Calculation of partial and total cross sections for deferent atomic number at gamma energy range (10^{-3} -10^{5}) MeV

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Abstract:
This object of the present work was to determine the partial cross sections photoelectric interaction, coherent (Rayleigh) , incoherent (Compton) scattering and pair production (in nuclear field and in electron field) as well as total cross sections for deferent atomic number (20, 40, 60, 80, and 100) at gamma energy range (10^{-3} -10^{5} MeV), using XCOM code. Furthermore, the total cross section of Al, Fe and Pb at gamma energies (0.6616, 1.1732 and 1.3325 MeV) emitted from radioactive point sources ^{137}Cs and ^{60}Co were measured, using NaI(Tl) scintillation detector. The results obtained have showed that the calculated and measured partial and total cross section values are sensitive to the incident photon energy and atomic number of target material.
Keywords: Gamma ray cross sections, XCOM code, photon energy. scintillation detector
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1. Introduction

The attenuation of gamma radiation is due to three mechanisms (photoelectric effect, scattering and pair production) as it interacts with the atoms in a material. Photoelectric effect predominate at lower photon energies. Incoherent (Compton) scattering cross section refers to the interaction of photon with an individual electron, as distinguished from the coherent (Rayleigh) scattering of a photon with the collective electrons[1,2].

Pair production often refers specifically to a photon creating an electron–positron pair near a nucleus. As energy must be conserved, for pair production to occur, the incoming energy of the photon must be above a threshold of at least the total rest mass energy of the two particles created.

Pair production cross section is important only for high energy photons (in MeV region). In this process, the incident photon creating an electron–positron pair near a nucleus. The phenomenon is induced by the strong electric field in the vicinity of the nucleus and has a photon threshold energy at least the total rest mass energy of the two particles created $2m_eC^2$ (≈1.022 MeV). [1,3].

The Beer's law established the relationship between attenuated radiation intensity by a materials. It can be written as [1,4]:

$$I(x) = I_0 \; e^{-\mu \cdot x} \qquad (1)$$

Where I_0 and I are the incident and emergent gamma ray beam intensity respectively (count/sec), μ is the linear attenuation coefficient of the sample (cm^{-1}) and x is the thickness of the sample (cm).

The linear attenuation coefficient can be written as:

$$\mu_m = \frac{\mu}{\rho} \qquad (2)$$

where μ_m is mass attenuation coefficient (cm^2 /gm) and ρ is the density of the sample (gm/cm^3).

The total gamma cross section (σ_T) is defined from μ as [1,2]:

$$\sigma_T = \frac{\mu}{n} \qquad (3)$$

Where *n* is the atomic density (atom / cm^3) which is defined as[1,2]:

$$n = \frac{\rho}{a} N_a \qquad (4)$$

Where *a* is the atomic weight of the target material and N_a is the Avogadro's number (6.022×10^{23} mol^{-1}).
Mass attenuation coefficient (μ_m) of some elements and building materials have been performed by Gurdeep et al.[5], Akkurt et al.[6], Demir et al. [7], Teli et al.[8] Medhat [9] and Abbas et al. [10,11] .
It is very important to determine the partial and total cross sections because there parameters have a large influence the efficiency of nuclear applications. The aim of the present work use for calculating partial and total cross sections at gamma energy range (10^{-3} - 10^5 MeV) for different atomic number (20, 40, 60, 80 and 100) of the target material by XCOM code. Furthermore, total cross sections were measured for aluminum, iron and lead at gamma energy: 0.6616 ,1.1732 and 1.3325 MeV

2. Calculation code

The calculation of the partial and total cross sections for atomic number (Z= 20, 40, 60, 80, and 100) of the target material at photon energy range (10^{-3} - 10^5 MeV) has been performed by XCOM code version 3.1 developed by Berger M.J. and Hubbell J.H. 1999 [12].

3. Experimental setup

The schematic arrangement of the experimental setup used in the present work is shown in Fig.1. The source - sample and sample - detector were 8 cm and 12 cm respectively. Radioactive point sources used were ^{60}Co (1.1732 and 1.3325 MeV) with an activity 2.735 μci and ^{137}Cs (0.6616 MeV) with an activity 4.543 μci.
The intensity of gamma photons were measured by using NaI(Tl) scintillation detector (Saint- Gobain Crystals Bicron model 1.5M2/2 made in U.S.A.)
The detector was coupled with LD Didactic GmbH sensor-cassy for data acquisition. The radioactive source was surrounded by lead to collimate photons beam. The detector was put in a hole of lead to reduce the radiation background as low possible. The samples used in this experimental study were aluminum, iron and lead. The typical spectra of the radioactive sources (^{60}Co and ^{137}Cs) measured in this work are shown in Figs. (2 and 3).

