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Electron Impact Excitations of $_{92}$U, $_{93}$Np, $_{94}$Pu, $_{95}$Am, $_{96}$Cm, $_{97}$Bk atoms N_i Subshell İonization Cross Sections Calculated by Using Lotz's Equation

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Abstract

Nonrelativistic N shell (σ^{nrel}_N) and N σ^{nrel}_{Ni} (i = 1,..,7) subshells ionization cross sections by electron impact on $_{92}$U, $_{93}$Np, $_{94}$Pu, $_{95}$Am, $_{96}$Cm, $_{97}$Bk *atoms calculated. By using Lotz' equation in Matlab(σ^{nrel}_N) and N σ^{nrel}_{Ni} cross section values obtained for 14 electron impact(E_0) values in the range of $E_{Ni}<E_0<7E_{Ni}$ for each atom. Starting from $E_0=E_{Ni}$(subshell ionization threshold energies), σ^{nrel}_N and σ^{nrel}_N are increasing rapidly with E_0. For about fixed (E_0 =*3,33 to 3,45keV*), while Z value increases from $_{92}U \leq Z \leq {}_{97}Bk$ atoms; σ^{nrel}_N and σ^{nrel}_{Ni} decrease. Results show that for smaller values of E_0(close to E_{Ni}), x-ray yields formation of N_i (i =1,...,7) subshells decreases while competing other yields are increase. Results may help to understand similar findings which obtained from other electron impact excitation of N σ^{nrel}_N, subshells σ^{nrel}_{Ni} studies for single atoms.*

Keywords: *Nonrelativistic σ^{nrel}_N, subshells σ^{nrel}_{Ni} subshells ionization cross sections calculations for* $_{92}$U, $_{93}$Np, $_{94}$Pu, $_{95}$Am, $_{96}$Cm, $_{97}$Bk, $_{98}$Cf *atoms, Near Ni subshells threshold region, Electron impact.*

1. Introduction

N subshell Inner-shell ionization cross section measurements or calculations of atoms by electron impact are subjects of ongoing research for many years [1-7, 13-14, 16, 17-23]. For the measurement of accurate and reliable electron impact ionization cross sections of atomic inner subshells, a multi-purpose electron-atom crossed beam system must be used. Due to the complexity of the physical process, during the measurements some uncertainty may occur. There are still less systematic theoretical studies on the subject. Inner shell ionization cross section studies help us to understand, Auger electron spectroscopy, x-ray source characterization of target atoms, astrophysics, fusion plasma physics, radiation protection, design of medical instrument, electron, photon bombardment of tissues with energy transfer in the study required [3, 4, 5..]. In this study, N shell and N_i subshells ionization cross section σ^{nrel}N and σ^{nrel}_{Ni}(i=1,..7) of $_{92}$U, $_{93}$Np, $_{94}$Pu, $_{95}$Am, $_{96}$Cm, $_{97}$Bk, atoms are calculated. For all atoms E_{0i}(i=1,.,14) electron impact values were chosen in the E_{Ni} < E_{0i} < $7.E_{Ni}$ range where E_{Ni} ionization energy of i^{th} N_i subshells for each atom. As a result of an electron impact on free neutral atom, ionization may occur at one of N_i subshells of that atom. Creation of electron holes in N_i subshells depends on how big the impact electron energy E_0 compare to E_{Ni} (i=1, 2, 3). If an atom A bombarded by an electron with sufficiently big E_0 under E_{Ni} < E_0 conditions, then neutral atom becomes excited ions A^{+*}. In addition to the scattered electron, probably an electron is ejected with specific energy from the proper subshell respectively. Ni subshells are also emits photons which characterize the characteristic x-rays of N_i subshells of that atom. The sum of the intensity of the characteristic x-rays, the ionization probability of the occurrence of the event that σ is a measure of the cross section. Lotz put forward a semi-empirical formula at [1-4], for calculation of ionization cross sections for low energetic electrons impact excitation of free atoms at inner shells which was based on Born Approximation [6]. Lotz added a correction factor as a multiplier to the Bethe formula for developing Lotz's equation [1-4]. After Lotz, Pessa and Newell also used Lotz's equation for σ^{nrel}_{Ntotal} and for σ^{nrel}_{Ni} subshells ionization cross sections calculations for near ionization threshold electron impact energies of several atoms [4, 6]. Calculations carried out by using Lotz's equations in Matlab program [3, 4, 5, 6,7, 9]. E_{Ni} is the ionization energy of that Ni subshells. Calculations done for σ^{nrel}_{Ntotal} and for σ^{nrel}_{Ni} by using the following Lotz's equation:

$$\sigma^{nrel}_{Ni} = a_i\, q_i \ln(E_0/E_i)/E_0E_i\, [1-b_i \exp(-c_i (E_0/E_i))] \quad (1)$$

a_i, b_i, c_i constants and q_i of the i^{th} subshell which were taken from Lotz [1-5]. q_i are the number of equivalent electrons at i^{th} N_i subshell and E_{Ni} is the ionization energy of the i^{th} subshell. The values of a_i, b_i, c_i and q_i are given in the same order for N_i(i=1,2,..7) subshells. Used values of a_i, b_i, c_i constants and

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of q_i given in Method section below [1-4, 6]. For selected 14 electron impact values, by using the Eq.1 and from sum of calculated seven $\sigma^{rel}{}_{Ni}$ of each atom, N shell $\sigma^{nonrel}{}_{Ntotal}$ calculated.

2. Method

Nonrelativistic N shell and N_i subshells σ^{nrelL} and $\sigma^{nrel}{}_{Ni}$ for $_{92}$U, $_{93}$Np, $_{94}$Pu, $_{95}$Am, $_{96}$Cm, $_{97}$Bk, $_{98}$Cf, $_{99}$Es, $_{100}$Fm $_{101}$Md, $_{102}$No, $_{103}$Lr atoms are calculated. Calculations done for 14 E_{0i}(i=1,2..,14) values which they chosen in energy range of $E_{N1i} \leq E_{0i} \leq 9.E_{N1i}$ for each atom. It means that for $_{92}$U used over all E_{0i} values fall in 0,45keV<E_0<4keV range. Used all energies in Matlab given in eV. E_{0i} values chosen according to the E_{N1i} of target atom which were taken from Gwyn and Porter [3, 19]. Calculations carried out by using written commands for Lotz's Eq.1 in MATLAB for each atom [1, 2, 3, 9-19]. The values of a_{Ni}, b_{Ni}, c_{Ni} parameters and q_{Ni} are given in the same order for N_i subshells as: For instance: a_{Ni} equal to (3, 2, 2,1,7 1,5…1,5.)10^{-14}cm^2(eV)^2; for b_{Ni} equal to (0.5, 0.92, 0,92, 0,7, 0,6…); for c_{Ni} equal to (0.6, 0.25, 0.19, 0,18,…); and for q_{Ni} equal to (2, 2, 4,1,6, 1,2…) similar values used [1-2,7,13-14]. By using the Eq.1 and using sum of calculated $\sigma^{nrel}{}_{Ni}$ subshell of each atom for 14 values of E_{0i} $\sigma^{nrel}{}_{Ltotal}$ of N shell calculated. Used N subshell electron binding energies given for $_{92}$U, $_{93}$Np, $_{94}$Pu, $_{95}$Am, $_{96}$Cm, $_{97}$Bk at Table.A in eV [3, 4]. N subshell binding energies fall between M_5 and O_1(2s.) subshells A. Electron impact energy values for each atom must be chosen between M_5(1s) shell and O_1(2s) subshell binding energies of that atom. For Ni subshell ionization; used any electron lost some parts of its energy as bremsstrahlung while incoming through atom and entering it, then passing O_i (i=1,2,..5) subshells.

