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Study of Nuclear Properties of High Purity Germanium

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Abstract

In the current study, the observations depended on some nuclear properties of Germanium isotopes that are used for multiple purposes by studying transverse sections when interacting with charged particles such as alpha and proton particles and their interaction with gamma rays of conjugal isotopes relative to the stability of the nucleus with other nuclei. By calculating the cross sections of the $^{74}_{32}$Ge (α,$^{2}_{1}$H) $^{76}_{33}$As , $^{74}_{32}$Ge (γ,x)0-NN-1, $^{74}_{32}$Ge(γ,2n)$^{72}_{32}$Ge , $^{74}_{32}$Ge(α,p)$^{77}_{33}$AS reactions of $^{74}_{32}$Ge isotope. Nuclear reactions in the newer global libraries (EXFOR, ENDF, JEF, JEFF, GENDL) have been published to identify appropriate energies in calculating the inverse nuclear reactions of the ground State.

Keywords: Germanium**,** nuclear properties, isotopes, cross sections.

1. Introductio

The two-particle effect between m1 and target m2, which is generally produced in m3 and m4 as nuclear reactions and controlled by the conversation [1]. Direct interaction is a term used for multiple nuclear processes, for example non-flammable nuclear collisions, stripping, and reverse pick-up interaction. Direct interaction is an interactive process without forming a composite nucleus. The time when the target attack and nucleus react is much shorter than the time of the compound nucleus. Therefore, the reaction products display some features that are quite different from those that appear in the case of the beginning of the interaction through the formation of a complex nucleus [2]. These processes (direct interaction and composite nuclei) represent sharp views of the nuclear reaction mechanism. In the process of direct interaction, the age of the target nucleus and the missile accident system is 10 to 22 seconds, presuming the probable interaction depth of some MeV scores. On the other hand, the installed nucleus has a default life of 10 to 14 seconds for the power supply to demand a fraction of the electron volt. Thus, time scales for interaction domains are quite different [2]. It is very difficult to determine the energy that a given reaction will follow according to a reaction or other reaction mechanism. It can be argued in the qualitative sense that as the transverse particle energy increases, the partial width increases as well as the number of channels of interaction, which in turn leads to a progressively shorter time spent by the system as a composite nucleus. The composition of the composite nucleus is more possible in lower energies, while the direct reaction mechanism will prevail in the upper energies [2]. Direct interaction is a one-step process. This was first identified by Oppenheimer and Philip in the analysis of low energy interactions ($^{2}_{1}$d, p)[2]. It was observed through experiments that (d, d) reactions were more frequent than (d, n) reactions. This is more accurate than expected if the interaction continues during the composition of the composite nucleus. Because there is no Coulomb barrier, there will be a predominance of interactions (d, n) on the interactions of (d, n) Oppenheimer and Phillips have shown that deuteron interaction is loosely linked. When approaching the target nucleus, the proton is separated from the deuteron by the Coulomb field, while the neutron is captured. [2]. This condition is known as Oppenheimer and Philips in low energies, although it is more commonly known as the abstraction process, in both low and high energies. Reactions (d, p) and (d, n) in the high energy zone are more likely. The difference between other nuclear reactions from direct interaction is that the angular distribution of decomposition products peaks in the anterior direction and is very small in the posterior direction [2]. The Germanic is a chemical element and its symbol is Ge and its atomic number is 32. It is a shiny, solid, greyish white color within the carbon group, similar to its adjacent group of tin and silicon chemically. Pure germanium is a semiconductor with a similar appearance to the silicon element where germanium reacts naturally and forms compounds with oxygen in nature. Unlike silicon, it is so reactive that it cannot be found naturally in the ground in a free (primary) state. The germanium has 5 natural isotopes ^{70}Ge, ^{72}Ge, ^{73}Ge, ^{74}Ge and ^{76}Ge. Of these, ^{76}Ge is slightly radioactive, decomposes by decomposing duo. 74Ge is the most common counterpart, with approximately 36% natural abundance. 76Ge is the least common with a natural abundance of about 7% [3]. The ^{72}Ge isotope generates stable ^{77}Se, when it is bombarded with alpha particles, releasing high-energy electrons in the process. For this reason, it is used in the manufacture of nuclear batteries in its composition with radon [4]. The main end-uses of germanium in 2007 worldwide were estimated at 35% for fiber optics, 30% for infrared optics, 15% polymerization catalysts, and 15% for solar electronics and solar applications [5]. The remaining 5% is in uses such as phosphorus, minerals, and chemotherapy [5]. In 2000, about 15% of US consumption of germanium was used for infrared optics technology and 50% for fiber optics. The use of infrared radiation over the past twenty years in the demand for optical fiber, however, has been slowly increasing. In America, 30-50% of current fiber-optic lines in America have stopped the use of non-dark fibers, and this is the cause of controversy over overproduction and reduced demand in the future. Worldwide, demand is growing dramatically as countries such as China are installing fiber optic communications lines across the country. [6].