4. Results and discussion

The results obtained have been shown in the tabular form in tables (1-4). The photoelectric cross sections data were presented in table1. It is quite clear that as photon energy decrease, the photoelectric cross section increase.
The variation of coherent and incoherent scattering cross sections vs. incident photon energy with different atomic number of target material was plotted in table2. It is seen that the coherent scattering cross sections greatly exceed incoherent scattering at low photon energy (below 0.01 MeV).
The pair production cross sections were presented in table 3. It is clear that the threshold energy of pair production in an electron field is about 3 MeV but the threshold energy of this phenomenon in nuclear field is $2m_eC^2$ (=1.022 MeV). Table 3 the pair

production cross section value increases with increasing atomic number of target material.

The variation of total cross sections vs. incident photon energy with different atomic number of target material were presented in table 4. It is important to see that the total cross sections are proportional with Z number of target material.

The experimental values of total cross section together with their theoretical values calculated by XCOM code for three gamma energies 0.6616, 1.1732 and 1.3325 MeV are shown in fig.8. The results obtained showed that the total cross section is sharply increased for Z ≥ 50.

The results of these calculations, at some gamma ray energies are compared with the results of [6,8] in Fig.4. It is seen that the two results agree very well.

5. Conclusions

The results obtained have showed that the calculated and measured cross section values are sensitive to the incident photon energy and atomic number of target material. The present results also have showed that the photoelectric cross section is more significant at gamma energy below 0.1 MeV. Also concluded that the incoherent scattering exceeds coherent scattering at gamma energy > 0.1 MeV.

From these results it could be concluded that the pair production cross section in an electron field was lower than pair production cross section in nuclear field, in general it has been found that after threshold energy, pair production cross section increases with photon energy, eventually approaching constant value at gamma energy ≥ 10MeV.

These results also showed that the absorber cross sections (photoelectric and pair production) were proportional with Z number of target material. It is quite clear from fig.4 that the calculated and measurement values obtained in this work were in agreement with results of other workers.

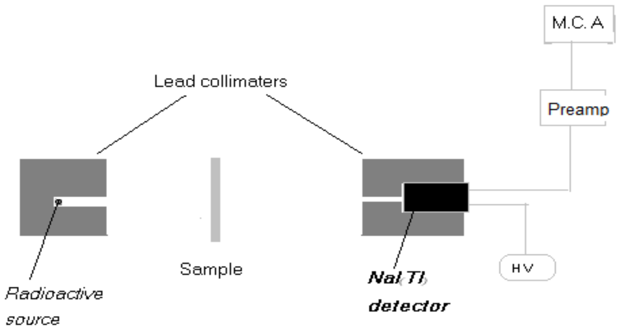

Fig.1. Scheme of the experimental setup.

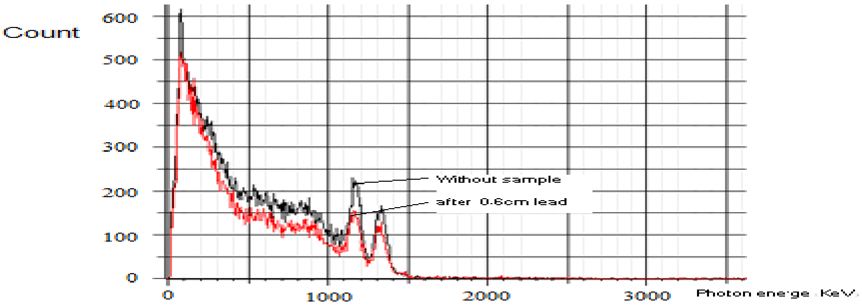

Fig.2:Energy spectra of gamma rays emitted from Co-60 without sample and after 0.6 cm lead.

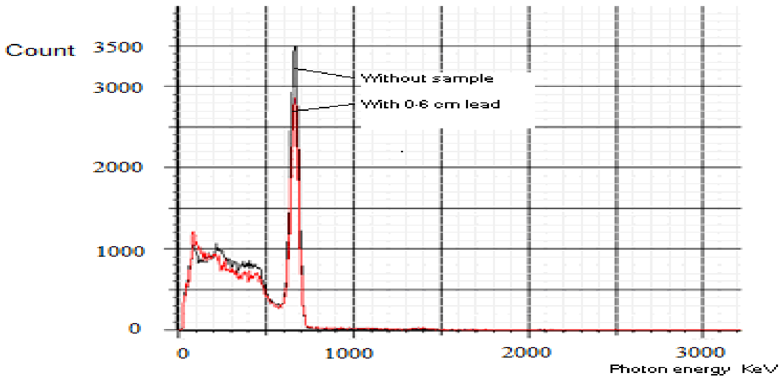

Fig.3: Energy spectra of gamma rays emitted from Cs-137 without sample and after 0.6 cm lead.

Table(1):Values of photoelectric absorption cross section(σ_{Ph}).