Table.A: Used electron binding energies of E_{Ni}(i=1,..7) subshells of $_{92}$U, $_{93}$Np, $_{94}$Pu, $_{95}$Am, $_{96}$Cm, $_{97}$Bk, $_{98}$Cf, $_{99}$Es, $_{100}$Fm $_{101}$Md, $_{102}$No, $_{103}$Lr in eV [4,19].

Atom Z	E_{N7}	E_{N6}	E_{N5}	E_{N4}	E_{N3}	E_{N2}	E_{N1}
92U	1439	1271	1043	778	762	388	377
93Np	1502	1167	1095	818	764	410	405
94Pu	1560	1207	1170	822	800	435	425
95Am	1620	1248	1200	852	825	456	360
96Cm	1655	1283	1250	886	850	481	460
97Bk	1744	1345	1310	922	900	508	487
98Cf	1801	1392	1360	955	970	533	515
99Es	1870	1442	1415	989	965	560	545
100Md	1941	1496	1460	1029	1110	590	575
101Fm	2011	1546	1510	1073	1049	627	605
102No	2083	1597	1530	1100	1070	641	625
103Lr	2159	1650	1500	1144	1115	675	655

3. Results

Nonrelativistic calculations for $\sigma^{nrel}{}_N$ and $\sigma^{nrel}{}_{Ni}$ $_{92}$U, $_{93}$Np, $_{94}$Pu, $_{95}$Am, $_{96}$Cm, $_{97}$Bk atoms carried out for 14 electron impact energies. $\sigma^{nrel}{}_N$ and $\sigma^{nrel}{}_{Ni}$ of N_i shell results for 14 E_{0i} were given in Table.1 to 7 under the name of each atom. These are nonrelativistic data similar to our earlier study which were carried out for E_{0i} electron impact energy close to N subshell ionization threshold energy values of to $_{92}$U to $_{97}$Bk [13,14,17]. Each table includes nonrelativistic results for each atom. For the same atomic results also given as colored graphs in a figure which named as same as that atomic Table data. These graphs helps to compare how each subshells $\sigma^{nrel}{}_{Ni}$ depends at any value of E_{0i} energy at any atom nonrelativistic N shell $\sigma^{nrel}{}_{Ntotal}$ and N_i subshells $\sigma^{nrel}{}_{Ni}$ calculations for each atom: $\sigma^{nrel}{}_{Ni}$ values are given in (b) in Tables 1-6 and in Figs.1-6. There are some common charcteristics of $\sigma^{nrel}{}_{Ni}$: For each atom very close to threshold region; $\sigma^{nrel}{}_{N1}$ crosses $\sigma^{nrel}{}_{N2}$ and $\sigma^{nrel}{}_{N3}$ and crosses only $\sigma^{nrel}{}_{N3}$ at higher energies namely through end region of graphs.. Each $\sigma^{nrel}{}_{Ni}$ increases differently with electron impact energy. Z dependency of ionization cross sections for about fixed E_{0i} = 3,45 keV impact given in Table.7 and Figure7a, b. All each $\sigma^{nrel}{}_{Ni}$ decrease with atomic number 92≤ Z ≤97.

Table.1 Nonelativistic $\boldsymbol{\sigma}^{\mathbf{nrel}}{}_{Ni}$ Ni subshell ionization cross section of $_{92}$U in 10^5 b for 4E_0.

E_o(keV)	$\sigma_{N1}10^5$b	$\sigma_{N2}10^5$b	$\sigma_{N3}10^5$b	$\sigma_{N4}10^5$b	$\sigma_{N5}10^5$b	$\sigma_{N6}10^5$b	$\sigma_{N7}10^5$b	$\sigma_{Ntotal}10^5$b
0,45	-0,0854	-0,0693	-0,01379	-0,00137	-0,00197	0,0011	0,00075	-0,16998
0,8	-0,3044	-0,2313	-0,3353	0,0071	0,0189	0,3966	0,2633	-0,1851
1,15	-0,0828	-0,0373	0,0927	0,0863	0,1411	0,5476	0,3587	1,1063
1,45	0,0023	0,0411	0,2616	0,1277	0,2051	0,6273	0,4088	1,6739
1,65	0,0363	0,0735	0,3298	0,1481	0,2365	0,6654	0,4326	1,9222
1,85	0,0601	0,0969	0,3773	0,1647	0,2619	0,6951	0,4501	2,1061
2,05	0,0772	0,1141	0,4112	0,1783	0,2829	0,7181	0,4652	2,247
2,25	0,0897	0,1268	0,4351	0,1897	0,3004	0,7361	0,4761	2,3539
2,45	0,0991	0,1364	0,4521	0,1993	0,315	0,7498	0,4844	2,4361
2,65	0,1061	0,1438	0,4641	0,2074	0,3274	0,7601	0,4905	2,4994
2,9	0,1123	0,1504	0,4736	0,2158	0,3403	0,7692	0,4957	2,5573
3,2	0,1175	0,1558	0,4795	0,2239	0,3526	0,7755	0,4991	2,6039
3,6	0,1216	0,1599	0,4809	0,2321	0,3649	0,7781	0,4998	2,6373
4,0	0,1236	0,1617	0,4776	0,2379	0,3736	0,7756	0,4975	2,6475

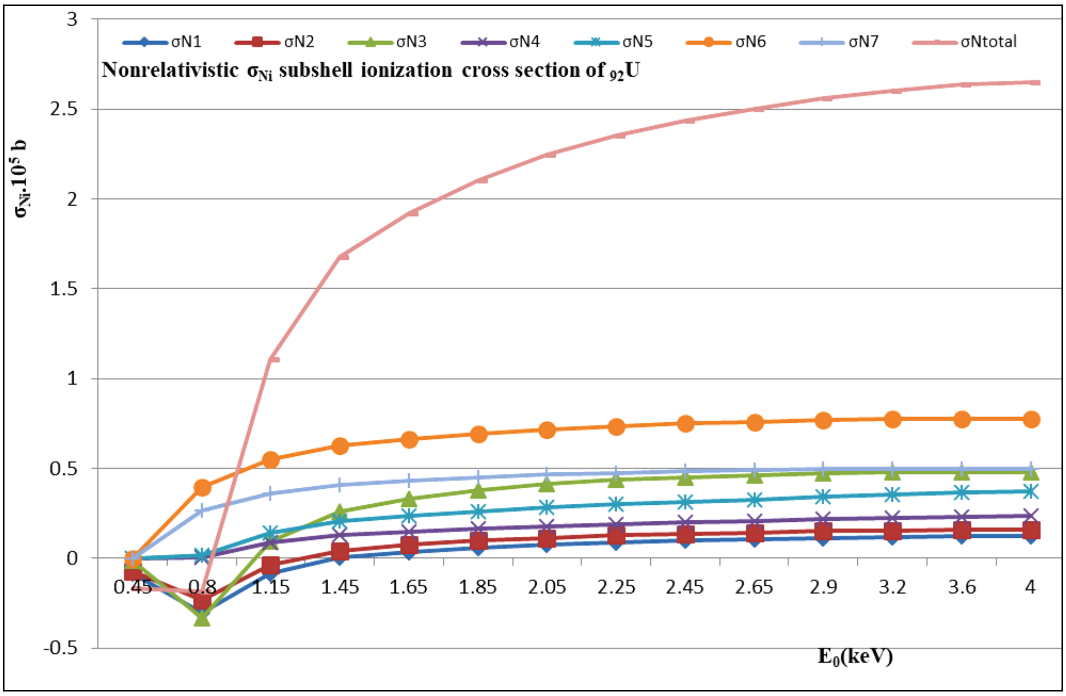

Fig 1a: Nonrelativistic $\sigma^{nrel}{}_{Ni}$ Ni subshell ionization cross section of ${}_{92}U$ in 10^5 b for $14E_0$.

