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Numerical Simulation of X-Ray Photoelectric Absorption Coefficients for Some Metals at 2-100 keV Energies: Comparison Study

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The aim of this research is the calculation of the mass absorption coefficient which come from photoelectric absorption of absorption spectra of x-ray as a function of energy through theoretical analysis of x-ray mass absorption coefficient are calculated on various energies of photon from 2 keV to100 keV which incident on Al, Au, Cu, Fe and Pb. This gave information about the sample could be attained, or sample properties can be predicted to some extent. The absorption of x-rays measurement as a function of x-ray energy is a good way for understand many properties of absorption medium. In the plot which show the mass absorption coefficient μ/ρ as a function of the x-ray energy appeared that the mass absorption coefficient decreases when energy increase. All plot and calculation done by MATLAB -2014 program and some of the instructions of this program were used to determine the extent of compatibility between the results such as polyfit, polyval and table.

Keywords: Mass absorption coefficient; X-rays; Photoelectric effect; XCOM

1. Introduction

X-ray radiation is a shape of electromagnetic radiation. These rays were defined in 1895 by the German physicist Röntgen and were so called X-ray because their origin was unknown at the time. Unlike normal light, these rays were unseen, but they moved in straight lines and influence photographic film where it is put on method as light. Otherwise, they were so much permeation than light and could easily flow out of the human body, wood, so thick metal pieces, and other "occult" objects [1]. The range of X-rays wavelength below 0.01 nm to 10 nm, for energies which located in the range 120 eV to over 120 keV. Though γ-rays may have energy in the identical range, γ-radiation comes from a nucleus in an excited state and decays and nuclear transitions while X-rays are created by changing electron wave function energies, i.e., mostly atomic origin.

Heisenberg's uncertainty principle gives us results which is the nuclear states life time is usually much longer than that the electronic excited states, the lifetime is the main physical difference between electromagnetic γ-ray and photons of X-ray in the equal energy and for that the energy width of the transition $\Delta E\Delta t=h/2\pi$ [2]. As X-ray are photons for that this photon conceivable reaction with maters in three ways. These ways can clear as these phenomena:

- Compton scattering or incoherent,
- Photoelectric effect,
- Pair production

Fewer important ways called coherent or Rayleigh scattering also happen.

The kind of interaction that a photon has been mainly depended on its energy and the kinds of material during which it is permitting through it [3]. Photons absorbed or scattered may be happened as the product of interaction with a material. The characteristics of absorption is vanishing a photon. Scattered photons are swerve from the original direction with or without a decrease in energy. Thus the total probability that a process happens per unit absorber thickness is the sum of the probabilities of event of the many absorption and scattering processes. For all kind of absorption process resembles a process of scattering; the scattering may be observed as a combination of absorption and emission of a photon, the emission happening in other direction. The process which is most important at low energy of photon is the photoelectric effect, defined as the absorption of a photon with follow expulsion of an atomic electron [3,4]. Absorption can be treated as a loss in X-ray intensity loss of primary X-rays when they passing through matter. The intensity, of a monochromatic beam reduction exponentially according to:

$$I = I_{\circ} \exp(-\mu x) \quad (1)$$

In Eq. (1), the linear absorption coefficient is indicated by μ(cm^{-1}), denotes the average number of absorption and scattering processes which one photon passes through an absorber *x* cm thick [5]. In other word X-rays are attenuated when they permit through matter. That is, the intensity of X-ray beam decreases when increase it penetrates into matter. Fundamentally, the atom electrons of the material which are absorbed X-ray photons, decreasing the spreading intensity of X-

ray. The two factors on which the decrease in the intensity of the X-ray beam depends are:

- Penetration depth (t) or thickness.
- The fundamental properties of matter, which are called the attenuation or absorption cross-section, σ=uMμ, (barns per atom).

