

## **Attenuation of X-ray Fluorescence by Cadmium Compounds (CdSO<sub>4</sub>, CdCl<sub>2</sub>, CdO)**

**Muataz A. Majeed<sup>1</sup>, Ghasan Adnan Naeem<sup>2</sup>, Laith Ahmed Najam<sup>3</sup>**

<sup>1</sup>Ministry of Education – Salahaldeen Education Directorate, IRAQ

<sup>2</sup>Anbar University – College of Applied Science, Department of Biophysics, IRAQ

<sup>3</sup>Mosul University, College of Science, Department of Physics, Mosul, IRAQ

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**Abstract:** *The mass attenuation coefficient of some cadmium compounds has been calculated. The gamma rays emitted from Am-241(40mCi) source were used to excite the sample and emitted ( $k_{\alpha}$ ) and ( $k_{\beta}$ ) x-rays lines were counted by a silicon drift detector(SDD) with resolution of 150eV at 6.4 KeV. The experiment results are good agreement with theoretical results by (XCOM) software.*

**Keywords:** *Attenuation, Am<sup>241</sup>, SDD, XRF, Cd Compounds*

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### **1. INTRODUCTION**

Cadmium is a white bright metal. The structure of cadmium metal deviates from perfect hexagonal close packing by protraction along the six fold axis. The metal is noticeable volatile for a heavy metal. It reacts easily with non-oxidizing acids to produce hydrogen and the bivalent ion, also does not dissolve in alkali solution. Cadmium reacts when heated with oxygen to give the oxides. It also reacts directly with halogens [1], Cadmium has a very high absorption cross-section for thermal neutrons hence its presence in amounts N1 ppm is not acceptable in nuclear materials[2-3]. Cadmium is an odorless, It has an atomic weight of 112.4 and belongs to group IIB of the periodic table. Almost all cadmium compounds have an oxidation state of +2. Cadmium is soluble in dilute nitric acid, ammonium nitrate, and hot sulfuric acid and insoluble in water. It is slowly oxidized in moist air but forms cadmium oxide fumes when heated. Cadmium and cadmium compounds are not combustible but may decompose in fires and release corrosive and toxic fumes. Hot cadmium metal reacts with phosphorus, selenium, sulfur, and tellurium, and cadmium vapor reacts with oxygen, carbon dioxide, water vapor, sulfur dioxide, sulfur trioxide, and hydrogen chloride. Cadmium is commercially available in purities ranging from 99% to 99.9999%, as powders, foils, ingots, slabs, sticks, and crystals [4,5]. X-ray fluorescence (XRF) has been a popular method for the main elemental analysis in samples. Specifically, the speed, versatility, and accuracy technique of XRF are the main features that have made it a very mature[6]. XRF having a potential application for determination of different elements. For the determination of Cadmium by XRF normally,  $k_{\alpha}$  line of Cd is used though it has disadvantages e.g. low fluorescence yield and energy, lying in low energy region having high background etc.[7]. X-ray absorption in metals has already been thoroughly studied in the early days of x-ray absorption spectroscopy since perfectly homogenous high-quality absorption specimens with optimum thickness of the order of 10  $\mu\text{m}$  can be prepared with routine mechanical procedures. The K edges of metals are often used as intermediary standards for the calibration of the energy scale of x-ray monochromators, allowing an accuracy of  $\sim 0.1\text{eV}$  or better[8,9] We have measured the absorption in Cd vapor and in a thin layer of Cd metal in the energy region of L edges, from 3400 to 4400 eV. A comparison of the two sets of data provides some results of metrological interest, notably the continuum threshold energies. The L-edge profiles and accompanying MPE are discussed and compared to the K-edge data [10]. The X-rays from an undulator were monochromatized by a Si(111) double-crystal monochromator to 37 keV in order to excite the K-lines of cadmium. The beam was focused to a spot size of 3.8  $\mu\text{m}$  (horizontal, H)  $\times$  1.3  $\mu\text{m}$  (vertical, V) using a pair of elliptical mirrors in the K-B configuration. The sample on the acrylic board was mounted on an x-y translation stage. Fluorescence X-rays were measured during a Si(Li)-SSD in air at room temperature. Cd K-edge  $\mu\text{-XANES}$  spectra were measured at the accumulating points of Cd, which were revealed by  $\mu\text{-XRF}$  imaging, in the fluorescence mode. A monochromator stabilization (MOSTAB) system [11]. Consider a beam of x-rays or gamma rays, such that I is the intensity of photons falling perpendicularly on a

slab of material of thickness  $\Delta x$ . Then the number of photon  $\Delta I$ , removed from the beam due to the interaction of gamma rays with matter is proportional to the thickness and the number of incident photons  $I$ . Thus [12]:-