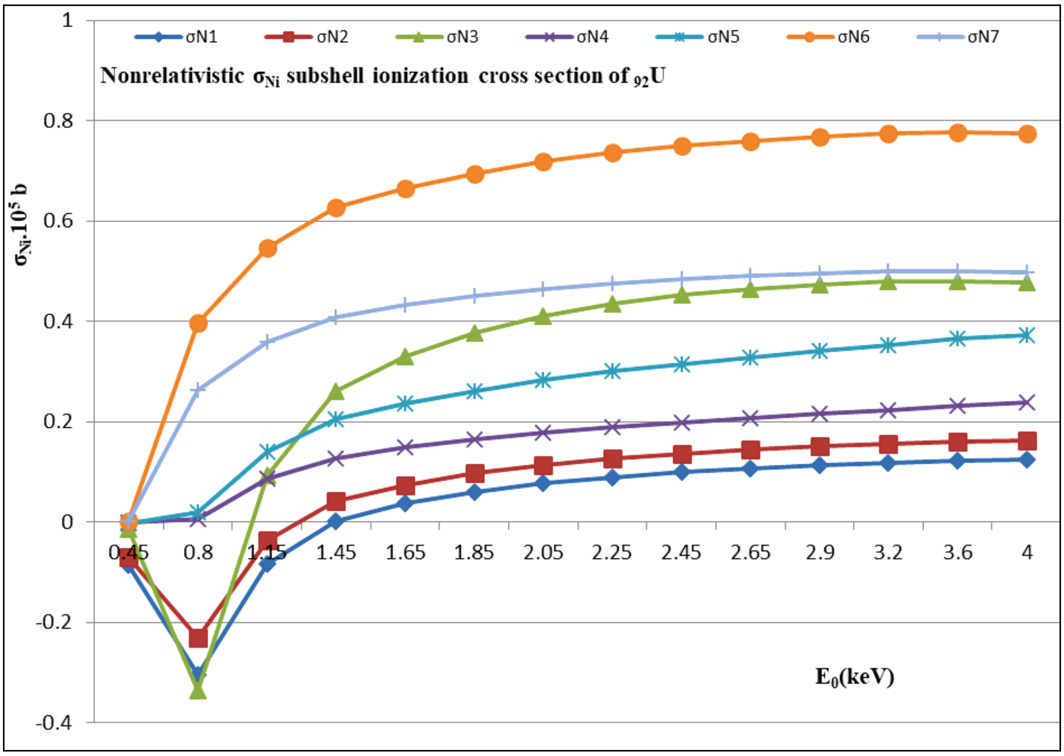

Fig 1b: Nonrelativistic $\sigma^{nrel}{}_{Ni}$ Ni subshell ionization cross section of ${}_{92}U$ in 10^5 b.

Table 2: Non relativistic σ^{nrel}_{Ni} Ni subshell ionization cross section of $_{93}$Np in 10^5 b for 14E0.

E0(keV)	σN1	σN2	σN3	σN4	σN5	σN6	σN7	σNtotal
0,5	-0,0854	-0,00693	-0,01379	-0,00137	-0,00197	0,0011	0,00075	-0,02221
0,8	-0,03122	-0,02087	-0,03744	-0,00051	0,00178	0,03322	0,02158	-0,00224
1,1	-0,01145	-0,0253	0,0042	0,0611	0,1263	0,4561	0,2944	0,9168
1,4	-0,0021	0,0647	0,1888	0,1024	0,1943	0,5355	0,3448	1,4305
1,7	0,0305	0,1151	0,2911	0,1312	0,2415	0,5896	0,3791	1,7476
2	0,0609	0,1455	0,3518	0,1524	0,2761	0,6273	0,4028	1,9559
2,3	0,0811	0,1645	0,3891	0,1686	0,3022	0,6538	0,4194	2,0976
2,6	0,0923	0,1765	0,4119	0,1812	0,3224	0,6721	0,4308	2,1949
2,9	0,1005	0,1841	0,4255	0,1911	0,3382	0,6842	0,4383	2,2614
3,1	0,1044	0,1874	0,4311	0,1965	0,3467	0,6897	0,4416	2,293
3,4	0,1085	0,1905	0,4354	0,2033	0,3571	0,6947	0,4446	2,3256
3,8	0,1118	0,1921	0,4362	0,2102	0,3675	0,6968	0,4456	2,3484
4,2	0,1135	0,1917	0,4333	0,2152	0,3747	0,6948	0,4441	2,3538
4,6	0,1141	0,1902	0,4281	0,2187	0,3795	0,6901	0,4407	2,3473

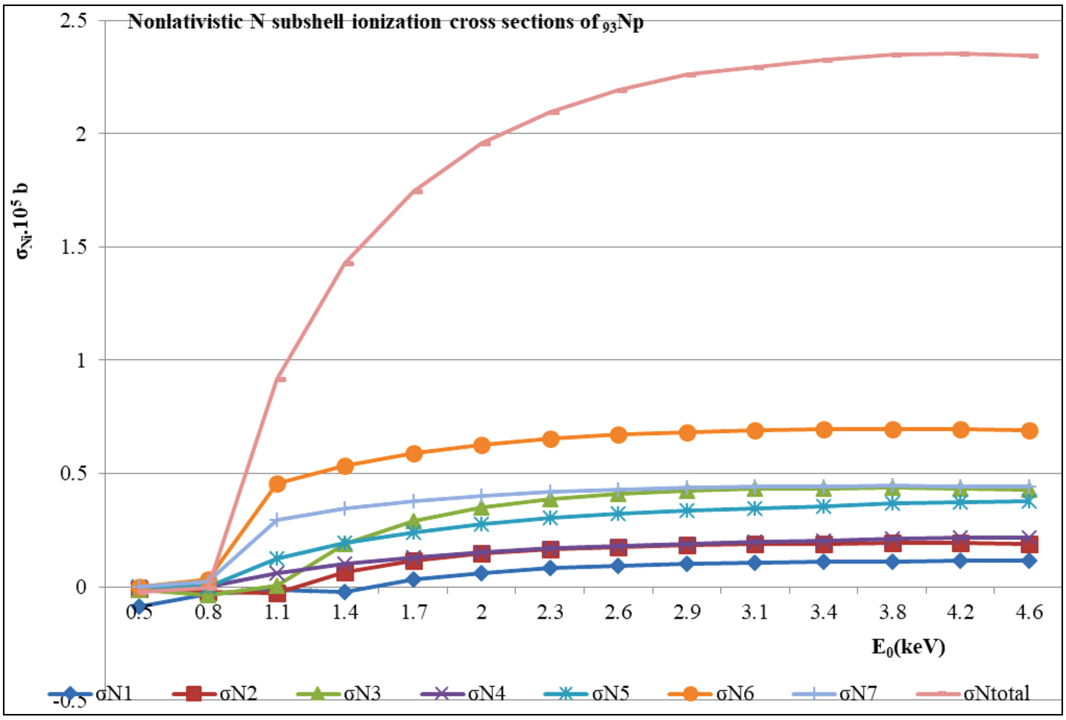

Fig 2a: Nonrelativistic σ^{nrel}_{Ni} Ni subshell ionization cross section of $_{93}$Np in 10^5 b.