Here u is the atomic mass unit (1.67377×10^{-27} kg = 1/12 of the mass of an atom of the nuclide 12C), and M is the relative atomic mass of the target element, and μ is the linear attenuation or absorption. The mass attenuation or absorption coefficient [μ/ρ]. The amount generally observed in material property tables. In the strict sense of the word, attenuation and absorption have two obviously different meanings. We can denote to attenuation by beam loss, which may contain scattering is forwarding of beam and/or loss of partial energy, but absorption is conversion of all energy of photon to another particle such as electron or others, mostly it is photoelectric effects. These two coefficients are related by the material density ρ as $[\mu/\rho]\rho=\mu$. The relation between the intensity and the distance travelled is decreases exponentially or $I=I_0$ where I_0 is the intensity of x-ray beam initial. This photon intensity exponential decay by put on in the electromagnetic spectrum optical region also and was initially definite forattenuation0f optical photon. Which it is called by the Beer-Lambert law. The Beer-Lambert law (or Beer's law, August Beer - German physicist) is a linear relationship between absorbance and thickness (or concentration) of an absorbing type [2]. The states of Lambert's law: the absorbance A are directly proportional with light pathlength d in a homogenous medium while by increasing absorbing medium thickness the intensity of the emitted radiation decreases [6]. This law relates the light absorption to the matter passing through it. Also, the absorption of x-rays is associated to the material through which we can obtain through the derivation steps below [7]:

- The absorbed photons number ΔI at a given thickness Δx is relative to the intensity of incident rays I_0 and the matter thickness: ΔI proportional to $-I_0\Delta x$, where the minus sign point to a decrease intensity with the thickness.
- If A is a constant of proportionality, then the absorption coefficient can be written as $\Delta I=-AI_0\Delta x$
- Let the Δ become ultrafine small, we have, in differential notation, $dI=-AI_0dx$.
- By integrating from x=0 to a depth x, we get $I = I_0e^{-Ax}$ where I_0 is the initial intensity at x=0.
- Then we get $I(x)=I_0e^{-[\mu/\rho]\rho x}$ which itself Eq. (1) [2,7].

The linear attenuation or absorption coefficient (μ) of the material in charge of the disparity of the X-ray image depends on the density of the material and is usually tabulated [7]. The linear absorption coefficient has a proportional relationship to density ρ, this means that the quantity μ/ρ is a constant for the substance and independent of its physical state (solid, liquid or gas). This last quantity is named the mass absorption coefficient [1]. The Beer-Lambert law is perfectly effective for a monochromatic X-ray source because lower energy X-ray beams are came more strongly absorbed than higher energy beams. For a multicolor source, this results in attenuation of the homogeneous sample out of proportion to its thickness. This produces alterations and spurious intensity gradients due to beam hardening. Hence, multicolor X-ray sources typically used in marketable X-ray machines filter out low-energy X-rays and apply trade algorithms to correct these defects. The X-ray attenuation of energies, E < 511 keV, is back to the fundamental mechanisms of photoelectric absorption, Compton scattering, and Rayleigh scattering. Compton scattering and photoelectric absorption control the attenuation of X-rays, while the photon Rayleigh scattering interaction is negligible, but only on a small scale [3,7]. On large low energy areas (< 0.5 MeV) and in materials with high atomic number, the photoelectric effect is prevailing and the mass absorption coefficient [μ/ρ](E) is the photon energy which is smooth function, changing approximately as:

$$[\mu/\rho](E)\sim Z^4/mE^3 \qquad (2)$$

There is an empirical relation occasionally: [μ/ρ](E)pe~$Z^{4.5}/E^{3.5}$, where ρ indicates the density of sample while Z and m are the atomic number and mass, correspondingly. A central property of X-rays is the strong dependence of [μ/ρ] on both Z and E is, and this is a reason to why X-ray absorption is beneficial form any applications such as medical and other imaging systems including X-ray calculated imaging (CT). Because of the adoption of Z4, the absorption coefficient of oxygen, calcium, iron and lead is completely unlike - so that good disparity between different materials can be carry out [2]. Mass absorption coefficient [μ/ρ] are fundamental amounts used in computation of penetration and energy deposition by photons (X-rays, gamma rays, and bremsstrahlung) in biological materials, shielding materials and other materials [8]. Understanding shielding properties such as the mass absorption coefficient is a necessity in the field of beam physics [9] which it often calculated to be obvious the shielding properties quality of any material against X or gamma rays.

