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Research Article

Investigation of Albedo Factor Parameters in Some Selected Sn Compounds

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ABSTRACT

In recent years, studies on the elements used in producing electronic device components and the interaction of their different compounds with radiation have been emphasized. In developing this situation, giving importance to space studies and other searches in energy production have been very effective. In the light of these developments, the interaction of tin, which is widely used in producing electronic device components and different industrial areas, with radiation has been investigated. For this purpose, the variation of albedo factor values in some compounds of the tin element was analysed and presented. Am-241 radioactive sources were used as incident radiation in determining the albedo factor values mentioned in the study. The albedo factor values obtained by examining the Compton and coherent scattering peaks were used to determine the albedo factor values.

1. Introduction

Tin is the oldest metal known to human-being. It is increasingly used in many fields such as coatings, compounds, alloys, and advanced technology from ancient times. Today, tin is an essential metal, although it is used in industry in small quantities. This is because it is used in small amounts in many areas. The tin element and some of its compounds, essential among the coating materials, are widely used in the transportation and chemical industry. Tin ore, which has a wide usage area and provides ease of use in many tools, has been the focus of attention of many researchers, and its different properties have been investigated. Tin is used in can making, coating, various alloys, solder, and chemicals. It is also used in engine bearings, bodywork, radiators, oil, and air filters in the automotive industry. It has a wide use area in the aircraft and ship industry and the electrical and electronics industry. It is consumed in a wide [1] area, from the production of paint, perfume, soap, and polyurethane to toothpaste production in the chemical industry. Besides, it is also used in printing, kitchen equipment, and the glass industry.

We can reach some crucial atomic information by directing X-ray photons on materials. The obtained data is evaluated whether the directed X-rays make elastic or inelastic collisions. [1] These scattering processes help understand the atomic features of each material. In this way, we gain important information about how materials behave when radiation exposure. In calculating albedo factor values, which are the subject of this study, x-rays irradiated the material are scattered from the material by inelastic collision. If we want to give an example of inelastic scattering,

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soft photon emitting, and target recoil events, all inelastic scattering events come to mind first. Photoelectric, Compton scattering, and pair production events occur because of inelastic scattering. Also, scattering from bound electrons (Rayleigh scattering), nuclear Thomson scattering, Delbrück scattering, and nuclear resonance scattering can be given as the phenomena observed because of elastic scattering.

The photon reflection capability of the target sample is called an albedo factor and is related to the atomic number, thickness, and incident x-ray photon energy [2]. Each target's derived albedo factor values are used in manufacturing radiation shielding material [3-8]. For this purpose, different materials used or recommended in the industry have been researched by various researchers and brought to the literature. Experimental studies were carried out using other materials and radiation sources.

This article uses experimental methods to explain the elastic and inelastic scattering intensity ratios, that is, the albedo factors of the selected samples. Defining the albedo factor parameter, which indicates the photon scattering ability of a material consisting of a combination of different elements or a pure element, will help select the elements to be used in material production. The albedo factor, which is only one of the screening parameters, consists of 3 different components: albedo number, albedo dose, and albedo energy.

2. Material and Methods

2.1. Experimental Arrangement

The experimental procedure of this study was carried out using a semiconductor detector (HPGe) and a circular radioactive source, respectively. These said components are in the scattering geometry and are shown in Figure 1. In addition, the experimental setup was covered with the sample chamber. The sample chamber provided radiation shielding for the researchers, and at the same time, the chamber prevented unexpected backscatter counts. The structural equipment of the sample chamber is shown in the Figure. 2. The sample chamber is lined with a lead layer and conical shape. The primary use of the sample chamber is also related to this structure. Thus, this shape of the lead-lined and conical-shaped sample chamber provides a monochromatic gamma-ray. Paired monochromatic gamma rays were directed into the sample chamber for scattering to occur so that the scattering photons were detected through an HPGe semiconductor X-ray detector. To align the photons coming from the radioactive source and scattered from the sample and to protect the experimental environment from unwanted harmful x-rays, the experimental setup was kept in the sample room. Gamma rays emitted from the source were directed at the target with a scattering angle of 168 degrees. It is aimed to minimize unwanted gamma-ray scattering with a scattering angle of 168 degrees.