Photon Energy (MeV)	Z=20	Z=40	Z=60	Z=80	Z=100
	$\sigma_{Ph.}$ (barn)	$\sigma_{Ph.}$ (barn)	$\sigma_{Ph.}$ (barn)	$\sigma_{Ph.}$ (barn)	$\sigma_{Ph.}$ (barn)
0.001	3.236E+5	6.367E+5	1.585E+6	1.605E+6	3.039E+6
0.0015	1.138E+5	2.462E+5	1.261E+6	7.201E+5	1.838E+6
0.002	5.303E+4	1.221E+5	6.874E+5	3.905E+5	1.043E+6
0.003	1.764E+4	2.677E+5	2.601E+5	7.019E+5	4.279E+5
0.004	7.968E+3	1.282E+5	1.270E+5	3.896E+5	2.209E+5
0.005	3.998E+4	7.147E+4	7.169E+4	2.261E+5	4.128E+5
0.006	2.473E+4	4.395E+4	4.494E+4	1.437E+5	3.057E+5
0.008	1.141E+4	2.014E+4	9.709E+4	6.932E+4	1.631E+5
0.01	6.150E+3	1.090E+4	5.429E+4	3.903E+4	9.366E+4
0.015	1.937E+3	3.512E+3	1.845+4	5.489E+4	3.367E+4
0.02	8.349E+2	1.081E+4	8.437E+3	2.628E+4	1.611E+4
0.03	2.482E+2	3.669E+3	2.749E+3	8.989E+3	2.128E+4
0.04	1.033E+2	1.656E+3	1.228E+3	4.142E+3	1.028E+4
0.05	51.91	8.813E+2	3.827E+3	2.256E+3	5.775E+3
0.06	29.47	5.224E+2	2.373E+3	1.369E+3	3.588E+3
0.08	11.98	2.264E+2	1.087E+3	6.197E+2	1.682E+3
0.1	5.944	1.175E+2	5.865E+2	1.656E+3	9.311E+2
0.15	1.664	35.42	1.883E+2	5.702E+2	1.240E+3
0.2	0.680	15.17	83.97	2.647E+2	6.049E+2
0.3	0.199	4.707	27.42	91.13	2.216E+2
0.4	8.729E-2	2.126	12.78	43.92	1.114E+2
0.5	4.763E-2	1.184	7.261	25.53	66.68
0.6	2.987E-2	0.751	4.673	16.69	44.50
0.8	1.517E-2	0.386	2.433	8.842	24.15
1	9.431E-3	0.240	1.522	5.568	15.37
1.5	4.369E-3	0.110	0.702	2.561	7.085
2	2.708E-3	6.785E-2	0.426	1.549	4.276
3	1.482E-3	3.632E-2	0.225	0.810	2.222
4	1.003E-3	2.423E-2	0.148	0.531	1.447
5	7.539E-4	1.801E-2	0.109	0.389	1.056
6	6.021E-4	1.427E-2	8.633E-2	0.305	0.824
8	4.278E-4	1.002E-2	6.017E-2	0.211	0.567
10	3.310E-4	7.701E-3	4.597E-2	0.160	4.299
15	2.110E-4	4.856E-3	2.875E-2	9.982E-2	0.265
20	1.546E-4	3.359E-3	2.086E-2	7.215E-2	0.191
30	1.007E-4	2.291E-3	1.344E-2	4.630E-2	0.122

40	7.464E-5	1.693E-3	9.905E-3	3.405E-2	8.975E-2
50	5.929E-5	1.342E-3	7.841E-3	2.692E-2	7.087E-2
60	4.917E-5	1.112E-3	6.487E-3	2.225E-2	5.854E-2
80	3.666E-5	8.274E-4	4.822E-3	1.652E-2	4.342E-2
100	2.922E-5	6.589E-4	3.837E-3	1.314E-2	3.340E-2
150	1.939E-5	4.366E-4	2.540E-3	8.686E-3	2.279E-2
200	1.450E-5	3.264E-4	1.898E-3	6.488E-3	1.702E-2
300	9.646E-6	2.169E-4	1.261E-3	4.307E-3	1.129E-2
400	7.226E-6	1.624E-4	9.437E-4	3.224E-3	8.451E-3
500	5.777E-6	1.298E-4	7.541E-4	2.576E-3	6.751E-3
600	4.811E-6	1.081E-4	6.279E-4	2.145E-3	5.621E-3
800	3.606E-6	8.103E-5	4.705E-4	1.607E-3	4.211E-3
1000	2.884E-6	6.480E-5	3.762E-4	1.285E-3	3.366E-3
1500	1.922E-6	4.317E-5	2.506E-4	8.558E-4	2.242E-3
2000	1.441E-6	3.237E-5	1.879E-4	6.416E-4	1.681E-3
3000	9.604E-7	2.157E-5	1.252E-4	4.275E-4	1.120E-3
4000	7.202E-7	1.618E-5	9.390E-5	3.206E-4	8.398E-4
5000	5.761E-7	1.294E-5	7.511E-5	2.564E-4	6.718E-4
6000	4.801E-7	1.078E-5	6.259E-5	2.137E-4	5.598E-4
8000	3.600E-7	8.086E-6	4.694E-5	1.602E-4	4.198E-4
10000	2.880E-7	6.469E-6	3.755E-5	1.282E-4	3.358E-4
15000	1.920E-7	4.312E-6	2.503E-5	8.545E-5	2.238E-4
20000	1.440E-7	3.234E-6	1.877E-5	6.468E-5	1.679E-4
30000	9.66E-8	2.156E-6	1.251E-5	4.272E-5	1.119E-4
40000	7.200E-8	1.617E-6	9.385E-6	3.204E-5	8.393E-5
50000	5.760E-8	1.294E-6	7.508E-6	2.563E-5	6.714E-5
60000	4.800E-8	1.078E-6	6.257E-6	2.136E-5	5.595E-5
80000	3.600E-8	8.085E-7	4.692E-6	1.602E-5	4.196E-5
100000	2.880E-8	6.468E-7	3.754E-6	1.282E-5	3.357E-5