2. Results and Discussion

In order to calculate the mass absorption coefficient [μ/ρ] which make us understand the shape of relation between it and the energy of incident X-ray we must need to limit range of X-ray energy will use in Eq. (2) in this research the energy range (2-100 keV) then comber the results we obtained with the mass absorption coefficient from The values can be got from the US reference tables: http://physics.nist.gov/PhysRefData/FFast/html/form.

html which it represent X-Ray form Factor, Attenuation, and Scattering Tables which signified Tables for form factors and strange dispersal are of wide general use in the UV, x-ray and γ-ray communities, and have been for a large period of time. There are many of the new theoretical basis for these was donated by Cromer, Mann and Liberman while much of the experimental data was synthesized by Henke et al. More recent growths in both areas have directed to new and revised tables. In the generality of these works has needed many simplifications compared to exhaustive relativistic S-matrix calculations; however, the final does not appear to give suitable tabular application for the range of Z and energy of general attention. Contrariwise, the previous tables look to have great regions of limited rationality during the range of Z and energies, and in specific have limits with consideration to extrapolation to energies which is outer tabulated ranges, and with the values can be obtained from XCOM: Photon Cross Sections Database: https://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html which it denotes the Data on the scattering and absorption of photons (x-rays, γ-rays, bremsstrahlung) are essential for many scientific, engineering and medical applications. The number of materials for which photon cross sections are required is large and ever rising. Photon cross sections data base it describes a web program called XCOM that performs this task quickly for any element, compound, or mixture, at energies between 1 keV and 100 GeV. By using Eq. (2) to calculate the absorption coefficients of X-ray in (Al, Au, Cu, Fe, Pb) and comber it with both results we obtained them from the US reference tables: http://physics.nist.gov/PhysRefData/FFast/html/form.html and XCOM: Photon Cross Sections Data base: https://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html where the energy range of incident X-ray (2-100 keV). All results in the tables below are calculated and represented in shapes that were programmed and drawn in MATLAB-2014 program to obtain an accurate understanding and correct comparison between these results. They are represented by the relationship between the energy (2-100 keV) of the X-rays on the x-axis and the mass absorption coefficient of each element on the y-axis.

From Figs. (1-5) the relationship between the X-ray mass absorption coefficient μ/ρ which due to photoelectric effect and its energy from 2 keV to 100 keV which incident on (Al, Au, Cu, Fe, Pb). It is clear the X-ray mass absorption coefficient which calculated by Eq. (2) which denoted by P.W in these figures are decreasing by increasing energy of incident X-ray on (Al, Au, Cu, Fe, Pb). This decrease in the mass absorption coefficient results from the effect of the atomic number and the mass of the substance on which the X-rays fall, according to Eq. (2) and we can note. The mass absorption coefficient for X-rays is highest in gold. If we done fitting for data of P. W we get a curve has a good agreement with P. W. The mass absorption coefficient which gets by the US reference tables and the Photon Cross Sections Database are agree at the same range of X-ray energy (2-100 keV).

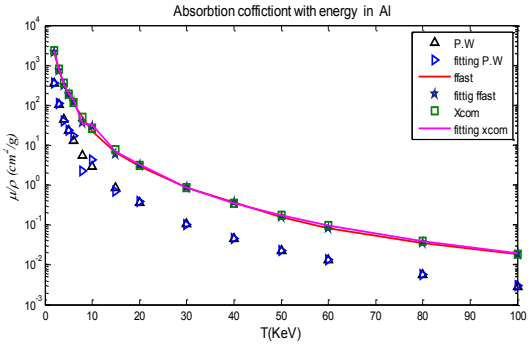

Fig. (1) X-ray mass absorption coefficient versus the energy of its photons in Al, with other practical values

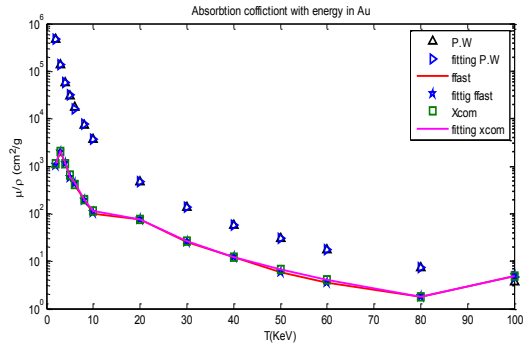

Fig. (2) X-ray mass absorption coefficient versus the energy of its photons in Au, with other practical values