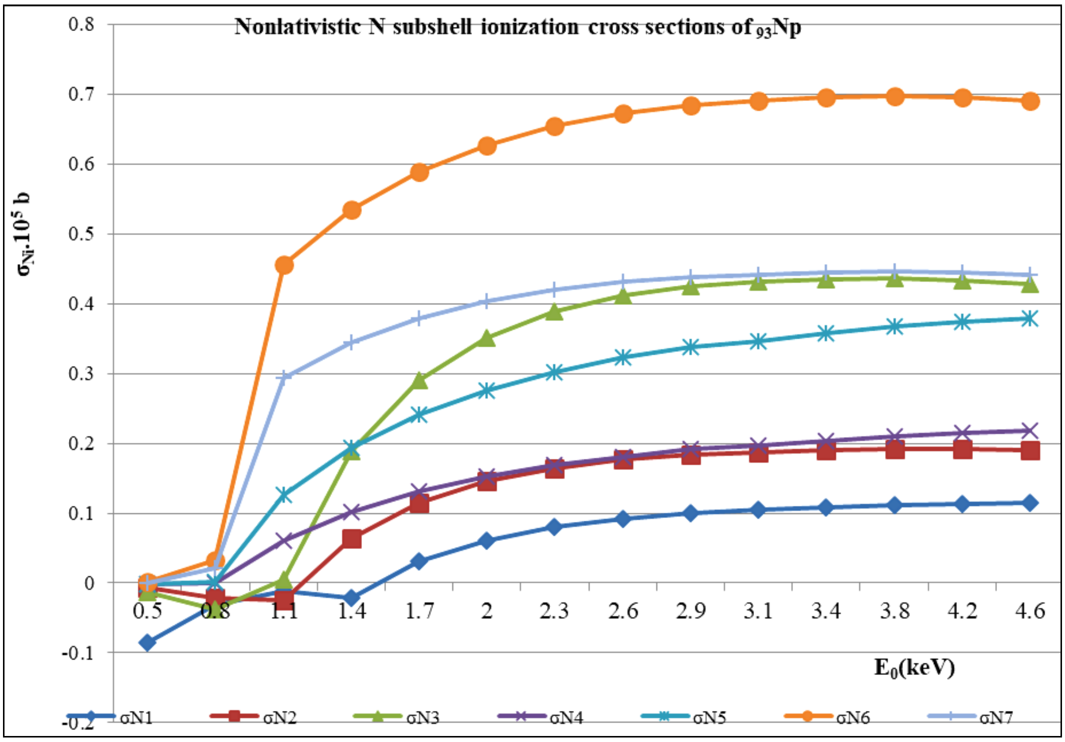

Fig 2b: Nonelativistic $\sigma^{nrel}{}_{Ni}$ subshell ionization cross section of of $_{93}$Np in 10^5 b.

Table.3: Non relativistic $\sigma^{nrel}{}_{Ni}$ Ni subshell ionization cross section of $_{94}$Pu in 10^5 b for 14E$_0$.

E_o(keV)	σ_{N1}	σ_{N2}	σ_{N3}	σ_{N4}	σ_{N5}	σ_{N6}	σ_{N7}	σ_{Ntotal}
0,55	-0,0071	-0,0057	-0,01135	-0,00106	-0,00155	0,00115	0,00086	-0,02475
0,9	-0,2343	-0,1417	-0,2631	0,0198	0,0404	0,3168	0,2238	-0,0383
1,2	-0,0854	-0,0022	0,0202	0,0751	0,1264	0,4139	0,2898	0,8378
1,5	-0,0104	0,0702	0,1669	0,1113	0,1826	0,4784	0,3335	1,3325
1,8	0,0321	0,1123	0,2515	0,1371	0,2225	0,5233	0,3638	1,6426
2,1	0,0581	0,1382	0,3033	0,1562	0,2523	0,5553	0,3852	1,8486
2,4	0,0746	0,1547	0,3361	0,1709	0,2751	0,5783	0,4004	1,9901
2,7	0,0856	0,1653	0,3568	0,1825	0,2929	0,5945	0,4111	2,0887
3	0,0929	0,1721	0,3697	0,1916	0,3069	0,6056	0,4182	2,157
3,3	0,0979	0,1763	0,3773	0,1989	0,3181	0,6129	0,4228	2,2042
3,6	0,1012	0,1786	0,3811	0,2047	0,3268	0,6171	0,4252	2,2347
4	0,1039	0,1796	0,3822	0,2106	0,3356	0,6191	0,4261	2,2571
4,4	0,1053	0,1791	0,3803	0,2148	0,3418	0,6176	0,4246	2,2635
4,8	0,1058	0,1776	0,3763	0,2177	0,3459	0,6139	0,4216	2,2588

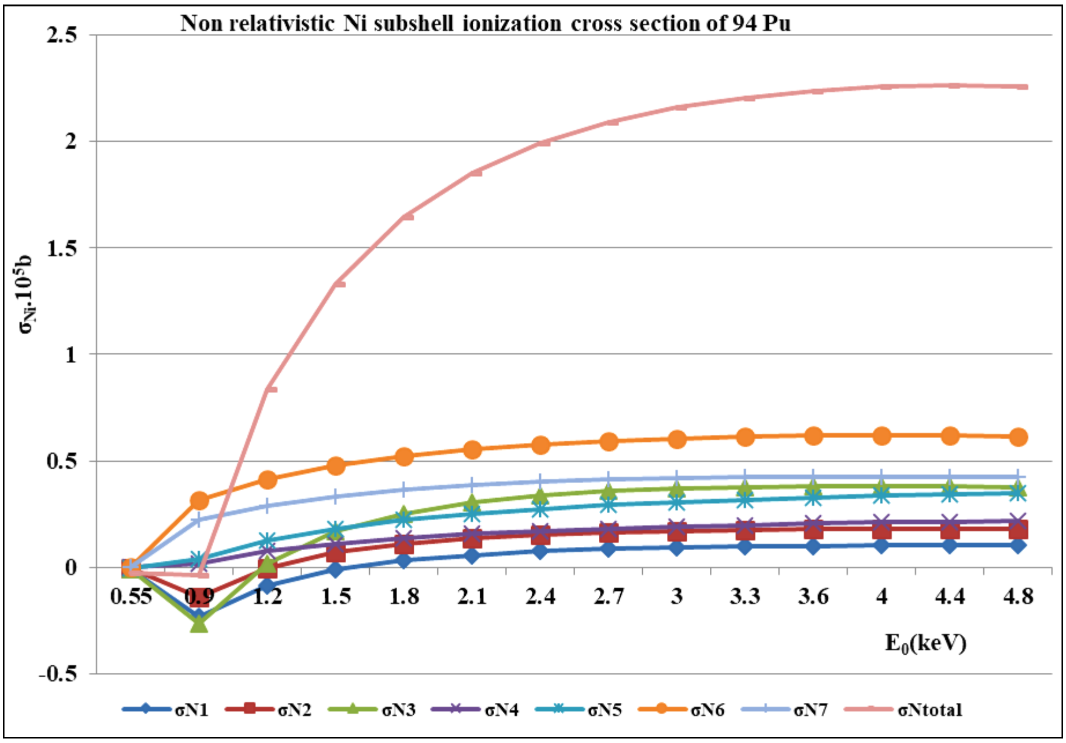

Fig 3a: Nonelativistic $\sigma^{nrel}{}_{Ni}$ subshell ionization cross section $_{94}$Pu in 10^5 b.