Note that 1barn=10^{-24} cm^2

Table(2):Values of Scattering cross section including coherent (Rayleigh) scattering (σ_{coh}) and incoherent (Compton) scattering (σ_{incoh}).

Photon Energy (MeV)	Z=20		Z=40		Z=60		Z=80		Z=100	
	$\sigma_{coh.}$ (barn)	$\sigma_{incoh.}$ (barn)	$\sigma_{coh.}$ (barn)	σ_{incoh} (barn)	$\sigma_{coh.}$ (barn)	σ_{incoh} (barn)	$\sigma_{coh.}$ (barn)	σ_{incoh} (barn)	$\sigma_{coh.}$ (barn)	σ_{incoh} (barn)
0.001	238.4	0.944	991.7	1.227	2252	1.585	4111	1.187	6392	1.670
0.0015	216.9	1.568	927.9	2.027	2130	2.452	3955	2.153	6139	2.794
0.002	197.2	2.063	864.2	2.748	2006	3.369	3772	3.105	5861	3.936
0.003	163.9	2.982	748.9	4.077	1766	5.141	3386	4.929	5290	6.718
0.004	136.5	3.804	650.9	5.278	1548	6.778	3019	6.664	4743	8.276
0.005	114.5	4.522	569.2	6.372	1361	8.259	3694	8.316	4249	10.21
0.006	97.48	5.319	502	7.363	1204	9.571	2412	9.897	3818	11.97
0.008	74.29	6.105	400	9.032	960.1	11.79	1963	12.81	3128	15.12
0.01	59.59	6.814	325.7	10.37	781.8	13.65	1626	15.29	2615	17.89
0.015	37.74	8.028	205	12.87	510.2	17.35	1073	19.94	1788	23.57
0.02	25.44	8.801	139.7	14.61	366.3	19.96	756.6	23.28	1303	27.65
0.03	13.70	9.576	78.99	16.67	213.5	23.06	446.2	27.81	772.5	32.92
0.04	8.66	9.853	51.26	17.7	138.9	24.68	297.3	30.46	516.8	36.09
0.05	6.016	9.922	35.72	18.2	98.65	25.56	211	31.98	376.2	38.07
0.06	4.424	9.889	26.28	18.39	74.08	26.01	157.9	32.83	284.9	39.29
0.08	2.670	9.677	16.02	18.29	46.06	26.21	99.26	33.43	179.2	40.32
0.1	1.779	9.388	10.85	17.93	31.29	25.92	68.46	33.32	124.4	40.37