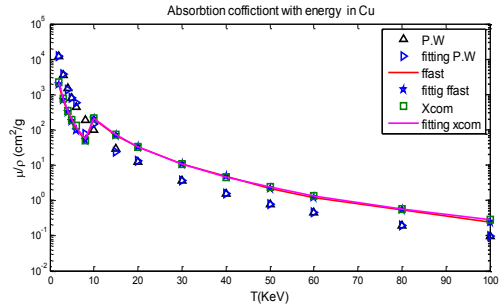

Fig. (3) X-ray mass absorption coefficient versus the energy of its photons in Cu, with other practical values

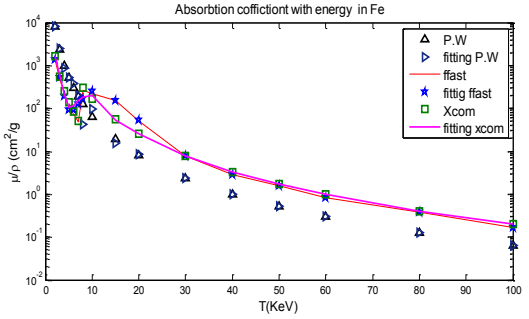

Fig. (4) X-ray mass absorption coefficient versus the energy of its photons in Cu, with other practical values

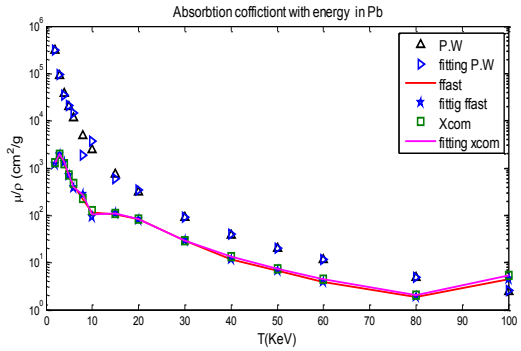

Fig. (5) X-ray mass absorption coefficient versus the energy of its photons in Pb, with other practical values

Tables (1-5) represent all the calculated values of the mass absorption coefficient of X-rays incident on (Al, Au, Cu, Fe, Pb) and calculated by Eq. (2), using the FFAST tool and the XCOM program, respectively.

As well as the fitting for both data have good agreed with them corresponding values. To disappear this agreement, we can use the special function in MATLAB called table which give us three blow table display the data, fit, and error (difference) is: table = [x y f y-f] where x represent the energy of X-ray (E), y is the mass absorption coefficient μ/ρ, f is value of fitting and y-f is the error or the difference.

Table (1) The mass absorption coefficient of X-ray in Al

E (keV)	Absorption coefficient of X-ray by P.W (cm^2/g)	Absorption coefficient of X-ray by using F Fast (cm^2/g)	Absorption coefficient of X-ray by using XCOM (cm^2/g)
2	356.23	2033.60	2261
3	105.55	709.06	786.5
4	44.52	334.05	359.1
5	22.79	157.41	192.20
6	13.19	108.08	114.3
8	5.56	50.0730	49.5
10	2.84	22.4910	25.56
15	0.84	6.6216	7.515
20	0.35	2.9314	3.100
30	0.10	0.8549	0.872
40	0.043	0.36663	0.3504
50	0.02	0.15602	0.1718
60	0.01	0.08227	0.095640
80	0.005	0.03502	0.03783
100	0.002	0.018447	0.01840

Table (2) The mass absorption coefficient of X-ray in Au

E (keV)	Absorption coefficient of X-ray by P.W (cm^2/g)	Absorption coefficient of X-ray by using F Fast (cm^2/g)	Absorption coefficient of X-ray by using XCOM (cm^2/g)
2	465868.67	1028.6	1125
3	138035.16	2000.3	2039
4	58233.58	1099.6	1135
5	29815.59	622.07	658
6	17254.39	395.6	418
8	7279.19	193.83	201.3
10	3726.94	100.52	113.2
20	465.86	73.837	76.5
30	138.03	25.548	26.11
40	58.23	12.252	12.01
50	29.81	5.9502	6.53
60	17.25	3.4596	3.962
80	7.27	1.7326	1.79
100	3.72	4.8446	4.855