1.1. Production of Ultra-Pure Germanium from Its Concentrat

Germanium appears in small amounts in different metals, especially zinc and coal ores. Therefore, its first cycle begins with the production of germanium (germanium supplied or oxide), followed by purification and disinfection / subsequent purification, the production of very pure germanium tetrachloride as a final product, then the germanium dioxide and thus reduced metal form. The latter will be further refined according to its final application as well as purification requirements. **Figure 1.** shows the germanium production steps from mineral concentration to crystal growth in general. The germanium endpoint obtained if zinc ore or coal fly ash, which consists of 0.5% - 6% Ge [7]. Follows either a waterway or a thermal pathway. The hydro-water course includes the sulfuric filtration process and the oxidation step of the sediments to GeO_2. In a tall pyro methane, the process of roasting or fumigation is often carried out, during which GeO_2 is volatilized and collected in fumes.

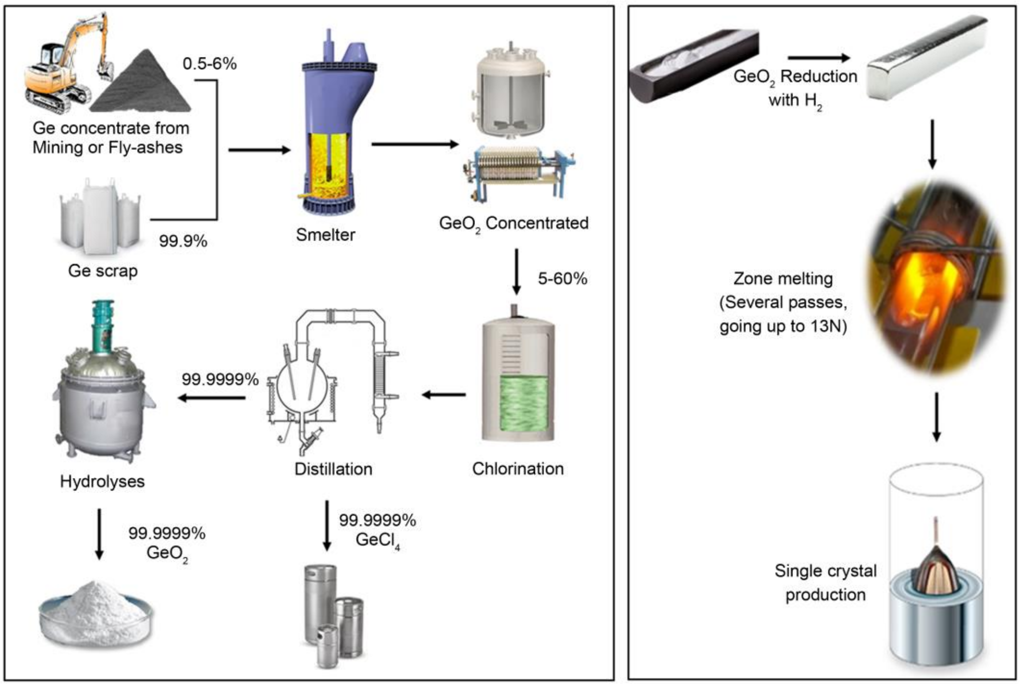

Figure 1. Example of production flow of germanium from concentrate to dioxide and tetrachloride via pyro metallurgical route (left) and from dioxide to ultra-pure metallic germanium (right), based on [8, 7].