0.15	0.833	8.641	5.236	16.67	15.24	24.52	33.7	31.91	62.85	39.90
0.2	0.481	7.994	3.065	15.65	9.050	23.02	20.09	30.15	37.76	37.06
0.3	0.218	7.007	1.415	13.84	4.250	20.50	9.579	27.01	18.19	33.38
0.4	0.124	6.299	0.811	12.49	2.454	18.58	5.592	24.55	10.76	30.44
0.5	0.0799	5.763	0.524	11.46	1.596	17.08	3.658	22.61	7.109	28.08
0.6	0.0556	5.337	0.366	10.63	1.119	15.86	2.577	21.04	5.045	26.15
0.8	0.0313	4.693	0.207	9.360	0.637	14.00	1.476	18.59	2.918	23.15
1	0.0201	4.222	0.133	8.427	0.410	12.61	0.954	16.77	1.900	20.90
1.5	0.0089	3.433	0.0595	6.859	0.183	10.28	0.430	13.68	0.864	17.07
2	4	2.930	0.0335	0	0.103	8.778	0.243	11.69	0.491	14.60
3	0.0050	2.306	0.0149	5.857	0.0462	6.912	0.108	9.21	0.220	11.51
4	3	1.924	0.00839	4.610	0.0260	5.768	0.0611	7.687	0.124	9.605
5	0.0022	1.661	0.00537	3.846	0.0166	4.982	0.0391	6.641	0.0799	8.298
6	3	1.469	0.00373	3.322	0.0157	4.404	0.0272	5.870	0.0555	7.336
8	0.0012	1.201	0.00209	2.936	0.0065	3.603	0.0153	4.803	0.0313	6.003
10	6	1.023	0.00134	2.402	0.0041	3.069	0.0098	4.091	0.0200	5.113
15	8.062E-	0.757	5.972E-	2.046	6	2.271	0	3.028	0.00891	3.785
20	4	2	4	1.514	0.0018	1.823	0.0043	2.431	0.00501	3.038
30	5.599E-	0.607	3.359E-	1.215	5	1.327	6	1.770	0.00223	2.212
40	4	8	4	0.884	0.0010	1.055	0.0024	1.406	0.00125	1.758
50	3.149E-	0.442	1.493E-	0.703	4	0.880	5	1.174	8.027E-	1.467
60	4	5	4	0.587	4.630E	0.758	0.0010	1.012	4	1.264
80	2.016E-	0.351	8.398E-	0.505	-4	0.598	9	0.797	5.757E-	0.997
100	4	6	5	0.398	2.604E	0.496	6.133E	0.662	4	0.827
150	8.958E-	0.293	5.375E-	0.331	-4	0.353	-4	0.471	3.136E-	0.589
200	5	5	5	0.235	1.667E	0.277	3.925E	0.369	4	0.462
300	5.039E-	0.252	3.732E-	0.184	-4	0.196	-4	0.262	2.007E-	0.327
400	5	9	5	0.131	1.157E	0.153	2.726E	0.205	4	0.256
500	2.240E-	0.199	2.099E-	0.102	-E	0.127	-4	0.169	8.919E-	0.212
600	5	4	5	0.084	6.510E	0.109	1.533E	0.145	5	0.181
800	1.260E-	0.165	1.244E-	9	-5	0.0852	-4	0.113	5.017E-	0.142
1000	5	5	5	0.072	4.167E	0.0700	9.813E	0.0934	5	0.116
1500	8.063E-	0.117	5.972E-	7	-5	0.0489	-5	0.0652	2.230E-	0.0815
2000	6	9	6	0.056	1.852E	0.0378	4.361E	0.0505	5	0.0631
3000	5.599E-	0.092	3.359E-	8	-5	0.0263	-5	0.0351	1.254E-	0.0490
4000	6	4	6	0.046	1.042E	0.0203	2.453E	0.0271	5	0.0338
5000	3.149E-	0.065	1.493E-	7	-5	0.0166	-5	0.0221	8.027E-	0.0277
6000	6	5	6	0.032	4.630E	0.0141	1.090E	0.0188	6	0.0235
8000	2.016E-	0.051	8.297E-	6	-6	0.0108	-5	0.0144	5.574E-	0.0181
10000	6	3	7	0.025	2.604E	0.0088	6.133E	0.0118	6	0.0147
15000	8.958E-	0.042	5.374E-	2	-6	6	-6	0.0081	3.136E-	0.0102
20000	7	4	7	0.017	1.667E	0.0061	3.925E	7	6	0.0078
30000	5.039E-	0.036	3.372E-	5	-6	2	-6	0.0062	2.007E-	5
40000	7	3	7	0.013	1.157E	0.0047	2.726E	8	6	0.0054
50000	2.239E-	0.028	2.099E-	5	-6	1	-6	0.0043	8.919E-	1
60000	7	4	7	0.011	6.510E	0.0032	1.533E	3	7	0.0041
80000	1.260E-	0.023	1.344E-	0	-7	4	-6	0.0033	5.017E-	5
10000	7	3	7	0.009	4.167E	0.0024	9.813E	2	7	0.0033
0	8.062E-	0.016	5.972E-	39	-7	9	-7	0.0027	2.230E-	8
	8	3	8	0.007	1.852E	0.0020	4.361E	0	7	0.0028
	5.599E-	0.012	3.359E-	24	-7	3	-7	0.0022	1.254E-	6
	8	6	8	0.005	1.042E	0.0017	2.453E	9	7	0.0021
	3.149E-	0.008	1.493E-	91	-7	1	-7	0.0017	8.027E-	9
	8	71	8	0.004	4.630E	0.0013	1.090E	5	8	0.0017

	2.015E-8 8.958E-9 5.039E-9 2.239E-9 1.260E-9 8.062E-10 5.599E-10 3.149E-10 2.015E-10 8.958E-11 5.039E-11 2.239E-11 1.260E-11 8.062E-12 5.599E-12 3.149E-12 2.015E-12	0.00677 0.00554 0.00469 0.00362 0.00295 0.00204 0.00157 0.00108 8.316E-4 6.772E-4 5.724E-4 4.389E-4 3.571E-4	8.397E-9 5.374E-9 3.732E-9 2.099E-9 1.244E-9 5.972E-10 3.359E-10 1.493E-10 8.397E-11 5.374E-11 3.732E-11 2.099E-11 1.344E-11	08 0.00314 0.00216 0.00166 0.00135 0.00114 8.77E-4 7.142E-4	-8 2.604E-8 1.667E-8 1.157E-8 6.510E-9 4.167E-9 1.852E-9 1.042E-9 4.630E-10 2.604E-10 1.667E-10 1.157E-10 8.000E-11 4.167E-11	1 0.001071	-7 6.133E-8 3.925E-8 2.726E-8 1.533E-8 9.813E-9 4.361E-9 2.453E-9 1.090E-9 6.133E-10 3.925E-10 2.726E-10 1.533E-10 9.813E-11	0.00142	5.574E-8 3.136E-8 2.007E-8 8.919E-9 5.017E-9 2.230E-9 1.254E-9 8.027E-10 5.574E-10 3.136E-10 2.007E-10	8