Table (3) The mass absorption coefficient of X-ray in Cu

E (keV)	Absorption coefficient of X-ray by P.W (cm^2/g)	Absorption coefficient of X-ray by using F Fast (cm^2/g)	Absorption coefficient of X-ray by using XCOM (cm^2/g)
2	12254.05	1870.7	2149
3	3630.83	661.4	744.9
4	1531.75	318.38	343.9
5	784.25	151.58	187
6	453.85	104.57	131.1
8	191.46	50.336	50.62
10	98.03	195.73	214.5
15	29.04	67.557	73.08
20	12.25	32.262	33.08
30	3.63	10.336	10.45
40	1.53	4.7527	4.52
50	0.78	2.138	2.335
60	0.45	1.1754	1.332
80	0.19	0.52858	0.5676
100	0.09	0.234	0.2878

Table (4) The mass absorption coefficient of X-ray in Fe

E (keV)	Absorption coefficient of X-ray by P.W (cm^2/g)	Absorption coefficient of X-ray by using F Fast (cm^2/g)	Absorption coefficient of X-ray by using XCOM (cm^2/g)
2	8017.48	1370	1620
3	2375.54	486	554.3
4	1002.18	227	253
5	513.11	107	137
6	296.94	74.6	82.7
8	186.99	48.7	51.3
10	125.27	262	304
15	64.13	221	169
20	19.004	154	56.2
30	8.017	51.6	25
40	2.37	7.670	7.76
50	1.002	2.81	3.31
60	0.51	1.54	1.69
80	0.29	0.843	0.977
100	0.12	0.377	0.406

Table (5) The mass absorption coefficient of X-ray in Pb

E (keV)	Absorption coefficient of X-ray by P.W (cm^2/g)	Absorption coefficient of X-ray by using F Fast (cm^2/g)	Absorption coefficient of X-ray by using XCOM (cm^2/g)
2	309332.09	1172.3	1274
3	91653.95	1913.6	1955
4	38666.51	1200.5	1242
5	19797.25	698	722.2
6	11456.74	432.4	459.8
8	4833.31	215.33	222.6
10	2474.65	111.74	125.6
15	733.23	104.53	108.2

20	309.33	81.16	83.97
30	91.65	28.297	28.86
40	38.66	11.337	13.35
50	19.79	6.5988	7.292
60	11.45	3.8521	4.432
80	4.83	1.8581	2.012
100	2.47	4.3907	5.230

In tables (6-20) we show the value of the error (or difference) at some values of energy of X-ray in negative values which it can be explained by the following explanation:

A negative value in *y-f* means that the fitting curve (model) predicts a higher absorption coefficient than the experimental measurement at that X-ray energy. This situation is normal in fitting analysis:

- Positive residual (*y-f*>0) the experimental absorption is larger than the fitted value and the model underestimates absorption.
- Negative residual (*y-f* <0) → the experimental absorption is smaller than the fitted value → the model overestimates absorption.

In practice, residuals (differences) should fluctuate around zero. If they are mostly positive or mostly negative, it indicates that the fitting function does not fully capture the physics of the absorption process, especially near absorption edges (K, L, etc.).

Table (6) The mass absorption coefficient of X-ray in Al which calculated by Eq. (2), their fitting corresponding values and the error between them

Al			
E (keV)	Absorption coefficient of X-ray by P.W (cm^2/g)	Fitting of P.W (cm^2/g)	Error
2	356.23	355.49	0.74
3	105.55	109.14	-3.59
4	44.52	39.04	5.48
5	22.79	23.66	-0.86
6	13.19	17.08	-3.89
8	5.56	2.17	3.38
10	2.84	4.24	-1.39
15	0.84	0.68	0.16
20	0.35	0.38	-0.03
30	0.10	0.10	0.002
40	0.04	0.04	-0.0003
50	0.02	0.02	5.98
60	0.01	0.01	-2.69e-06
80	0.005	0.005	1.31e-05
100	0.002	0.002	-0.0001

Table (7) The mass absorption coefficient of X-ray in AL which calculated by US reference tables (f fast), their fitting corresponding values and the error between them

