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The Comparison Between Measured and Calculated Values of Gamma Ray Absorption on Lead Nitrate Solutions

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The method of concentration determination of lead nitrate solutions in the concentration range up to 20 grams per 100 ml by gamma rays absorption measurements was described. ^{60}Co and ^{137}Cs were used as gamma ray sources. The gamma ray intensities were measured using a scintillation counter.

Using a simple equation for the absorption of gamma rays, the equation which contains the directly measured values only, was developed. Using that equation the absorption for all used concentrations was calculated. The agreement between measured and calculated values is fairly well. The possible reason of obtained disagreement is discussed.

INTRODUCTION

The interaction of gamma rays with matter can occur in two general ways: scattering and absorption. Because both gamma ray scattering and absorption intensities are dependent upon the atomic number of the material, they can be applied to the quantitative analysis of two-component systems. In a number of published papers the use of gamma ray absorptiometry in analysis of heavy metal salts and especially uranium salts have been described[1-3]. Some published articles describe the application of the method for chemical processes[4]. Miller and Conally described the gamma ray absorptiometer for in-line determination of plutonium and uranium[5].

As gamma ray sources in these experiments americium-241 and thulium-170 were used in most cases. It can be said in general that low energy gamma ray sources are more convenient than those of higher energy, because of the greater difference between the mass absorption coefficients of water or solvent and dissolved heavy metal salt. The judicious application of these facts can confer a higher sensitivity to the method.

In most cases an ionization chamber was used for the measurement of gamma ray intensities. Thurnau used a scintillation detector instead of the ionization chamber and the signals were recorded on a ratio recorder[1].

The concentration determination by absorption is fast, simple and non-destrucive.

EXPERIMENTAL

A schematic diagram of the apparatus used in the gamma ray absorption measurements is shown in **Fig. 1.**

As gamma ray sources 0.5 mC of cobalt-60 and 3 mC of caesium-137 were used. In order to prevent the contamination of the equipment used, the sources were sealed in aluminium capsules having walls 0.2 mm in thickness. The sources were placed in the lead container and a collimated gamma ray beam was allowed to pass through the test tube filled with the test solution. The lower energy 662 keV gamma rays are more readily absorbed by the lead test solution than the 1.33 and the 1.17 MeV gamma rays emitted from a cobalt-60 source. The measurement of the absorption with caesium-137 and cobalt-60 emitting gamma rays was easily done because of the very long half-life of both isotopes. The gamma ray sources used in this work were obtained from Harwell.

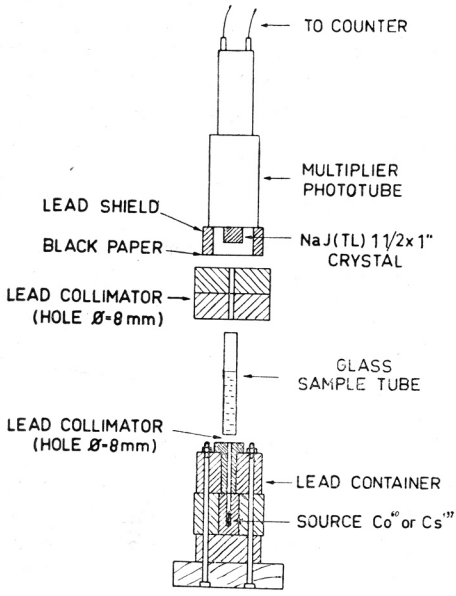

Fig. 1. Schematic diagram of gamma ray absorptiometer

A lead tube, 75 mm long, with a hole 8 mm in diameter was used as a collimator. After passing the glass tube filled with the lead nitrate solution, the beam passed through another collimator. The gamma ray beam thus collimated was allowed to enter the 1½″×1″ NaI(Tl) scintillation crystal connected with a multiplier phototube and the scaler. The counting equipment used in this work was obtained from EKCO Electronics.

The known solutions were prepared by weighing the desired amount of lead nitrate and dissolving it in distilled water. The concentration of the investigated solutions varied from 0 to 200 grams of lead nitrate per liter. The high purity (p.a.) lead nitrate used was obtained from Merck. The sample tube was always filled with the same volume of solution (50 ccm). As sample a glass test tube 200 mm long and 23±0.5 mm inner diameter was used. Measurements of intensities without the gamma ray beam passing the absorption solution and after its passing solutions of various concentrations of lead nitrate were taken. The obtained values were corrected for the background by measuring the activity when the gamma ray source was closed in the lead container by a lead plug.

RESULTS

The results of absorption measurements obtained with the cobalt-60 source are shown in Fig. 2, and those obtained with the caesium-137 source in Fig. 3.