Table(3): Pair production cross sections in nuclear field (σ_{pnucl})and in electron field (σ_{pele}) .

Photon Energy (MeV)	Z=20		Z=40		Z=60		Z=80		Z=100	
	$\sigma_{pnucl.}$ (barn)	$\sigma_{pele..}$ (barn)	σ_{pnucl} (barn)	σ_{pele} (barn)	σ_{pnucl} (barn)	σ_{pele} (barn)	σ_{pnucl} (barn)	σ_{pele} (barn)	$\sigma_{pnucl.}$ (barn)	σ_{pele} (barn)

0.00	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0
0.00	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
0.00	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
0.00	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
0.00	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
0.00	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
0.00	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
0.00	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
0.01	0	0	0	0	0	0	0	0	0	0
0.01	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
0.02	0	0	0	0	0	0	0	0	0	0
0.03	0	0	0	0	0	0	0	0	0	0
0.04	0	0	0	0	0	0	0	0	0	0
0.05	0	0	0	0	0	0	0	0	0	0
0.06	0	0	0	0	0	0	0	0	0	0
0.08	0	0	0	0	0	0	0	0	0	0
0.1	3.569E	0	1.880E	0	5.553E	0	0.128	0	0.215	0
0.15	-3	0	-2	0	-2	0	0.578	0	1.099	0
0.2	1.878E	0	9.018E	0	0.256	0	1.756	0	3.157	0
0.3	-2	8.070E	-2	1.613E	0.838	2.417E	3.882	3.218E	6.339	4.018E
0.4	7.323E	-4	0.322	-3	2.049	-3	5.604	-3	8.707	-3
0.5	-2	3.295E	0.857	6.582E	3.092	8.955E	7.046	1.312E	10.68	1.636E
0.6	0.205	-3	1.343	-3	3.988	-3	8.288	-2	12.31	-2
0.8	0.330	6.564E	1.767	1.311E	4.758	1.961E	10.37	2.609E	15.19	3.253E
1	0.440	-3	2.137	-2	6.054	-2	12.09	-2	17.61	-2
1.25	0.539	1.008E	2.765	2.011E	7.121	3.008E	15.42	3.999E	22.37	4.984E
1.5	0.706	-2	3.282	-2	9.165	-2	17.81	-2	25.83	-2
2	0.842	1.699E	4.247	3.365E	10.61	5.058E	21.13	6.717E	30.71	8.362E
3	1.095	-2	4.932	-2	12.61	-2	23.39	-2	34.04	-2
4	1.277	2.335E	5.891	4.648E	13.97	6.936E	25.07	9.202E	36.52	0.114
5	1.531	-2	6.542	-2	14.98	-2	26.38	-2	38.45	0.177
6	1.706	3.657E	7.024	7.258E	15.77	0.108	28.30	0.143	41.28	0.225
8	1.836	-2	7.399	-2	16.93	0.137	29.65	0.181	43.28	0.294
10	1.938	4.685E	7.954	9.273E	17.75	0.180	31.78	0.238	46.40	0.342
15	2.090	-2	8.349	-2	19.06	0.211	33.04	0.277	48.26	0.377
20	2.199	6.202E	8.976	0.122	19.84	0.234	34.51	0.306	50.43	0.406
30	2.376	-2	9.352	0.143	20.75	0.252	35.35	0.329	51.67	0.447
40	2.484	7.292E	9.789	0.158	21.28	0.279	35.90	0.364	52.48	0.478
50	2.611	-2	10.04	0.171	21.62	0.299	36.29	0.389	53.06	0.527
60	2.686	8.313E	10.21	0.190	21.87	0.331	36.81	0.429	53.83	0.557
80	2.736	-2	10.33	0.204	22.20	0.352	37.15	0.454	54.33	0.594
100	2.772	8.804E	10.48	0.227	22.41	0.377	37.64	0.485	55.04	0.615
150	2.820	-2	10.59	0.242	22.72	0.392	37.90	0.503	55.44	0.630
200	2.851	9.834E	10.73	0.260	22.89	0.402	38.19	0.515	55.84	0.641
300	2.897	-2	10.82	0.270	23.07	0.410	38.34	0.524	56.10	0.655