Al			
E (keV)	Absorption coefficient of X-ray by F Fast (cm^2/g)	Fitting of F Fast (cm^2/g)	Error
2	2033.6	2029.69	3.90
3	709.06	728.89	-19.83
4	334.05	299.94	34.10
5	157.41	173.20	-15.79
6	108.08	118.98	-10.90
8	50.073	36.06	14.005
10	22.491	28.58	-6.09
15	6.6216	5.88	0.73
20	2.9314	3.07	-0.13
30	0.8549	0.84	0.010
40	0.36663	0.36	-0.001
50	0.15602	0.15	0.0002
60	0.08227	0.08	-1.58e-05
80	0.03502	0.03	4.37e-05
100	0.018447	0.018	-0.0002

Table (8) The measured mass absorption coefficient of X-ray in Al which calculated by XCOM: Photon Cross Sections Data base, their fitting corresponding values and the error between them

Al			
E (keV)	Absorption coefficient of X-ray by XCOM (cm^2/g)	Fitting of XCOM (cm^2/g)	Error
2	2261	2257.53	3.46
3	786.5	803.26	-16.76
4	359.1	333.65	25.44
5	192.2	195.88	-3.68
6	114.3	132.77	-18.47
8	49.5	33.57	15.9280
10	25.56	32.09	-6.53
15	7.515	6.75	0.76
20	3.1	3.24	-0.14
30	0.8722	0.86	0.01
40	0.3504	0.35	-0.001
50	0.1718	0.17	0.0002
60	0.09564	0.095	-2.55e-05
80	0.03783	0.03	8.48e-05
100	0.0184	0.01	-0.0006

Table (9) The measured mass absorption coefficient of X-ray in Au which calculated by Equation (2), their fitting corresponding values and the error between them

Au			
E (keV)	Absorption coefficient of X-ray by P.W (cm^2/g)	Fitting of P.W (cm^2/g)	Error
2	465868.6	465768.37	100.29
3	138035.16	138695.35	-660.19
4	58233.58	56489.84	1743.73
5	29815.59	32077.51	-2261.91
6	17254.39	15954.66	1299.72
8	7279.19	7546.92	-267.72
10	3726.94	3680.57	46.37
20	465.86	466.2001	-0.33
30	138.035	137.99	0.04
40	58.23	58.24	-0.008
50	29.81	29.81	0.0006
60	17.25	17.24	0.006
80	7.27	7.19	0.08
100	3.72	4.60	-0.88

Table (10) The measured mass absorption coefficient of X-ray in Au which calculated by US reference tables (f fast), their fitting corresponding values and the error between them

Au			
E (keV)	Absorption coefficient of X-ray by F Fast (cm^2/g)	Fitting of F Fast (cm^2/g)	Error
2	1028.6	1030.92	-2.32
3	2000.3	1985.0004	15.29
4	1099.6	1140.009	-40.409
5	622.07	569.65	52.41
6	395.6	425.71	-30.11
8	193.83	187.62	6.20
10	100.52	101.59	-1.07
20	73.837	73.82	0.007
30	25.548	25.54	-0.001
40	12.252	12.25	0.0001
50	5.9502	5.95	4.85
60	3.4596	3.45	3.27e-05
80	1.7326	1.73	0.0009
100	4.8446	4.84	0.002

Table (11) The measured mass absorption coefficient of X-ray in Au which calculated by XCOM: Photon Cross Sections Data base, their fitting corresponding values and the error between them

Au			
E (keV)	Absorption coefficient of X-ray by XCOM (cm^2/g)	Fitting of XCOM (cm^2/g)	Error
2	1125	1127.39	-2.39
3	2039	2023.208	15.79
4	1135	1176.707	-41.70
5	658	603.89	54.10
6	418	449.08	-31.08
8	201.3	194.89	6.40
10	113.2	114.30	-1.10
20	76.5	76.49	0.007
30	26.11	26.11	-0.001
40	12.01	12.009	0.0001
50	6.53	6.53	-1.01e-05
60	3.962	3.96	-9.82e-05
80	1.79	1.79	-0.002
100	4.855	4.86	-0.009

Table (12) The measured mass absorption coefficient of X-ray in Cu which calculated by Eq. (2), their fitting corresponding values and the error between them