In this process, an increase of 10 factors can be obtained in the germanium concentration [7, 9, 10].Trace the recycling of germanium scrap the same path as for the ore and fly ash center, where carbon dioxide is formed subsequent operations are performed [11, 7]. The chlorination process is done with hydrochloric acid on the center germanium dioxide, which is collected from fuse fumes According to the interaction described in equation (1). The product of this reaction is the crude germanium tetrachloride ($GeCl_4$), which is accompanied by very low amounts of impurities, which are also in the form of chloride. Since $GeCl_4$ has a boiling point higher than most of these impurities, while the distillation of these impurities will volatilize and $GeCl_4$ will remain with purity up to ^{6}N [12]. Then the product of this step becomes ready to use, for example, fiber optic industry [10].

$$GeO_2 + 4HCl \rightarrow GeCl_4 + 2H_2O \qquad (1)$$

For further processes, the ultra-pure $GeCl_4$ will be decomposed with pure deionized water as shown in equation (2) The result is pure germanium dioxide, which can then be reduced in hydrogen atmosphere Equation (3) to its first metallic form [11, 7].

$$GeCl_4 + 2H_2O \rightarrow GeO_2 + 4HCl \qquad (2)$$

$$GeO_2 + 2H_2 \rightarrow Ge + 2H_2O \qquad (3)$$

Temperature control of the equation (3) is a major challenge in order to avoid undesirable re-interaction between germanium and steam water at temperatures above 700 ° C and produce germanium oxide monoxide. Therefore, the reaction (3) should occur at temperatures between 650 ° C and 670 ° C. When the reduction is completed, the temperature can be increased to about 1000 ° C so that the metallic Ge is dissolved and poured into the area to melt the appropriate molds and send them to additional purification steps [12]. Later super-purity materials will be grown as a single crystal for specific applications.

2. Results

In this work, in light of the importance of industrial germanium, especially in the nuclear field and its uses in the medical field and its nutritional benefits. Some nuclear properties of germanium isotopes (4), atomic mass, excess mass (keV), abundance of isotopes [13]. Nuclear rotation and equivalence, pattern (decomposition) and the daughter's side were studied. These data were obtained from the most recent NRC nuclear card (NNDC) [13]. The cross-section of finite steps (0.5 MeV) depends on the type of reaction replicated directly from plots showing cross-sectional variation with alpha, proton particles and gamma energy. The cross section of $^{74}_{32}Ge$ (α,$^{2}_{1}H$) $^{76}_{33}As$, $^{74}_{32}Ge$ (γ,x)0-NN-1, $^{74}_{32}Ge$(γ,2n)$^{72}_{32}Ge$ reactions of $^{74}_{32}Ge$ For the isotopes available in the literature as mentioned, they were redrawn and inserted into the **Table 1.** These plots were analyzed to gain the formula for each reaction from the cross-section values of each author using the Matlab computer software (version 8.2-2013b) to get cross sections of the various power intervals as follows.

Table 1. The cross sections of $^{74}_{32}$Ge (α,x) $^{76}_{33}$As reaction as afunction of alpha energy and $^{74}_{32}$Ge (γ,x)0-NN-1 reaction as a function of gamma energy.