$$\Delta I = -\mu I \Delta x \tag{1}$$

Where  $(\mu)$  is the proportionality constant known as the total linear attenuation coefficient. The intensity of gamma rays thus decrease with the absorber thickness. The attenuation coefficient  $(\mu)$  depends on the material and on the energy of the gamma rays. For a given material and monochromatic gamma rays  $(\mu)$  we can obtain the following relation:-

$$I = I_0 e^{-\mu x} \tag{2}$$

Where:

$$\mu = n(\sigma_{ph} + \sigma_c + \sigma_p) \tag{3}$$

$(I_0)$  is the intensity of the incident beam, while  $(I)$  is the intensity of the beam after traversing a distance  $x$  in the absorber,  $(n)$  is the number of atoms per  $\text{cm}^3$ ,  $(\sigma_{ph})$  is the cross section of photoelectric,  $(\sigma_c)$  is the cross section of Compton scattering,  $(\sigma_p)$  is the cross section of pair production. Thus, the intensity of  $\gamma$ -ray beam of particular energy passing through homogeneous material follows an exponential law of absorption, in contrast to a definite range which characterizes charged particles. The linear absorption coefficient  $(\mu)$  has unit of  $\text{cm}^{-1}$

$$\mu = \mu_{ph} + \mu_c + \mu_p \tag{4}$$

Where  $\mu_{ph}$ ,  $\mu_c$ ,  $\mu_p$  are the partial attenuation coefficients arising out of photoelectric effect, Compton effect and pair production respectively [13]. It is often useful to measure the surface density  $(d)$  of the absorber instead of its thickness  $X$ . If  $(\rho)$  is mass density  $d = (\rho) x$ , and more usually a total mass attenuation coefficient  $(\mu_m)$  is used. It is defined by  $(\mu_m) = (\mu/\rho)$ . Then equation (2) becomes [14]

## 2. EXPERIMENTAL

Which include preparation of powders cadmium compounds form (oxide, chloride and sulfate). The powders provided from Sigma Aldrich British company. We calculated mass attenuation coefficients of (XRF) the results have been compared with (XCOM) program adopted by National Institute Standard of Technology (NIST). The results are in a good agreement with (XCOM). The mass attenuation coefficients have been determined by measuring of X-rays fluorescent emitted through sample compound of known thickness. The experimental arrangement is shown in figure (1).

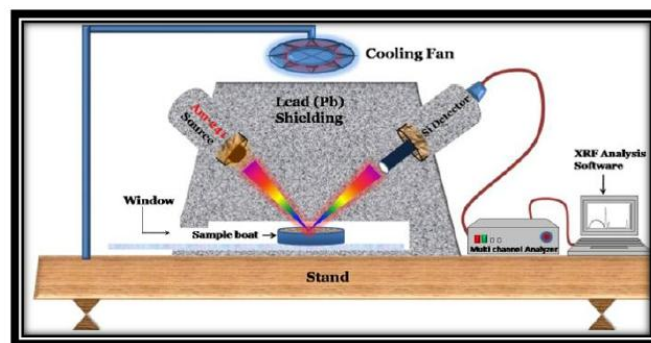


Figure1. The Experimental Set up

The sample compounds have been irradiated with (59.53) keV X-rays obtained from the Am-241 (40 mCi) annular source. The emitted K-line X-rays fluorescents have been collimated by the lead collimator shielded with aluminum and iron to fall on samples, this sample compound was placed in circular ring having various thicknesses (0.25-1.8) mg/cm. The X-rays fluorescent has been recorded with the help of silicon drift detector (SDD) connected to the Fast Comtech multi-channel analyzer card. The distance between sample to source is (15) mm same as the distance between sample to detector with an angle  $(90^\circ)$  as shown in figure( 1)

## 3. RESULTS AND DISCUSSIONS

The figure (2) show the (XRF) measurements for pure Cadmium(Cd) and Compounds (Sulfate, Chloride and Oxide) respectively. This figure clearly indicate that  $K_\alpha$  and  $K_\beta$  X-ray energy peaks for pure Cadmium with higher Intensity. It has been observed that for compound samples intensity of these  $K_\alpha$  an

d K<sub>β</sub>. X-ray energy peaks were decreased, because of the high density of Cadmium Oxide(8.15 gm/cm<sup>3</sup>), we show less intensity. While we find the intensity of chloride is less than sulfate although the density of sulfate is higher than chloride.