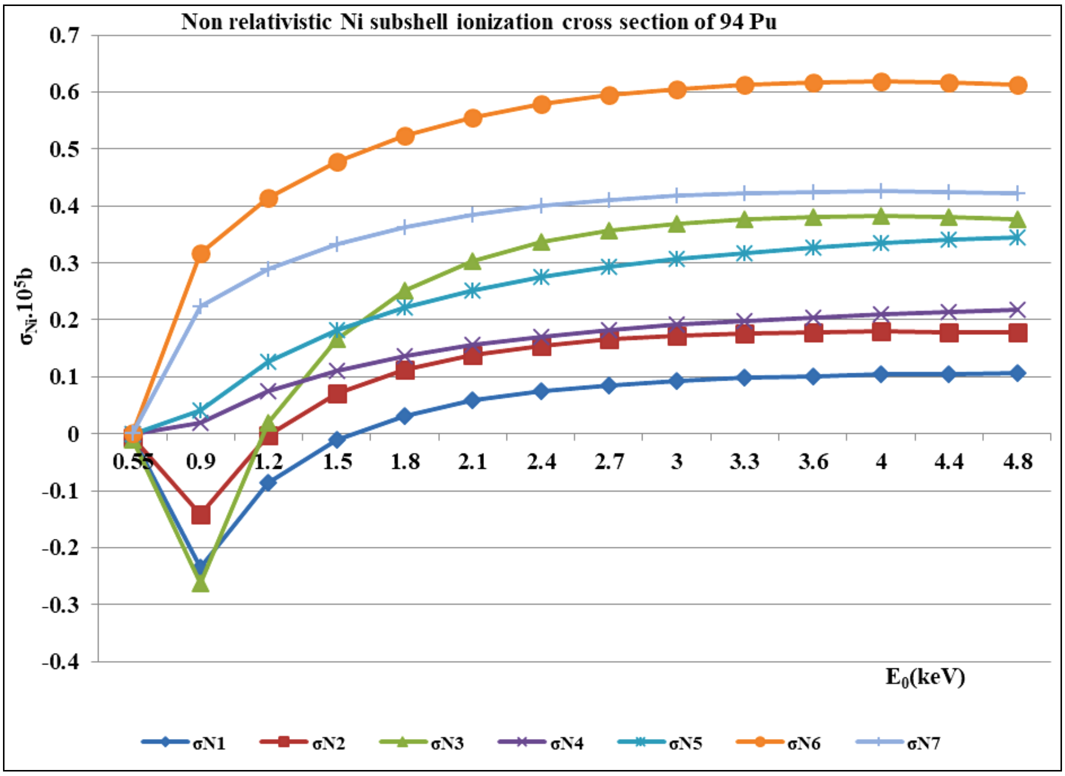

Fig 3b: Nonelativistic $\sigma^{nrel}{}_{Ni}$ subshell ionization cross section $_{94}$Pu in 10^5 b.

Table.4: Nonelativistic $\sigma^{nrel}{}_{N_i}$ subshell ionization cross section of of ${}_{95}$Am in 10^5 b.

E_0(keV)	$\sigma_{N1}.10^5$ b	$\sigma_{N2}10^5$ b	$\sigma_{N3}10^5$ b	$\sigma_{N4}10^5$ b	$\sigma_{N5}10^5$ b	$\sigma_{N6}10^5$ b	$\sigma_{N7}10^5$ b	$\sigma_{Ntotal}10^5$ b
0,6	-0,5981	-0,4748	-0,9405	-0,0846	-0,1213	0,1209	0,2243	-1,8741
0,9	-0,2406	-0,1517	-0,2797	0,0113	0,0284	0,2725	0,3668	0,007
1,2	-0,0938	-0,0145	0	0,0641	0,1109	0,3631	0,4501	0,8799
1,4	-0,0396	0,0376	0,1058	0,0884	0,1491	0,4059	0,4881	1,2353
1,7	0,0109	0,0871	0,2059	0,1157	0,1917	0,4536	0,5287	1,5936
2	0,0413	0,1172	0,2665	0,1358	0,2232	0,4878	0,5557	1,8275
2,3	0,0605	0,1365	0,3048	0,1512	0,2472	0,5127	0,5735	1,9864
2,6	0,0732	0,1491	0,3294	0,1633	0,2659	0,5307	0,5847	2,0963
3	0,0842	0,1592	0,3489	0,1756	0,2849	0,5471	0,5922	2,1921
3,4	0,0905	0,1648	0,3589	0,1848	0,2989	0,5567	0,5937	2,2483
3,8	0,0944	0,1673	0,3629	0,1916	0,3092	0,5618	0,5911	2,2783
4,2	0,0966	0,1681	0,3631	0,1966	0,3167	0,5633	0,5854	2,2898
4,6	0,0977	0,1674	0,3608	0,2002	0,3221	0,5621	0,5778	2,2881
5	0,0981	0,1659	0,3569	0,2028	0,3257	0,5591	0,5686	2,2771

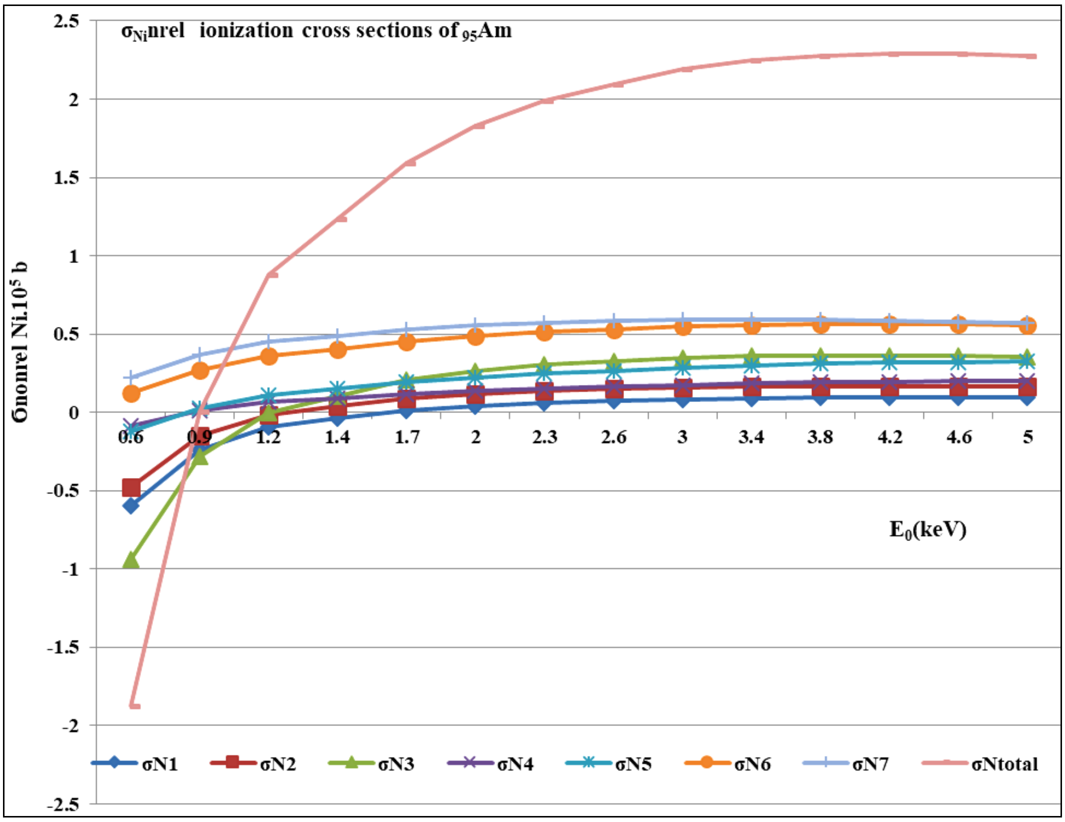

Fig 4a: Nonelativistic σ^{nrel} N_i subshell ionization cross section of of ${}_{95}$Am in 10^5 b.