400	2.922	0.106	10.90	0.278	23.17	0.420	38.44	0.536	56.25	0.657
500	2.949	0.118	10.95	0.283	23.23	0.427	38.51	0.544	56.35	0.680
600	2.964	0.127	10.98	0.291	23.27	0.438	38.59	0.556	56.48	0.688
800	2.973	0.137	11.00	0.296	23.33	0.444	38.65	0.569	56.56	0.697
1000	2.979	0.144	11.03	0.304	23.36	0.450	38.73	0.570	56.67	0.702
1500	2.988	0.148	11.04	0.308	23.41	0.454	38.77	0.574	56.74	0.705
2000	2.99	0.151	11.07	0.313	23.44	0.456	38.81	0.577	56.79	0.708
3000	3.001	0.156	11.08	0.316	23.47	0.458	38.83	0.578	56.84	0.711
4000	3.005	0.159	11.09	0.318	23.48	0.460	38.85	0.581	56.86	0.713
5000	3.009	0.164	11.10	0.319	23.49	0.462	38.86	0.582	56.87	0.715
6000	3.011	0.167	11.11	0.321	23.50	0.464	38.87	0.584	56.88	0.717
8000	3.012	0.170	11.11	0.322	23.51	0.465	38.88	0.586	56.90	0.718
1000	3.013	0.172	11.11	0.323	23.51	0.466		0.587		0.719
0	3.015	0.173	11.11	0.324		0.466		0.588		0.720
1500	3.015	0.174		0.325		0.467		0.588		0.720
0		0.175		0.325		0.467		0.588		0.720
2000		0.176		0.326		0.467		0.589		0.721
0		0.176		0.326		0.468		0.589		
3000		0.177		0.326						
0		0.178		0.326						
4000		0.178								
0		0.178								
5000		0.178								
0		0.178								
6000		0.178								
0										
8000										
0										
1000										
00										

Table(4):Values of the total cross section(σ_T)

Photon Energy (MeV)	Z=20	Z=40	Z=60	Z=80	Z=100
	σ_T. (barn)	σ_T. (barn)	σ_T (barn)	σ_T. (barn)	σ_T. ((barn)

0.001	3.238	6.377	1.587	1.609	3.045
0.0015	E+5	E+5	E+6	E+6	E+6
0.002	1.140	2.471	1.263	7.241	1.844
0.003	E+5	E+5	E+6	E+5	E+6
0.004	5.323	1.230	6.894	3.943	1.049
0.005	E+4	E+5	E+5	E+5	E+6
0.006	1.781	2.685	2.619	7.053	4.332
0.008	E+4	E+5	E+5	E+5	E+5
0.01	8.108	1.289	1.286	3.926	2.257
0.015	E+3	E+5	E+5	E+5	E+5
0.02	4.010	7.205	7.333	2.288	4.171
0.03	E+4	E+4	E+4	E+5	E+5
0.04	2.843	4.446	4.615	1.461	3.095
0.05	E+4	E+4	E+4	E+5	E+5
0.06	1.149	2.055	9.806	7.130	1.662
0.08	E+4	E+4	E+4	E+4	E+5
0.1	6.216	1.124	5.509	4.067	9.629
0.15	E+3	E+4	E+4	E+4	E+5
0.2	1.983	3.73E	1.898	5.598	3.548
0.3	E+3	+4	E+4	E+4	E+4
0.4	8.691	1.096	8.823	2.706	1.744
0.5	E+2	E+4	E+3	E+4	E+4
0.6	2.715	3.765	2.986	9.463	2.209
0.8	E+2	E+3	E+3	E+3	E+4
1	1.218	1.725	1.392	4.470	1.083
1.5	E+2	E+3	E+3	E+3	E+4
2	6.785	9.352	3.951	2.499	6.189
3	E+1	E+2	E+3	E+3	E+3
4	4.378	5.671	2.472	1.560	3.912
5	E+1	E+2	E+3	E+3	E+3
6	2.433	2.607	1.159	7.524	1.902
8	E+1	E+2	E+3	E+2	E+3
10	1.711	1.463	6.437	1.758	1.096
15	E+1	E+2	E+2	E+2	E+3
20	1.114	5.742	2.281	6.358	1.494
30	E+1	E+1	E+2	E+2	E+3
40	9.155	3.388	1.160	3.149	1.342
50	7.425	E+1	E+2	E+2	E+3
60	6.511	1.996	5.217	1.277	6.797
80	5.891	E+1	E+1	E+2	E+2
100	5.423	1.543	3.381	7.406	2.732
150	4.740	E+1	E+1	E+1	E+2
200	4.252	1.317	2.594	5.180	1.526
300	3.465	E+1	E+1	E+1	E+2
400	3.011	1.175	2.165	4.031	1.019
500	2.516	E+1	E+1	E+1	E+2
600	2.260	9.954	1.707	2.891	7.569
800	2.110	8.801	E+1	E+1	E+1
1000	2.020	7.120	1.454	2.329	5.022