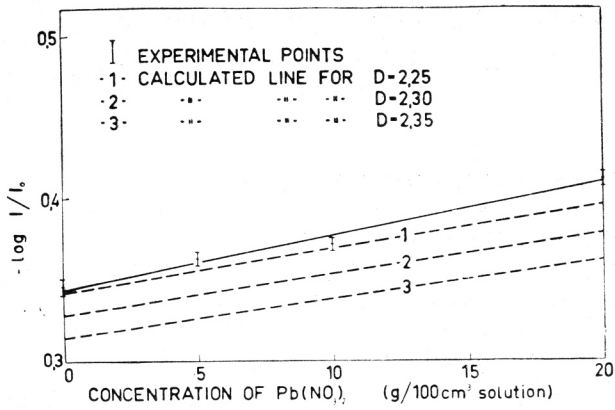

Fig. 2 -log I/I_0 *vs.* concentration of lead nitrate. ^{60}Co used as a gamma ray source. Solution volume 50 ccm.

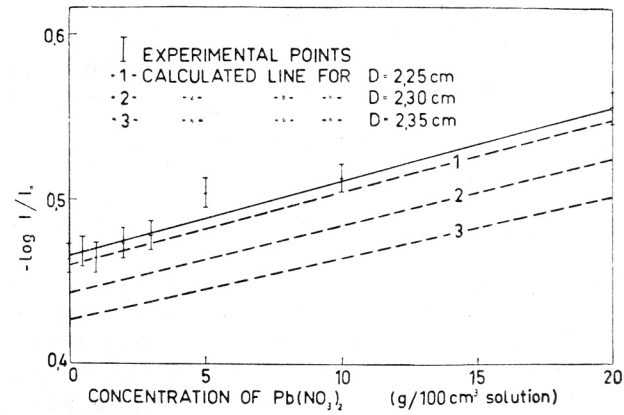

Fig. 3. -log I/I_0 *vs.* concentration of lead nitrate. ^{137}Cs used as a gamma ray source. Solution volume 50 ccm.

Results are plotted in the form of -log I/I_0 *vs.* concentration of lead nitrate. I and I_0 represent the intensity of gamma rays after passing the test tubes filled or not filled with the solution investigated. The size of the plotted points show the standard error. The dotted lines represent calculated values for concentrations used in the experimental work. The diameter of the test tube was 2.30 ± 0.05 cm, so the calculations were done for 2.25, 2.30, and 2.35 cm.

DISCUSSION

Values of -log I/I_0 as a function of concentration can be calculated using the formula:

$$-\log I/I_0 = X\, d \log e \qquad (1)$$

where,

X is the mass absorption coefficient in cm^2/g

d is the thickness in g/cm^2.

Eq. 1 can be transformed into the following form:

$$-\log I/I_0 = \frac{4\,V}{D^2\pi}\left[\frac{c(X_1-X_2)}{100} + \gamma X_2\right]\log e \qquad (2)$$

where,

D is the diameter of the test tube in cm;
V the volume of the solution in the test tube in cm^3;
γ the specific gravity of the solution in g/cm^3;
X_1 the mass absorption coefficient of lead nitrate in cm^2/g;
X_2 the mass absorption coefficient of water in cm^2/g;
c the concentration of lead nitrate in g/100 cm^3;
π and e are common values.

The mass coefficients for lead nitrate were calculated from the data of R. G. Jaeger[6]. The values used in our calculations are shown in Table I.

TABLE I

Gamma source	D [cm]	V [cm^3]	c [g/100 cm^3]	X_1 [cm^2/g]	X_2 [cm^2/g]
Caesium-137	2.30 ± 0.05	50	from 0 to 20	0.093	0.085
Cobalt-60	2.30 ± 0.05	50	from 0 to 20	0.058	0.063

The specific gravity was calculated from the formula:

$$\gamma = 0.008191\,c + 1$$

evaluated on the basis of measured data observed at the temperature of 17.5°C.

Calculated values obtained in that way are not far from the experimental points, especially those calculated on the basis of D = 2.25 cm. There is a small discrepancy between calculated results and experimental points. The probable reason for this is that the calculated values were obtained using the specific gravity at 17.5°C, while the actual temperature was different from 17.5°C.

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IZVOD

Komparacija mjerenih i izračunatih vrijednosti za apsorpciju gama zraka u otopinama olovnoga nitrata

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Opisana je metoda za određivanje koncentracije olovnoga nitrata u vodenim otopinama od 0 — 20 g/100 ml, mjerenjem apsorpcije gama zraka. Kao izvori gama

zraka upotrebljavani su ^{60}Co i ^{137}Cs. Mjerenje intenziteta gama zraka vršeno je scintilacionim brojačem.

Na temelju osnovne jednadžbe za apsorpciju gama zraka izvedena je jednadžba, koja sadrži samo direktno mjerljive veličine, i po njoj je izračunata apsorpcija za sve upotrebljene koncentracije. Slaganje između mjerenih i izračunatih vrijednosti dosta je dobro. Prikazan je i vjerojatni razlog odstupanja.

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