$^{74}_{32}Ge(\alpha,^{2}_{1}H)^{76}_{33}As$				$^{74}_{32}Ge$ (γ,x)0-NN-1			
Alpha-energy (MeV)	**Cross-section (mb)**	**Alpha-energy (MeV)**	**Cross-section (mb)**	**Gamma-energy (MeV)**	**Cross-section (mb)**	**Gamma-energy (MeV)**	**Cross-section (mb)**
18.5	2.8056	33.0	103.0000	10.0	6.9143	24.5	64.2222
19.0	3.8333	33.5	106.0000	10.5	17.3667	25.0	59.1074
19.5	4.8611	34.0	99.0000	11.0	21.6778	25.5	56.6852
20.0	5.8889	34.5	101.0000	11.5	27.1259	26.0	52.8333
20.5	8.6813	35.0	99.0000	12.0	32.0667	------	------
21.0	12.6500	35.5	94.0000	12.5	34.9185	------	------
21.5	16.6187	36.0	91.8000	13.0	46.3667	------	------
22.0	20.4286	36.5	89.8000	13.5	64.0259	------	------
22.5	24.0000	37.0	83.6000	14.0	82.9593	------	------
23.0	27.5714	37.5	74.6000	14.5	98.2556	------	------
23.5	32.5000	38.0	75.3333	15.0	98.6889	------	------
24.0	38.0000	38.5	82.5556	15.5	100.4429	------	------
24.5	43.0000	39.0	82.6667	16.0	106.4185	------	------
25.0	51.2000	39.5	81.0000	16.5	104.5296	------	------
25.5	56.1111	40.0	82.5000	17.0	107.2333	------	------
26.0	60.0000	40.5	84.0000	17.5	109.3000	------	------
26.5	65.3750	41.0	75.0000	18.0	121.1852	------	------
27.0	72.2500	41.5	66.0000	18.5	123.2296	------	------
27.5	76.2000	42.0	61.5556	19.0	122.9185	------	------
28.0	82.0000	42.5	58.6000	19.5	125.5000	------	------
28.5	90.6667	43.0	61.6000	20.0	112.6963	------	------
29.0	98.5000	43.5	63.5556	20.5	114.5481	------	------
29.5	101.0000	44.0	61.3333	21.0	103.8000	------	------
30.0	101.8333	44.5	59.3333	21.5	103.5481	------	------
30.5	100.6667	45.0	57.6667	22.0	93.2000	------	------
31.0	102.5714	45.5	57.7500	22.5	91.2370	------	------
31.5	106.0000	46.0	59.0000	23.0	83.4296	------	------
32.0	106.0000	------	------	23.5	80.8536	------	------
32.5	108.0000	------	------	24.0	68.8000	------	------

Table 2. The cross sections, $^{74}_{32}$Ge(γ, 2n) $^{72}_{32}$Ge reaction as a function of gamma energy.

$^{74}_{32}Ge(\gamma,2n)^{72}_{32}Ge$	
Gamma-energy (MeV)	Cross-section (mb)
17.0	0.4444
17.5	8.9704
18.0	22.5778
18.5	32.7259
19.0	36.2370
19.5	46.0667
20.0	42.7444
20.5	48.7926
21.0	43.1429
21.5	41.5148
22.0	42.0000
22.5	37.6222
23.0	36.7667
23.5	40.1179
24.0	32.2111
24.5	31.7889
25.0	25.1519
25.5	24.0704
26.0	23.2000

Table 3. The cross sections of $^{74}_{32}$Ge(α,p)$^{77}_{33}$AS reaction as a function of alpha energy.

$^{74}_{32}Ge(\alpha,p)^{77}_{33}AS$			
Alpha energy (MeV)	Cross-section (mb)	Alpha energy (MeV)	Cross-section (mb)
13	3.6182	27.5	19.1818
13.5	4.9136	28.0	17.8182
14.0	6.2091	28.5	17.1833
14.5	7.5045	29.0	17.6417
15.0	8.8000	29.5	18.1000
15.5	10.3882	30.0	16.5583
16.0	11.9765	30.5	15.0167
16.5	13.5647	31.0	14.4231
17.0	15.2235	31.5	14.4615
17.5	16.9294	32.0	14.5000
18.0	18.6353	32.5	14.1667
18.5	20.1111	33.0	13.8333
19.0	20.6667	33.5	13.5000
19.5	21.2222	34.0	13.1667
20.0	21.7778	------	------
20.5	22.5625	------	------
21.0	23.5000	------	------
21.5	24.4375	------	------
22.0	25.2857	------	------
22.5	26.0000	------	------
23.0	26.7143	------	------
23.5	26.3571	------	------
24.0	25.2857	------	------
24.5	24.2143	------	------
25.0	22.8571	------	------
25.5	21.4286	------	------

