Figure 4: Energy of incidence particles vs cross section of the nuclide of (p, n), (Data Sources: IAEA, 2020).

As described above the reason for increasing and decreasing of cross sectional area with increasing the energy of proton particle for production of ^{103}Pd in (d, 2n) nuclide reaction. The plot of 50 data points up to 50 MeV for compound nuclide that is $^{103}Rh(p, n)^{103}Pd$ and the cross-section value is maximum for this nuclide is approximately 600mb. On emission of the neutron from nuclide sample cross sectional area goes to decrease and tends to original value but not same i.e. initial state due to repulsion because as neutron decrees from nuclide sample the majority of charge particle in the sample is the proton, also the same result is seen in (d, 2n) reaction.

On comparison of cross section area of both reaction, for (d, 2n) reaction has larger cross section area with wide range energy range while (p, n) reaction small cross sectional area with narrow-band energy ranges, but the nature of symmetry above certain cross sectional areas are seen in both reaction.

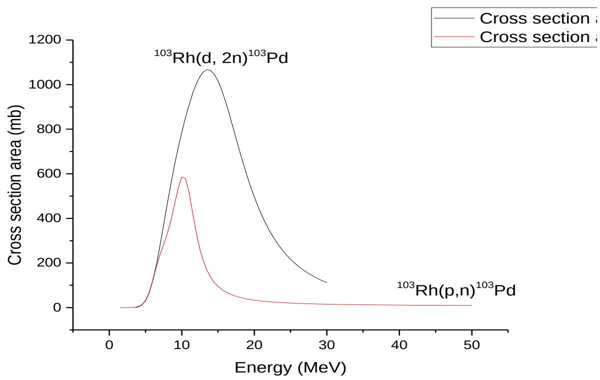

Figure 5: Comparison of Energy of incidence particles vs cross section of the nuclide of (p, 2n) and (p, n), (Data Sources: IAEA, 2020)

As we are comparing the cross sectional area of the same element for the same treatment in the medical field, therefore it is necessary to select the best one with suitable scientific reason. At the peak with a certain fixed amount of energy, the cross sectional area is high which means maximum vibration and emission of the maximum neutron in reaction. After the emission of the maximum neutron, the cross sectional area goes decrease because this emission neutron cross sectional area overcomes the cross sectional area due to vibration. Since energy increases at a final state, the cross sectional decrease and tends to original cross sectional are abut not same because the number of proton in a nuclide is greater than neutron and due to repulsion, the cross sectional area of nuclide after decay has higher cross sectional area before decay, one can visualize in the above figure 5.

On selecting the radionuclide for therapy, for the protection and solving the difficulties related to damaging the healthy cell which surrounded cancer cells or other treated surface. This cross sectional area is important, the nuclide with less cross sectional area protect the healthy cell from damage while the larger cross sectional area nuclide used for the therapy damage the healthy cell.
Hence in this, we can prevent the healthy cell from damage, with the knowledge of the cross sectional area of radionuclide used in therapy.

V. CONCLUSION AND FUTURE SCOPE

The comparison of cross section area of (p, n) and (d, 2n) nuclear reaction in figure 5 give the knowledge of cross section of nuclide used in medical field. On obtaining the knowledge of cross section area from figure 5 clinician or medical person can suggest the type of nuclide used for treatment.

This is because the cross section area during the treatment is different from the reaction that is the cross section area of (p, n) reaction is less than (d, 2n). So, if the infected surface is large then one can prefer (d, 2n) reaction but if small then one can prefer (p, n) for safe, precious and fast treatment.

The same knowledge of cross section can be used for imaging technology, the nuclear reaction for high accuracy, safety, and soundly. Hence on calculation and knowledge of cross sectional area of nuclide prevent healthy cells that surrounded infected cells. Since for this work, the nuclide is Rh is used as the treatment of nuclear therapy cancer treatment. Therefore the knowledge of cross section area from figure 5 help to use the nuclear reaction of (p, n) and (d, 2n) according to the infected surface area

ACKNOWLEDGMENT

We would like to thanks all the members (directly and indirectly) connected to Innovative Ghar Nepal, Department of Physics, Robotics Academy of Nepal, and Motivation Funnel for their kind support to us during the work.

REFERENCES

[1] G. Bak, S.B. Selcuklu, H. Yap, *"Medical Radioisotope Production in a Power-Flattened ADS Fuelled with Uranium and Plutonium Dioxides"*, Science and Technology of Nuclear Installations, Vol. **2016**, pp.**1-11**, Art. No. 5302176, **2016**

[2] C.H. Yeong, M.H. Cheng, N.G.K. Hoong NG, "*Therapeutic radionuclides in nuclear medicine: current and future prospects"*, Biomedicine & Biotechnology, Vol.**12**, Issue.**4**, pp.**34-35**, **2014**.

[3] E. A. Eliot, D. Hicks, L. E. Beghian, H. Halban, *"Inelastic Scattering of Neutrons"*, Physics Review, Vol.**94**, Issue.**144**, pp.**50-70**, **1954**.

[4] M.A. Majali, A.R. Mathakar, S. Banerjec, G. Samuel, M.R.A. Pillai, "*^{153}Sm Complexes of Phosphonic Acid Ligands, Isotope Division*", Radiation Medicine Centre, Bhabha Atomic Research Centre, Mumbai, India, pp.**133-139**, **2020**.

[5] Y.E. Demidtchik, S.D. Kirinuk, *"Radioiodine Therapy for Pediatric Patients with Thyroid Cancer, Research Institute of Radiation"*, Medicine and Endocrinology, Minsk, Belarus, pp.**158-161**, **2020**.

[6] F. Tárkányi, F. Ditrói, S. Takács, A. Hermanne, M. Baba, H. Yuki And A.V. Ignatyuk, *"Investigation of Activation Cross Sections of Proton induced reactions on rhodium up to 70 Mev for practical applications"*, arxiv, pp.**1-20**, **2020**,

[7] A.J.M. Plompen, M.B. Chadwick, A.J. Koning, "*Neutron Activation Cross-Section Measurements from Threshold to 20 Mev for the Validation of Nuclear Models and Their Parameters"*, Vol.**19**, pp.**3-50**, **2015**.

[8] Gilbert Gedeon, P.E. , Nuclear Characteristics of a Reactor CourseNo:N03-001 Lecture Note, pp.**12-16**, **2012**.

[9] F. Tarkanyia, F. Ditroia, S. Takacsa, J. Csikaia, A. Hermanneb, S. Uddind, M. Babad, *"Activation Cross Sections of Proton Induced Nuclear Reactions on Palladium up to 80 MeV"*, Preprint submitted to Applied Radiation and Isotopes, Vol.**114**, Issue.**128**, pp.**14-26**, **2016**.

AUTHORS PROFILE

Mr. Saddam Husain Dhobi pursed B. Sc., & M. Sc., in Physical Science from Tribhuvan University, Kathmandu Nepal 2016, & 2020. He is currently working as Sr. Researcher in Innovative Ghar Nepal Laboratory and Robotics Academy of Nepal, Lalitpur Nepal since 2013. He has published more than 30 research papers in reputed international journals including Thomson Reuters (SCI & Web of Science), it's also available online. His main research work focuses on electron and photon properties beyond the general properties, Data Analytics, Virology, Nuclear Physics, and Computational Intelligence based education. He has 4 years of research experience.