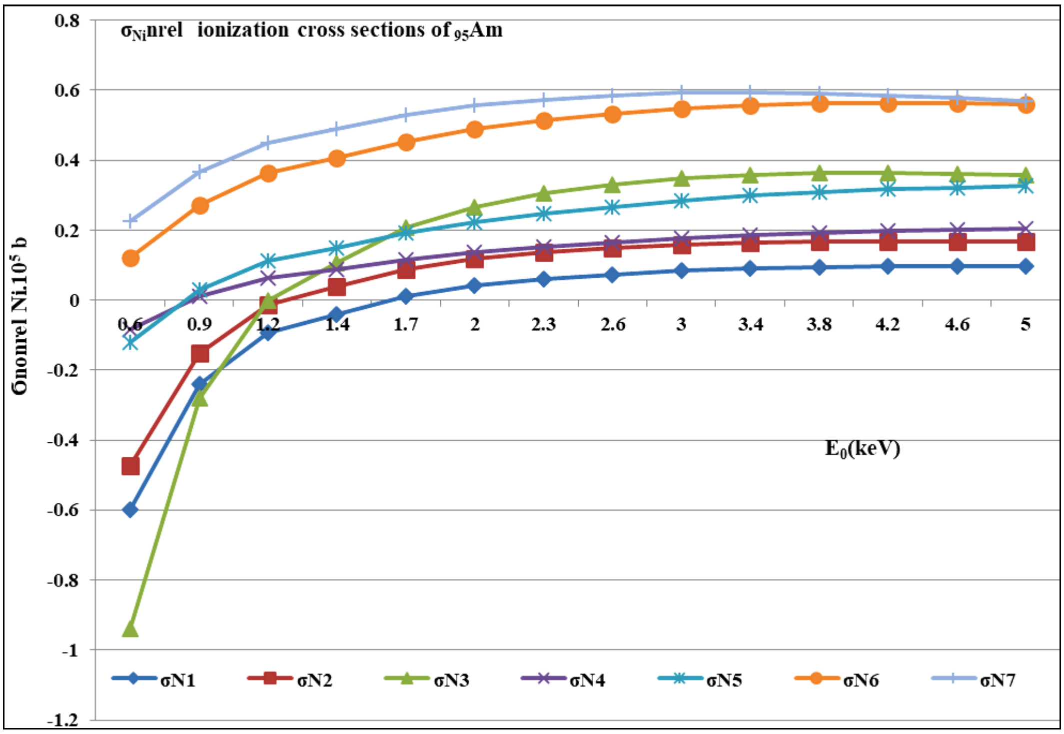

Fig 4b: Nonelativistic σ^{nrel} N_i subshell ionization cross section of of $_{95}$Am in 10^5 b.

Table.5: Nonelativistic σ^{nrel} N_i subshell ionization cross section of of $_{96}$Cm in 10^5 b.

E_o(keV)	σ_{N1}	σ_{N2}	σ_{N3}	σ_{N4}	σ_{N5}	σ_{N6}	σ_{N7}	σ_{Ntotal}
0,65	-0,5097	-0,3991	-0,7913	-0,0681	-0,0943	0,1184	0,0969	-1,6472
0,9	-0,2438	-0,1592	-0,3042	0,0031	0,0178	0,2284	0,1745	-0,2834
1,15	-0,1158	-0,0404	-0,0635	0,0463	0,0863	0,3006	0,2253	0,4388
1,45	-0,0339	0,0377	0,0943	0,0812	0,1416	0,3604	0,2672	0,9485
1,75	0,0121	0,0826	0,1851	0,1057	0,1804	0,4027	0,2966	1,2652
2,05	0,0401	0,1105	0,2409	0,124	0,2094	0,4334	0,3178	1,4761
2,4	0,0603	0,1308	0,2813	0,1402	0,2347	0,4592	0,3354	1,6419
2,75	0,0731	0,1433	0,3059	0,1524	0,2541	0,4773	0,3474	1,7535
3,15	0,0821	0,1518	0,3223	0,1631	0,2706	0,4912	0,3564	1,8375
3,55	0,0875	0,1564	0,3309	0,1711	0,2829	0,4998	0,3617	1,8903
3,95	0,0908	0,1585	0,3344	0,1771	0,2921	0,5045	0,3642	1,9216
4,35	0,0927	0,1591	0,3347	0,1816	0,2987	0,4987	0,3646	1,9301
4,75	0,0937	0,1583	0,3328	0,1849	0,3035	0,5057	0,3635	1,9424
5,2	0,0941	0,1568	0,3291	0,1875	0,3071	0,503	0,3608	1,9384

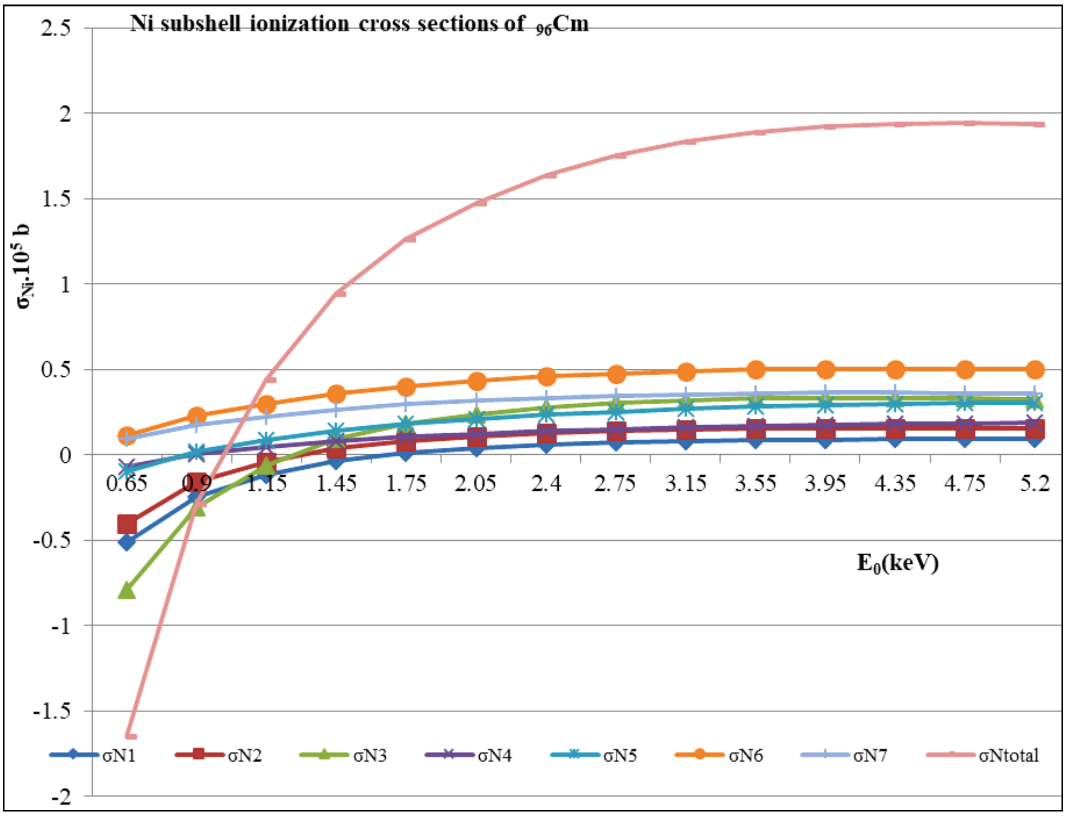

Fig 5a: Nonrelativistic σ^{nrel} Ni subshell ionization cross section of of $_{96}$Cm in 10^5 b.