26.0	20.0000	------	------
26.5	20.0000	------	------
27.0	20.0000	------	------

Figure 2. The $^{74}_{32}$Ge (α,x) $^{76}_{33}$AsreactionThe germanium-74, which contains an equal nucleus that interacts with alpha particles that carry a range of energies (18.5-46.00 MeV) is 2.8056 - 59.0000 mb respectively and obtain the highest cross section value (108.00 mb) in 32.5 Me. **Figure 2.** And above this energy, the cross section is reduced, in addition to the value of the narrowed passageways between 28.0-37.0MeV (82.0000 - 83.6000mb) in that order offers a high reaction possibility to Arsenic production with an atomic number of (Z= 33) and mass number (A=76) these data are **Table 1.** This element is very important in the industrial field. When mixed with lead it produces a very strong and solid metal, which can be used in car batteries and bullets. Arsenic is also used in the glass industry It is also used in improving bullet bullets and in fireworks to give additional color to the flame. Gallium arsenide is used in a laser that transforms electricity into coherent light. It is also used to increase efficiency in transistors. Arsenic compounds are used as a medical insecticide, previously used in the treatment of skin problems such as psoriasis, but have recently been phased out because they cause cancer. In order for the human body to maintain a healthy nervous system and to grow well, it needs a rate of 0.00001%**.**

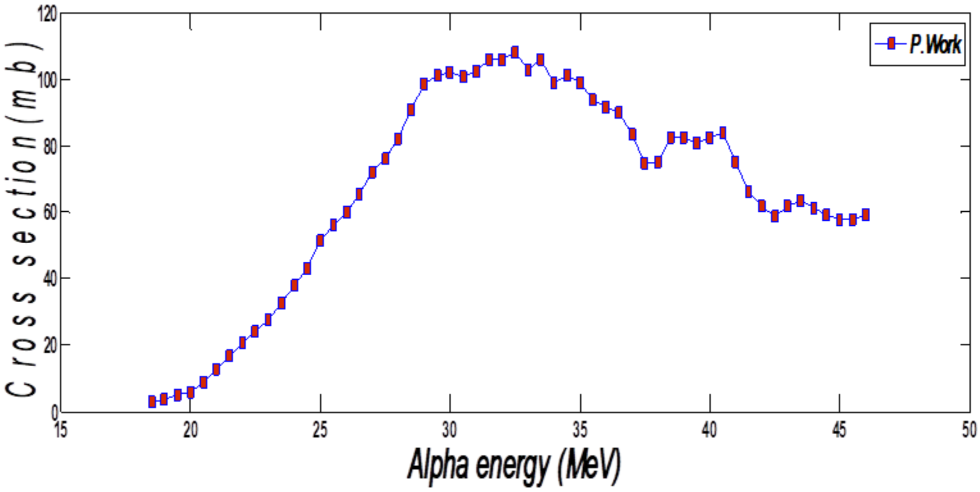

Figure 2. The cross section of $^{74}_{32}$Ge(α,$^{2}_{1}$H)$^{76}_{33}$As reaction by fitting and interpolation.

Figure 3. The $^{74}_{32}$Ge(α,3n)$^{75}_{34}$Se reaction Germanium's 74 cross-section contains an equal nucleus that interacts with alpha particles and carries a range of energies (28.0 - 46.00 MeV), (0.1425 - 0.7430 MB) and the highest value of the cross section is (1.0640 MB) in power (40.5MeV) as displayed in **Figure 3.** And The cross section is reduced at a higher level of this energy and the narrow path value is also reduced between (38.5 - 40.5MeV) and (1.0308 - 1.0640 mb) in that order, giving a high likelihood of interaction on Selenium production with an atomic number (Z = 34) (A= 75), these data are demonstrated in **Figure 3.** Selenium has a great role in preventing fat oxidation, thus protecting the immune system, preventing the formation of free cracks that negatively affect the body and destroy it. Selenium protects against certain types of cancer, works with vitamin E to help produce antibodies and maintains heart and liver safety. The body needs small amounts of it enough for the human body, but it is important for the pancreas to function properly for its functions and tissue flexibility. When the amounts are added to vitamin E and zinc, its quality reduces prostate enlargement. Selenium has a close relationship with cancer and heart disease. Hippocampi a leads to fatigue, poor growth, increased cholesterol levels, infection, liver and pancreatic degeneration and infertility.