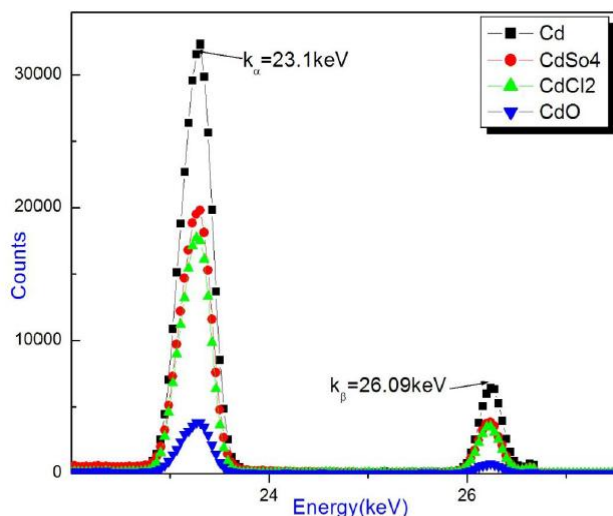


Figure2. X-ray Fluorescence Plots for (Cd) Compounds

We have calculated the mass attenuation coefficient ( $\mu_m$ ) for these compounds by equation (2), when we calculated the area under the peak of pure Cadmium represented ( $I_0$ ) and calculated for compounds with same method represented ( $I$ ).

In tables(1,2)we

measured values of ( $\mu_m$ ) at( $k_\alpha$ ),( $k_\beta$ ) and compared with theoretical values by(XCOM)software, near absorption energy edge, they are in a good agreement.

Table1. Show the values of( $\mu_m$ ) at( $k_\alpha$ )

Compounds	Theoretical	Experimental	Error
CdO	15.80	15.20	-0.03
CdCl <sub>2</sub>	13.93	12.94	-0.07
CdSO <sub>4</sub>	10.94	9.93	-0.09

Table2. Show the values of ( $\mu_m$ ) at( $k_\beta$ )

Compounds	Theoretical	Experimental	Error
CdO	32.4	32.75	0.01
CdCl <sub>2</sub>	23.5	23.92	0.017
CdSO <sub>4</sub>	20.35	20.78	0.02

Figures (3, 4) represented the relation between mass attenuation coefficient and density for( $k_\alpha$ ),( $k_\beta$ ) energies.

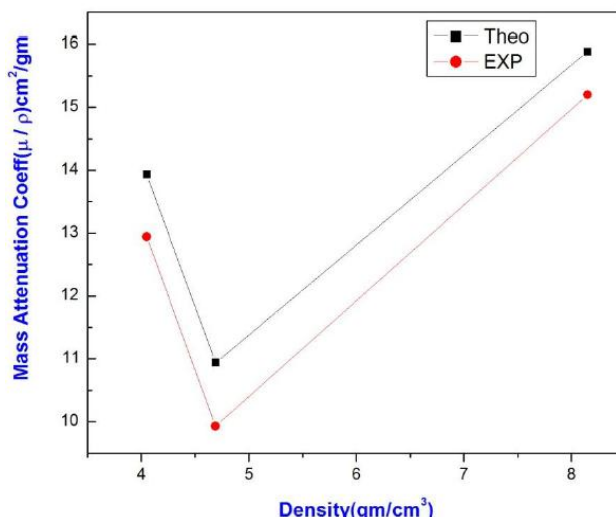
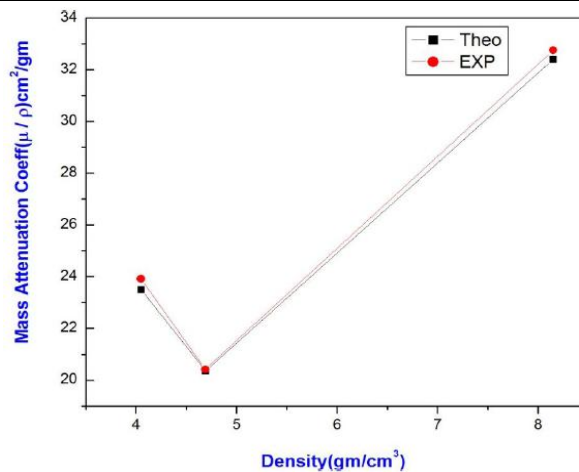


Figure3. Relation between mass attenuation coefficient and Density at ( $k_\alpha$ ) energy



**Figure4.** Relation between mass attenuation coefficient and Density at ( $k_{\beta}$ ) energy

#### 4. CONCLUSION

The mass attenuation coefficient of cadmium oxide is higher than for sulfite and chloride because of high density at ( $k_{\alpha}$ ) and ( $k_{\beta}$ ) energies. The mass attenuation coefficient of cadmium chloride has density ( $4.05 \text{ gm/cm}^3$ ) is higher than for cadmium sulfite has density ( $4.69 \text{ gm/cm}^3$ ) because of different binding energy of atoms and arrangement of atoms in crystal structure.

#### ACKNOWLEDGMENT

This work has been financially supported by University of Tikrit and College of Education of Pure Sciences. We thank the Ministry of Sciences & Technology for supporting this work and providing laboratory services. The author Muataz A. Majeed is grateful to Prof. Dr. Fareed M. Mohammed.

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