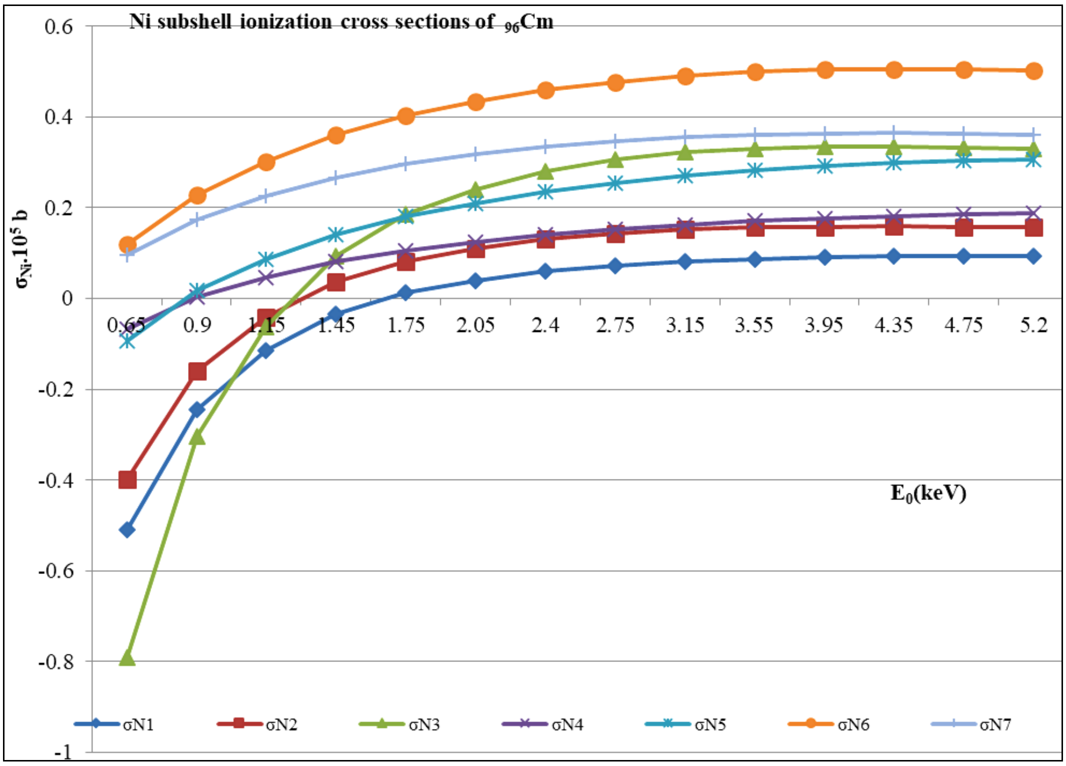

Fig 5b: Nonrelativistic σ^{nrel} Ni subshell ionization cross section of of $_{96}$Cm in 10^5 b.

Table.6: Nonrelativistic σ^{nrel} Ni subshell ionization cross section of of $_{97}$Bk in 10^5 b.

E_0(keV)	σN1	σN2	σN3	σN4	σN5	σN6	σN7	σNtotal
0,7	-0,1151	-0,0886	-0,1755	-0,0147	-0,0211	0,0352	0,0287	-0,3511
1	-0,04971	-0,03084	-0,05822	-0,00412	0,00835	0,07977	0,06146	0,00669
1,3	-0,0211	-0,0031	-0,0014	0,0173	0,0292	0,1211	0,0913	0,2333
1,6	-0,0136	0,0108	0,0295	0,0337	0,0439	0,1532	0,1229	0,3804
1,9	0,0094	0,0179	0,0465	0,0412	0,0582	0,1876	0,1493	0,5101
2,2	0,0117	0,0347	0,0764	0,0474	0,0772	0,2313	0,1738	0,6525
2,5	0,0156	0,0412	0,0921	0,0556	0,0883	0,2648	0,2013	0,7589
2,8	0,0211	0,0481	0,1043	0,0647	0,1049	0,3011	0,2246	0,8688
3,1	0,0244	0,0534	0,1154	0,0729	0,1181	0,3328	0,2488	0,9658
3,4	0,0272	0,0581	0,1252	0,0809	0,1307	0,3646	0,2722	1,0589
3,8	0,0305	0,0636	0,1367	0,0911	0,1471	0,4052	0,3021	1,1763
4,3	0,0339	0,0695	0,1491	0,1034	0,1667	0,4534	0,3373	1,3133
4,8	0,0368	0,0747	0,1611	0,1151	0,1854	0,4986	0,3703	1,442
5,3	0,0394	0,0792	0,1695	0,1263	0,2032	0,5411	0,4012	1,5599

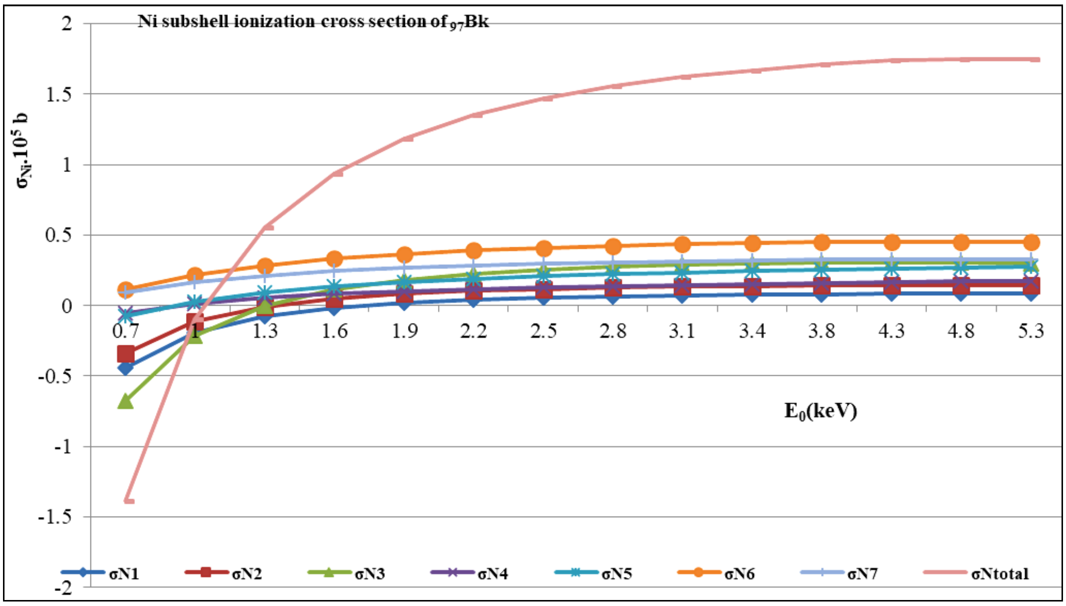

Fig 6a: Nonelativistic σ^{nrel} Ni subshell ionization cross section of of $_{97}$Bk in 10^5 b.