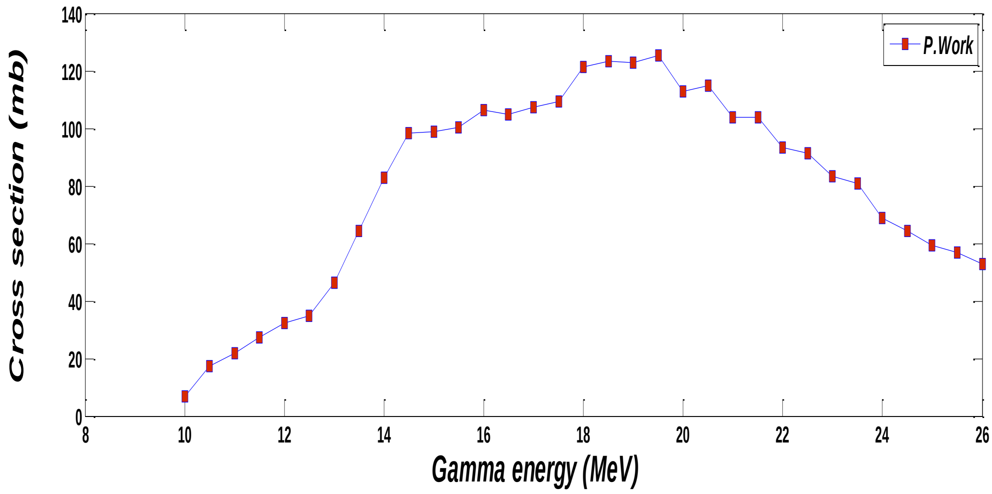

Figure 3. The cross section of $^{74}_{32}Ge$ (γ,x)0-NN-1reaction by fitting and interpolation.

Figure 3. The $^{74}_{32}$Ge(γ,2n) $^{72}_{32}$Ge reaction in the $^{74}_{32}$Ge(γ, 2n) $^{72}_{32}Ge$ reaction , Germanium-74, which contains an equaled nucleus that interacts with gamma rays. Cross-sectional ratings have a range of energies (17-26.0MeV) (0.4444-23.2000 MB), respectively. The highest cross section value is (48.7926 MB) 20.5MeV) as in **Figure 3.** At a higher level of this energy, the cross section is reduced. In addition to the cross-pass value between 19.5-23.5MV (46.0667- 40.1179 MB) respectively, Germanium with atomic number (Z = 32) and mass number (A = 72) these data are in **Figure 3.** Germanium Being a good semiconductor is considered one of the most commonly used materials with no significant and powerful properties. Germanium is used in the manufacture of devices such as diodes, solar batteries, transistors, and is also used in various infrared optical devices. Germanium improves the access of oxygen to the cells in the body in the medical field, helping to resist pain, maintain immune function and rid the body of toxins. It has also been shown that eating germanium foods is an effective catalyst for oxygen, similar to the consumption of germanium hemoglobin in terms of its function as an oxygen carrier of cells. Eating 100 to 300 mg of germanium metal daily has treated many conditions, including rheumatoid arthritis, food allergies, high blood cholesterol, Candida, chronic viral infections, and even AIDS and cancer, according to a Japanese scientist. It also found that this element strengthens the immune system and helps the body to get rid of toxins. Also helps in the treatment of some types of allergies and suitable for the treatment of some types of wounds and burns. It also improves the lack of discipline in the menstrual cycle, as well as eczema, sore throat, mouth ulcers, insect pests and even headaches.