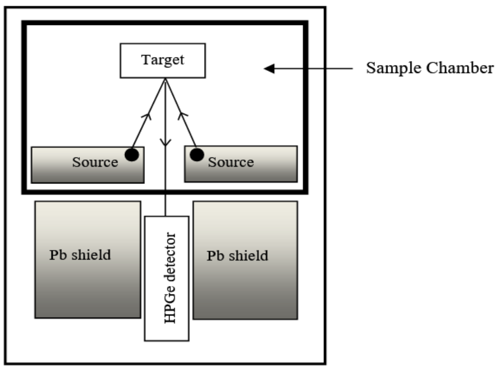

Figure 1 Experimental setup
(radius of the collimator is 0.53 cm)

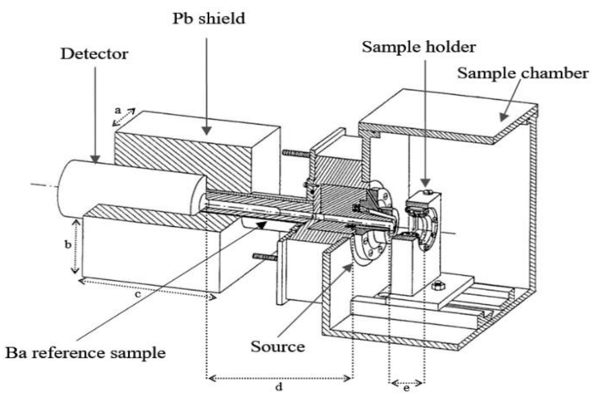

Figure 2 Sample chamber
(a=6.5 cm, b=6.3 cm, c=13.5 cm, d=11 cm, e=5 cm)

2.2. Calculation of Albedo Factors

The experimental setup has an HPGe semiconductor detector, and the detector was linked to the multichannel analyzer, Genie-2000, and controlled by a computer. With the mentioned Genie-2000 program, characteristic photo peaks are revealed, and analysis is provided with the data obtained. The determined photopic areas were calculated by using the Origin 7.5 program. The calculated photo-peak areas consist of backscattered and incident constituents and are represented by N_{bs} and N_i, respectively [7]. At this moment, these related photopeak constituents were used in the calculation of the albedo number by the following equation,

$$A_N = \left[\frac{N_{bs}/\varepsilon(E_{bs})}{(N_i/\varepsilon(E_i))(1/d\Omega)(1/2)}\right] \quad (1)$$

Where $\varepsilon(E_{bs})$ and $\varepsilon(E_i)$ terms represent the backscattered and the incident photo-peak efficiencies of the HPGe detector, respectively. It is also seen that the term solid angle ($d\Omega$) is used together with the terms mentioned in the formula. The solid angle term ($d\Omega$) expressed here is the solid angle seen by the detector collimator opening from the center of the target. A factor of 1/2 added to the denominator means that half of the gamma photons emitted by the radioactive source hit the target.

Another constituent of the albedo factor parameter is the albedo energy and calculated by using the following equation,

$$A_E = \left[\frac{E_{bs}}{E_i}\right] A_N \quad (2)$$

Equation (2) has the photon energies of the incident and the backscattered gamma rays, represented by E_i and E_{bs}, respectively. Finally, the calculation of albedo energy has been used to derive the last term of the albedo parameter called the albedo dose. The albedo dose is directly proportional to the albedo energy, as shown below,

$$A_D = \left[\frac{\sigma_a(E_{bs})}{\sigma_a(E_i)}\right] \quad (3)$$

Equation (3) has the gamma photon absorption coefficient of the air layer. So, the backscattered and incident gamma photon absorption coefficient terms were expressed separately. Also, the air layer is composed of different elements in different percentages, which are taken from Table 1. These coefficient terms have been calculated using related percentages from the XCOM photon cross-section database [8].