1500 2000 3000 4000 5000 6000 8000 10000 15000 20000 30000 40000 50000 60000 80000 100000	1.925 1.889 1.883 1.932 2.036 2.131 2.211 2.279 2.388 2.471 2.613 2.704 2.814 2.811 2.927 2.960 3.005 3.034 3.078 3.102 3.128 3.143 3.152 3.158 3.167 3.172 3.180 3.184 3.188 3.190 3.191 3.192 3.194 3.194	6.281 5.520 5.228 5.125 5.111 5.213 5.384 5.839 6.244 6.901 7.390 7.771 8.077 8.544 8.885 9.440 9.779 1.018 E+1 1.041 E+1 1.057 E+1 1.069 E+1 1.083 E+1 1.093 E+1 1.107 E+1 1.115 E+1 1.123 E+1 1.128 E+1 1.131 E+1 1.133 E+1 1.136 E+1 1.137 E+1 1.140 E+1 1.141 E+1	E+1 1.142 E+1 1.015 E+1 9.235 9.044 9.116 9.290 9.774 1.031 E+1 1.157 E+1 1.259 E+1 1.413 E+1 1.525 E+1 1.610 E+1 1.579 E+1 1.781 E+1 1.855 E+1 1.975 E+1 2.047 E+1 2.133 E+1 2.183 E+1 2.215 E+1 2.239 E+1 2.271 E+1 2.291 E+1 2.321 E+1 2.337 E+1 2.355	E+1 1.725 E+1 1.524 E+1 1.401 E+1 1.390 E+1 1.414 E+1 1.453 E+1 1.547 E+1 1.644 E+1 1.870 E+1 2.050 E+1 2.319 E+1 2.511 E+1 2.658 E+1 2.774 E+1 2.948 E+1 3.071 E+1 3.269 E+1 3.387 E+1 3.526 E+1 3.606 E+1 3.659 E+1 3.696 E+1 3.746 E+1 3.779 E+1	E+1 3.817 E+1 2.612 E+1 2.252 E+1 2.030 E+1 1.990 E+1 2.015 E+1 2.058 E+1 2.188 E+1 2.329 E+1 2.929 E+1 3.334 E+1 3.623 E+1 3.844 E+1 4.018 E+1 4.277 E+1 4.462 E+1 4.754 E+1 4.930 E+1 5.136 E+1 5.255 E+1 5.333 E+1 5.389 E+1 5.463 E+1 5.512 E+1

		1.142 E+1 1.143 E+1 1.144 E+1 1.144 E+1 1.144 E+1 1.144 E+1	E+1 2.364 E+1 3.370 E+1 2.374 E+1 2.380 E+1 2.383 E+1 2.388 E+1 2.391 E+1 2.394 E+1 2.395 E+1 2.396 E+1 2.397 E+1 2.398 E+1 2.398 E+1	3.826 E+1 3.851 E+1 3.880 E+1 3.894 E+1 3.904 E+1 3.911 E+1 3.919 E+1 3.924 E+1 3.932 E+1 3.936 E+1 3.940 E+1 3.942 E+1 3.944 E+1 3.945 E+1 3.946 E+1 3.947 E+1	5.580 E+1 5.619 E+1 5.658 E+1 5.684 E+1 5.698 E+1 5.708 E+1 5.721 E+1 5.729 E+1 5.740 E+1 5.747 E+1 5.751 E+1 5.765 E+1 5.758 E+1 5.759 E+1 5.760 E+1 5.762 E+2

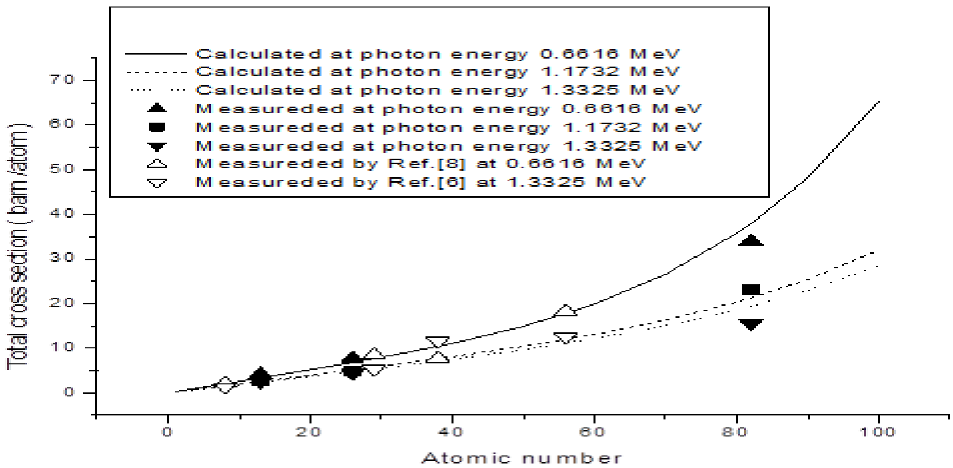

Figure 4: Vareiation of total cross section with atomic number of target material at different photon energy.

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