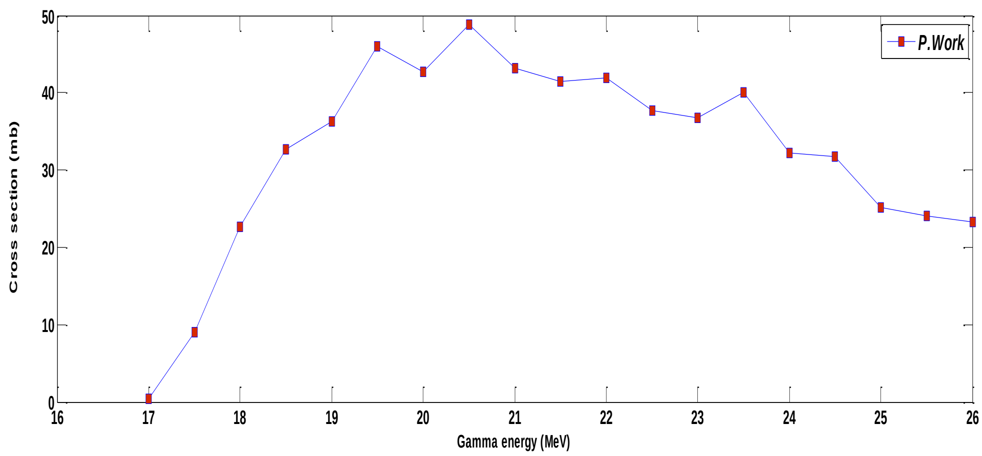

Figure 3. The cross section of $^{74}_{32}$Ge(γ,2n)$^{72}_{32}$Ge reaction by fitting and interpolation.

Figure 4. The $^{74}_{32}Ge$(α,p)$^{77}_{33}AS$ reactionGermanium-74 contains an equal nucleus, and its cross-section is a function of alpha molecules that have a range of energies (13-34.0MeV) and (3.6182-13.1667 MB). The highest value of the cross sections is (26.7143mb) in the energy of (23.0MeV), as displayed in **Figure 4.** The cross section is reduced at a higher level of this energy, in addition to the narrowed arc value between 18.5 - 27.0MeV (20.1111 - 20.0000mb), This gives a high possibility of reaction of Arsenic production with atomic number (Z = 33) and mass number (A = 77). These data are **Table 3.**

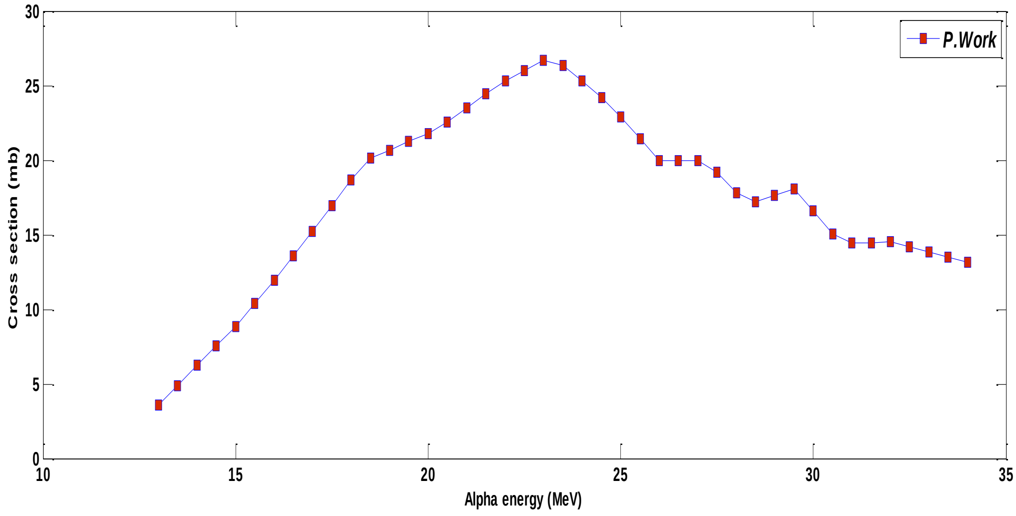

Figure 4. The cross section of $^{74}_{32}Ge$(α, p)$^{77}_{33}As$ reaction by fitting and interpolation.

3. Conclusions and discussion

In the present study, some nuclear features of germanium isotopes used for various purposes have been studied through studying the transverse sections when reacting with charged particles such as alpha and proton molecules and their interaction with gamma rays, as well as studying the relative double deformation parameters to steadiness of the nucleus with other nuclei.

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