Table 1 Table of gaseous composition of dry air

Constituent	Chemical symbol	Mole percent
Nitrogen	N_2	78.084
Oxygen	O_2	20.947
Argon	Ar	0.934
Carbon dioxide	CO_2	0.0350
Neon	Ne	0.001818
Helium	He	0.000524
Methane	CH_4	0.00017
Krypton	Kr	0.000114
Hydrogen	H_2	0.000053
Nitrous oxide	N_2O	0.000031
Xenon	Xe	0.0000087
Ozone	O_3	0.00000001

3. Results

This study investigated the radiation absorption and shielding properties of some tin compounds. The fact that tin and its compounds are frequently used in industry and technology has led to this. The tin element has a wide range of uses. The element Sn, which requires a high degree of polishing, is used to protect metal materials prone to corrosion, such as coating steel cans. Materials such as soft solder, tin, bronze, and phosphor bronze are important tin alloys. In addition, the niobium-tin alloy is widely used for superconducting magnets. It is obtained using molten glass floating on the molten tin to create a flat surface on most window glass. In addition, molten tin salts are sprayed onto the glass surface to form a conductive structure. The most essential tin salt used in these processes is tin (II) chloride, used as a reducing agent and mordant in dyeing calico and silk. Tin (IV) oxide is frequently used in ceramic and gas sensor production.

Zinc stannate (Zn2SnO4) is a fire retardant used in plastics. Some tin compounds have been used as antifouling paints for ships and boats to prevent mussels. However, these compounds are deadly to marine life, especially oysters, even at low levels. Its use is now banned in most countries. Tin is a bidirectional metal because it can react with strong acids and bases. Pure water does not affect it. In aqueous solutions, oxygen accelerates the corrosion process. In the absence of oxygen, the high potential of tin (0.75 V) causes a hydrogen layer to form on its surface, which will reduce even the effect of acids. Normally, its surface and thickness are covered with a thin oxide layer that increases the temperature. When a tin-plated steel in an airless environment is brought into contact with acidic solutions, a tin-iron couple is formed at negative potential. During this event, the tin plating is used as the anode, and the molecule itself, not the iron, undergoes aggregation. Otherwise, molten iron; In canning, which is its main area of use, the process is a cornerstone because it impairs taste and vision. Tin; does not react directly with hydrogen, nitrogen, carbon dioxide and gas ammonia. When moist, sulfur dioxide affects tin. It reacts readily with chlorine, bromine, and iodine and slowly with phosphorus at room temperature. Halogen acids react violently with tin, especially when hot and concentrated. Hot sulfuric acid melts the tin. Reacts gradually with nitric acid; however, it becomes hydrated tin oxide when the acid is concentrated. It reacts rapidly with sulfuric, chlorosulfuric and pyrosulfuric acids. The tin dissolving effect of phosphoric acid is much less than other mineral acids. In the atmospheric environment, it reacts slowly with organic acids such as lactic acid, citric acid, tartaric acid, and oxalic acid. The effect on diluted solutions such as ammonium hydroxide and sodium carbonate are weak; However, strong alkalis such as sodium and potassium hydroxide dissolve tin when cold and diluted to form tin compounds with (+4) valence. Oxidizing salts and their solutions, such as potassium peroxy sulphate, ferric chloride, sulfate, and stannous chloride, dissolve tin.