Cu			
E (keV)	Absorption coefficient of X-ray by P.W (cm^2/g)	Fitting of P.W (cm^2/g)	Error
2	12254.05	12228.52	25.5
3	3630.83	3754.56	-123.72
4	1531.75	1343.13	188.62
5	784.25	813.90	-29.64
6	453.85	587.84	-133.98
8	191.46	74.98	116.48
10	98.03	145.91	-47.88
15	29.046	23.45	5.58
20	12.25	13.29	-1.04
30	3.63	3.55	0.076
40	1.53	1.54	-0.01
50	0.78	0.78	0.002
60	0.45	0.45	-0.0001
80	0.19	0.19	0.0009
100	0.09	0.094	0.003

Table (13) The measured mass absorption coefficient of X-ray in Cu which calculated by US reference tables (f fast), their fitting corresponding values and the error between them

Cu			
E (keV)	Absorption coefficient of X-ray by F Fast (cm^2/g)	Fitting of F Fast (cm^2/g)	Error
2	1870.7	1869.25	1.44
3	661.4	669.88	-8.488
4	318.38	299.14	19.2
5	151.58	171.58	-20.009
6	104.57	96.5	8.02
8	50.336	49.94	0.39
10	195.73	196.43	-0.70
15	67.557	67.42	0.12
20	32.262	32.28	-0.02
30	10.336	10.33	0.002
40	4.7527	4.75	-0.0003
50	2.138	2.13	5.68e-05
60	1.1754	1.17	3.49
80	0.19	0.19	0.0009
100	0.09	0.09	0.0034

Table (14) The measured mass absorption coefficient of X-ray in Cu which calculated by XCOM: Photon Cross Sections Data base, their fitting corresponding values and the error between them

Cu			
E (keV)	Absorption coefficient of X-ray by XCOM (cm^2/g)	Fitting of XCOM (cm^2/g)	Error
2	2149	2148.72	0.27
3	744.9	747.42	-2.52
4	343.9	334.93	8.96040
5	187	202.17	-15.17
6	131.1	119.87	11.22
8	50.62	54.40	-3.78
10	214.5	213.38	1.11
15	73.08	73.17	-0.092
20	33.08	33.06	0.0149
30	10.45	10.45	-0.00095
40	4.52	4.51	0.00015
50	2.335	2.33	-2.51e-05
60	1.332	1.33	1.58e-05
80	0.56	0.56	1.33e-05
100	0.28	0.28	0.00086

Table (15) The measured mass absorption coefficient of X-ray in Fe which calculated by Eq. (2), their fitting corresponding values and the error between them

Fe			
E (keV)	Absorption coefficient of X-ray by P.W (cm^2/g)	Fitting of P.W (cm^2/g)	Error
2	8017.48	8000.74	16.7
3	2375.54	2456.33	-80.78
4	1002.18	879.93	122.25
5	513.11	531.68	-18.56
6	296.94	380.05	-83.10
7	186.99	197.13	-10.14

8	125.27	42.10	83.16
10	64.13	96.79	-32.65
15	19.004	15.25	3.753
20	8.017	8.71	-0.69
30	2.37	2.32	0.05
40	1.0021	1.0105	-0.008
50	0.51	0.51	0.001
60	0.29	0.29	-0.00012
80	0.12	0.12	-4.40e-05
100	0.06	0.06	-0.0007

Table (16) The measured mass absorption coefficient of X-ray in Fe which calculated by US reference tables (f fast), their fitting corresponding values and the error between them

Fe			
E (keV)	Absorption coefficient of X-ray by F Fast (cm^2/g)	Fitting of F Fast (cm^2/g)	Error
2	1370	1362.4	7.57
3	486	518.84	-32.84
4	227	189.40	37.59
5	107	92.86	14.13
6	74.6	92.1	-17.50
7	48.7	126.15	-77.45
8	262	169.94	92.05
10	221	246.64	-25.64
15	154	151.48	2.51
20	51.6	52.049	-0.449
30	7.67	7.63	0.03
40	2.81	2.81	-0.005
50	1.54	1.53 6	0.0008
60	0.843	0.84	-8.45
80	0.377	0.37	6.93 e-06
100	0.165	0.16	-0.0002