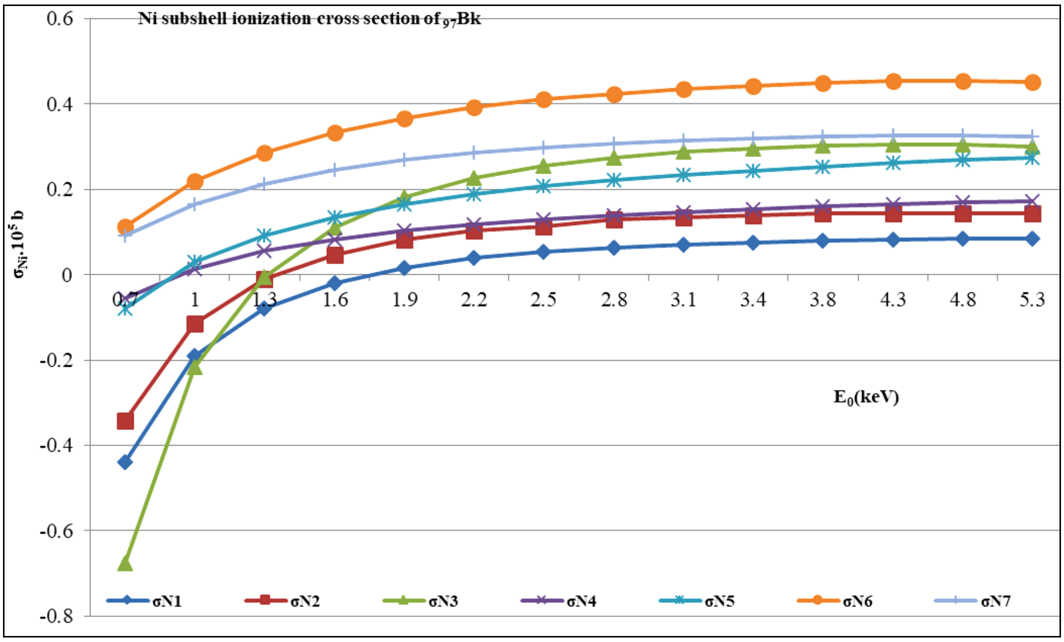

Fig 6b: Nonelativistic σ^{nrel} Ni subshell ionization cross section of of $_{97}$Bk in 10^5 b

Table.7: Z dependency of Ni subshell $\sigma^{nrel}{}_{Ni}$ of $_{95}$Am to $_{107}$Bh with about (3,33 to 3,45keV) electron impacts near N_{1i} thresholds of 6 atoms.

E0(keV)	Atom Z	$\sigma_{N1}10^5$b	$\sigma_{N2}10^5$b	$\sigma_{N3}10^5$b	$\sigma_{N4}10^5$b	$\sigma_{N5}10^5$b	$\sigma_{N6}10^5$b	$\sigma_{N7}10^5$b	$\sigma_{Ntot.}10^5$b
3,4	92U	0,1196	0,15785	0,48005	0,22751	0,35845	0,7758	0,4993	2,6185
3,4	93Np	0,1085	0,1905	0,43541	0,2033	0,3571	0,6947	0,4446	2,4258
3,3	94Pu	0,0979	0,1763	0,3773	0,1989	0,3181	0,6129	0,4228	2,2042
3,45	95Am	0,10821	0,14348	0,33073	0,18572	0,33703	0,34256	0,29739	1,74512
3,5	96Cm	0,09961	0,13452	0,30746	0,16617	0,30444	0,30347	0,26381	1,57948
3,4	97Bk	0,09007	0,13944	0,30096	0,15283	0,24322	0,26872	0,23574	1,43098

Figure.7a For fixed energy (3,33 to 3,45keV); Nonrelativistic $\sigma^{nrel}{}_{Ni}$ N_i(1,,.7) subshell ionization cross section of $_{92}$U to $_{107}$Bh in 10^5 b.

4. Conclusions

Nonrelativistic N shell $\sigma^{nrel}{}_{Ntotal}$ and N_i subshells $\sigma^{nrel}{}_{Ni}$ for $_{92}$U, $_{93}$Np, $_{94}$Pu, $_{95}$Am, $_{96}$Cm, $_{97}$Bk atoms results given in tables and figures under the name of each atom separately. Following each table, for the same atomic results also given as colored graphs in a figure. These graphs helps to compare how each subshells $\sigma^{nrel}{}_{Ntotall}$ and N_i subshells $\sigma^{nrel}{}_{Ni}$ depends at any value of E_{0i} electron impact energy. $\sigma^{nrel}{}_{N}$ values are given in (b) in Tables 1-6 and in Figs.1-6. There are some common charcteristics of $\sigma^{nrel}{}_{Ni}$: For each atom very close to threshold region; 1) Seven $\sigma^{nrel}{}_{Ni}$ For 1keV to about 2 keV electron impact of $_{92}$U as seeing at Figs.1a, and 1b: σ^{nrel} N_3 crosses the other cross sections in the following order (1,2,4,5: $\sigma^{nrel}{}_{N1}$ $\sigma^{nrel}{}_{N2}$ $\sigma^{nrel}{}_{N4}$ and $\sigma^{nrel}{}_{N5}$. But can not cross the $\sigma^{nrel}N_6$ and $\sigma^{nrel}N_7$. As seeing at Figs.2a and 2b for $_{93}$Pu atom: $\sigma^{nrel}{}_{N3}$; $\sigma^{nrel}{}_{N1}$, $\sigma^{nrel}{}_{N2}$, $\sigma^{nrel}{}_{N4}$, and 5. But $\sigma^{nrel}{}_{N5}$ but can not cross the $\sigma^{nrel}N_6$ and $\sigma^{nrel}N_7$ as seeing Fig 5b. For 95Cm $\sigma^{nrel}{}_{N3}$ crosses $\sigma^{nrel}{}_{N1}$, σ^{nrel} N_2,$\sigma^{nrel}{}_{N4}$; but can not cross the $\sigma^{nrel}{}_{N6}$ and $\sigma^{nrel}{}_{N7}$. at Figure 6b for $_{97}$Bk; $\sigma^{nrel}{}_{N3}$ crosses $\sigma^{nrel}{}_{N1}$ $\sigma^{nrel}{}_{N2}$ $\sigma^{nrel}{}_{N4}$ and $\sigma^{nrel}{}_{N5}$. But can not cross the $\sigma^{nrel}N_6$ and $\sigma^{nrel}N_7$. $\sigma^{nrel}{}_{N3}$ crosses the other cross sections in the this order for electron impact energy range of 1,0 to 2,2 keV. For higher energies namely through end region of graphs.. each $\sigma^{nrel}{}_{Ni}$ increases differently by E_0 impact energy. But it seems to subshell electrons responding impact electron in an accord. How much Auger and Coster-Cronig transitions effects to these $\sigma^{nrel}{}_{Ni}$ cross sections? For a fixed about E_{oi}=(3,3 to 3,45)keV, while Z value changes from $_{92}U \leq Z \leq _{97}$Bk $\sigma^{nrel}{}_{Ni}$ decrease with atomic number Z. It will be better if the presented results compared with single electron impact on single free atom experimental cross section measurements and with other calculations such as Distorted wave Born approximation (DWBA) and Modified Relativistic Bethe Born Approximations (MRBEB) [5-16,18,19-23].

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