X-ray room armouring is one of the foremost safety procedures for X-ray rooms. According to the medical study regulation prepared by the Ministry of Health, it is forbidden to carry out radioactive treatment and diagnostic studies without radiation shielding. Taking radiation shielding measures is very, very important for the protection of human health. In addition, it includes significant measures for both human health and the stable operation of other devices. To prevent the radiation emitted by X-rays and minimize the harmful effects, it is necessary to cover the rooms where the X-ray films are taken. In medical treatment environments, especially in chemotherapy units where cancer patients undergo chemotherapy, the rays that may cause radioactive damage should be minimized without damaging the room design, and the beam source should be well protected. In such environments, shielding can be made with copper, reducing the radiation intensity. High radiation level, maximum ideal level is reached with shielding. How to determine the ideal armour thickness to reduce the radiation level by making some calculations. The calculation is based on the radiation dose value and MMED value that may occur in case of overwork. Products used for armouring can be lead, concrete, copper, barite aggregate and heavy concrete. The materials used in the armour vary according to the radioactive source and radiation type. In treatment environments with low radiation intensity, the shielding process can be made of light aluminium. In high-risk environments, the material with the highest atomic number among the materials to protect the rooms is lead.

In this study, albedo factor analyses were performed for some tin compounds, one of the most widely used materials for shielding environments where radiation-based treatment methods are used. Albedo factor is only one of the radiations shielding parameters and consists of 3 different sub-terms. The sub-terms mentioned are called albedo number, albedo energy and albedo dose.

4. Discussion

The calculation of each parameter according to the gamma-ray counts obtained from the experiment was determined using the relevant formulas. The albedo factor values calculated using the formulas are given in Figures 1-3. If we interpret the numbers, the albedo parameter values decrease with the increasing value of the atomic numbers of the target samples. The increase in photoelectric cross-section and decrease in Compton cross-section with a rising atomic number are the main reasons for this situation.

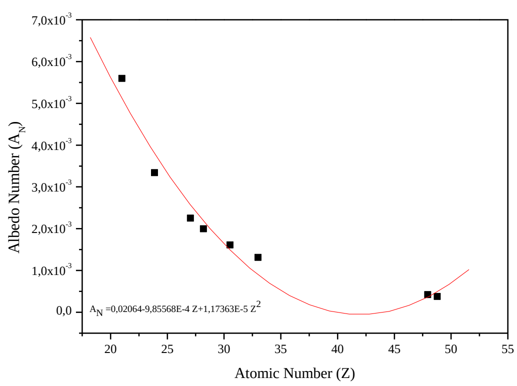

Figure 3 The albedo number distribution of target samples is a function of the atomic number

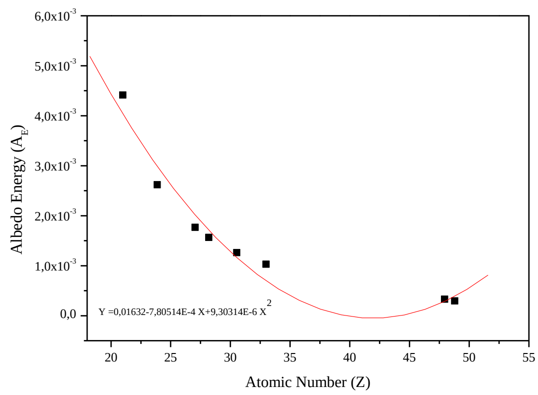

Figure 4 The albedo energy distribution of target samples is a function of the atomic number

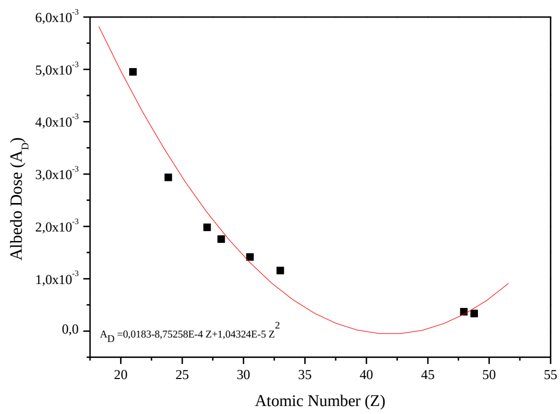

Figure 5 The albedo dose distribution of target samples is a function of the atomic number

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