Table (17) The measured mass absorption coefficient of X-ray in Fe which calculated by XCOM: Photon Cross Sections Data base, their fitting corresponding values and the error between them

Fe			
E (keV)	Absorption coefficient of X-ray by XCOM (cm^2/g)	Fitting of XCOM (cm^2/g)	Error
2	1620	1610.21	9.78
3	554.3	595.87	-41.57
4	253	209.46	43.53
5	137	107.76	29.23
6	82.7	115.13	-32.43
7	51.3	150.50	-99.20
8	304	181.90	122.09
10	169	203.23	-34.23
15	56.2	52.83	3.36
20	25	25.59	-0.59
30	7.76	7.71	0.04
40	3.31	3.31	-0.0068
50	1.69	1.68	0.001
60	0.977	0.97	-0.0001
80	0.406	0.40	1.46 8e-05
100	0.204	0.20	-0.0001

Table (18) The measured mass absorption coefficient of X-ray in Pb which calculated by Eq. (2), their fitting corresponding values and the error between them

Pb			
E (keV)	Absorption coefficient of X-ray by P.W (cm^2/g)	Fitting of P.W (cm^2/g)	Error
2	309332.09	308687.63	644.46
3	91653.95	94777.28	-3123.32
4	38666.51	33904.96	4761.55
5	19797.25	20545.52	-748.26
6	11456.74	14839.07	-3382.33
8	4833.31	1892.95	2940.35
10	2474.65	3683.46	-1208.80
15	733.23	592.201	141.02
20	309.33	335.69	-26.36
30	91.65	89.73	1.91
40	38.66	38.98	-0.31
50	19.79	19.74	0.05
60	11.45	11.45	-0.002
80	4.83	4.83	-0.0002
100	2.47	2.56	-0.08

Table (19) The measured mass absorption coefficient of X-ray in Pb which calculated by US reference tables (f fast), their fitting corresponding values and the error between them

Pb			
E (keV)	Absorption coefficient of X-ray by F Fast (cm^2/g)	Fitting of F Fast (cm^2/g)	Error
2	1172.3	1183.77	-11.47
3	1913.6	1857.99	55.60
4	1200.5	1285.20	-84.70
5	698	684.86	13.13
6	432.4	372.00	60.39
8	215.33	267.75	-52.42
10	111.74	90.19	21.54
15	104.53	107.04	-2.51m
20	81.16	80.6	0.46
30	28.297	28.33	-0.03
40	11.337	11.3	0.005
50	6.5988	6.59	-0.0009
60	3.8521	3.85	8.21
80	1.8581	1.85	-0.0004
100	4.3907	4.38	0.002

Table (20) The measured mass absorption coefficient of X-ray in Pb which calculated by XCOM: Photon Cross Sections Data base, their fitting corresponding values and the error between them

Pb			
E (keV)	Absorption coefficient of X-ray by F Fast (cm^2/g)	Fitting of F Fast (cm^2/g)	Error
2	1274	1285.08	-11.08
3	1955	1901.87	53.12
4	1242	1320.49	-78.49
5	722.2	716.58	5.61
6	459.8	395.46	64.33
8	222.6	275.61	-53.01
10	125.6	104.020	21.57
15	108.2	110.69	-2.49
20	83.97	83.50	0.46
30	28.86	28.89	-0.03

40	13.35	13.34	0.005
50	7.292	7.29	-0.0009
60	4.432	4.43	8.01 e-05
80	2.012	2.011 2	9.05 e-5
100	5.23	5.22	0.002

3. Conclusions

From this data, we can gain some information about the mass absorption coefficient, which can aid in the design of diagnostic devices used in medical x-ray examination laboratories and laboratory devices in educational laboratories that incorporate these metals. There are lots of specific boundaries and conditions to be taken into version when using Eq. (2) to calculate the mass absorption coefficient. The values of the mass absorption coefficient show inversely proportional to energy. As the X-ray photons are incident on (Al, Au, Cu, Fe, Pb) and suffer energy loss after several collisions in it, the particle velocity is importantly reduced. Through this action it is appear that X-ray mass absorption coefficient which travel in any absorber medium must depend on several variables, the energy of X-ray, the atomic weight and atomic number of the absorbent medium which X-ray passes through it, and the density of this absorbent medium.

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