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GAMMA RAY SPECTRUM OF AM-241 IN A BACK SCATTERING GEOMETRY USING A HIGH PURITY GERMANIUM DETECTOR

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ABSTRACT

A back scattering geometry using an annular Am-241 source and a HPGe detector has been set up to study both the coherent and incoherent scatterings of photon emissions of Am-241 from medium-Z and high-Z elements. Besides the coherent and incoherent scattered peaks of the emissions from the source, the gamma ray spectrum from the different target elements obtained using a microcomputer based multichannel analyser showed the presence of several other peaks. These peaks have been identified to arise from the fluorescence of the targets, the fluorescence of the shielding material Pb, and also as fluorescence sum peaks and X-ray escape peaks of the detector material Ge. The spectra are presented for three target elements viz. Mo, Zn and W.

INTRODUCTION

Earlier studies in our laboratory on scattering of gamma photons have been focused on scattering by medium and high Z elements over the angular range of 5-25° for moderate energy photons from ^{203}Hg and ^{137}Cs [1-3]. However, less extensive data are available for medium and low Z elements, especially at photon energies of a few tens of keV or less, and at large scattering angles. To address this situation, a back-scattering geometry using an annular ^{241}Am source and a high purity germanium detector has been set up to study both coherent and incoherent scatterings.

The objective of the experimental set-up is to obtain new results for photon scattering from a number of low, medium and high Z elements having their K-edges close to the exciting photon energies 13.9, 17.8, 26.4 and 59.5 keV emitted by ^{241}Am. A preliminary study for the medium-Z elements, Mo, Nb and Zr has already been reported [4]. However, there exists some problems in resolving and identifying several other peaks in the gamma-ray spectrum obtained besides the coherent and incoherent scattered peaks of the emissions from the source. In the present study the various peaks are identified so that appropriate corrections could be made to the intensities of the scattered peaks with which they may overlap.

EXPERIMENTAL

The basic experimental arrangement is shown in Fig. 1. Measurements were carried out using an annular ^{241}Am source of activity 3.7 x 10^9 Bq (Amersham International). A high purity germanium detector of 3 mm thickness and 10 mm active diameter (EG & G ORTEC) was used throughout the investigation. For this particular detector, its FWHM was about 450 eV for the 59.5 keV peak.

Metal foils (Aldrich Chemical Company) of better than 99.9% purity were used as targets. The thickness of these foils ranged from 0.1-0.25 mm. The gamma ray spectra from the target elements were collected for 2000 s counting time using a microcomputer based multichannel analyser (EG & G ORTEC) and peak analysis was carried out with the Peak Fit V.4 programme (Jandel). The data are presented for only three target elements viz. Zn (Z = 30), Mo (Z = 42) and W (Z = 74) since they are representative of the group of 11 elements under study. In the peak fitting analysis, the number of known and assigned peaks, their centres and widths were specified and the programme then performed the final fitting of the data. The errors were due to the most part to the counting statistics. The residuals of the fit were insignificant and did not reveal the existence of possible hidden peaks.

RESULTS AND DISCUSSION

The spectrum of the photon emissions from the ^{241}Am source directly into the detector is shown in Fig. 2, and the spectra of the back scattered photons from the three different elements Zn, Mo and W are presented in Fig. 3, 4 and 5 respectively. To reduce the cluttering of the spectra, each of the figures is divided into three energy regions viz. 0-12 keV, 10-30 keV and 30-60 keV. The various peak energies and their assignments are listed in Table 1. Uncertainty in the energy calibration is ±0.05 keV. The identified X-ray and γ-ray peaks follow the listing by Browne and Firestone [5]. In addition to the Compton scattered peaks, we have also identified the other noticeable peaks in each of the specific spectra. A few peaks which are of very low intensity are however not included in Table 1.

(a) Direct ^{241}Am source

The direct ^{241}Am spectrum shows several other minor peaks besides the usual intense gamma peaks (59.5 and 26.3 keV) and a number of characteristic L X-rays from Np (20.7, 17.7, 16.9 and 13.9 keV). Some of the minor peaks are ascribed to the other weaker characteristic X-rays from Np and also to Am itself. Some other minor peaks particularly at the low energy region correspond to the escape of characteristic Kα (9.87 keV) and Kβ (11.0 keV) X-rays of germanium. The X-ray escape peaks are more prominent for low energy incident photons and also for small detectors with large surface-to-volume ratio.

(b) Back-scattering from Zn

The back-scattered photon spectrum from Zn shows some new features different from the ^{241}Am source spectrum. Compton scattered peaks appear alongside the major coherent scattered peaks. Intense Kα (8.67 keV) and Kβ (9.61 keV) X-ray florescence peaks of the target material also appear in the low energy region.

(c) Back-scattering from Mo

As expected for higher Z material and low energy photons, the Compton scattered peak intensity compared with the coherent peak is reduced. The Kα and Kβ X-ray fluorescence peaks at 17.4 keV and 19.6 keV respectively are extremely intense such that the Np L X-rays could not be resolved. Furthermore, arising from this high intensity, two other types of peaks are observed. Two sum peaks, one due Kα_1 + Kα_2 and the other due to Kα + Kβ are observed at 34.6 keV and 36.9 respectively. A set of four Ge escape peaks is present in the energy region of 6-10 keV.

(d) Back-scattering from W

In this case of high Z target material, several of the L X-ray fluorescence peaks are observed, the most intense peaks being the Lα (8.39 keV) and Lβ (9.66 and 9.92 keV) peaks. Since these intense fluorescence peaks do not overlap generally with the other peaks, many of the peaks observed in the spectrum for Zn are also present here.

CONCLUSIONS

The complex back-scattered photon spectra from metal targets could be generally resolved using an efficient peak fitting program. The peak intensities which are resolved could then be determined with a higher certainty. Such a peak-fitting analysis is necessary particularly for the study of photon scattering cross-sections.

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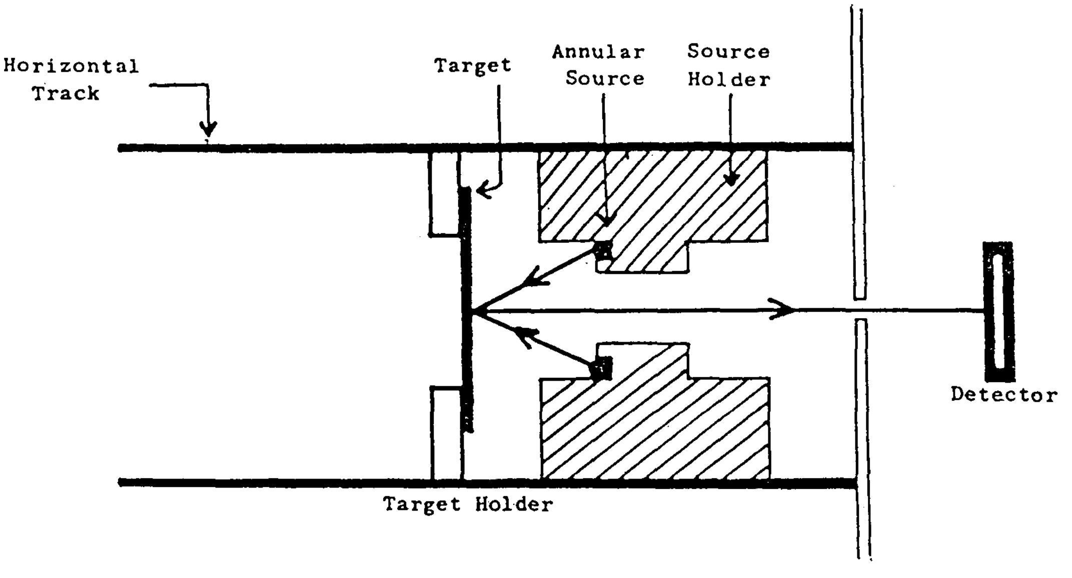

Fig. 1. Experimental set-up of back-scattering geometry

Table 1: Photon peak energies and assignments.

Peak Energy (keV)	Assignment	Peak Energy (keV)	Assignment
^{241}Am Source		Back-scattering from Zn	
2.88	Ge escape from 13.9	8.67	Zn Kα
4.04	Ge escape from 13.9	9.61	Zn Kβ
6.94	Ge escape from 17.8	12.6	Pb Lβ
7.85	Ge escape from 17.8	13.3	Compton of 14.0
11.8	Np Lℓ	14.0	Np Lα
13.9	Np Lα	14.7	Am Lα
14.6	Am Lα	16.1	Compton of 17.0
16.9	Np Lβ_2	16.7	Compton of 17.8
17.7	Np Lβ_1	17.0	Np Lβ_2
18.8	Am Lβ_1	17.8	Np Lβ_1
20.7	Np Lγ_1	20.8	Np Lγ_1
21.3	Np Lγ_3, Lγ_6	21.4	Np Lγ_3, Lγ_6
26.3	Am γ	24.2	Compton of 26.3
33.2	Am γ	26.3	Am γ
49.5	Ge escape from 59.5	49.1	Compton of 59.5
58.6	W Kα	59.5	Am γ
59.5	Am γ		

Table 1 ... contd.

Peak Energy (keV)	Assignment	Peak Energy (keV)	Assignment
Back-scattering from Mo		Back-scattering from W	
2.78	Ge escape from 12.6	1.47	Ge escape from 11.3
4.13	Ge escape from 13.9	1.77	Ge escape from 11.6
6.50	Ge escape from 17.4	7.44	W $L\ell$
		8.39	W $L\alpha$
7.61	Ge escape from 17.4	9.66	W $L\beta_1$
		9.92	W $L\beta_2$
8.65	Ge escape from 19.6	11.3	W $L\gamma_1$
9.75	Ge escape from 19.6	11.6	W $L\gamma_{2,3,6}$
		12.6	Pb $L\beta$
10.6	Pb $L\alpha$	14.0	Np $L\alpha$
12.6	Pb $L\beta$	14.6	Am $L\alpha$
13.9	Np $L\alpha$	16.1	Comptom of 17.0
14.6	Am $L\alpha$	16.9	Np $L\beta_2$
17.4	Mo $K\alpha$	17.8	Np $L\beta_1$
19.6	Mo $K\beta$	18.8	Am $L\beta_1$
26.3	Am γ	20.8	Np $L\gamma$
34.6	Mo $K\alpha_1 + K\alpha_2$	21.4	Np $L\gamma$
36.9	Mo $K\alpha + K\beta$	26.3	Am γ
49.2	Compton of 59.5	49.2	Compton of 59.5
59.5	Am γ	57.9	W $K\alpha_2$
		59.5	Am γ

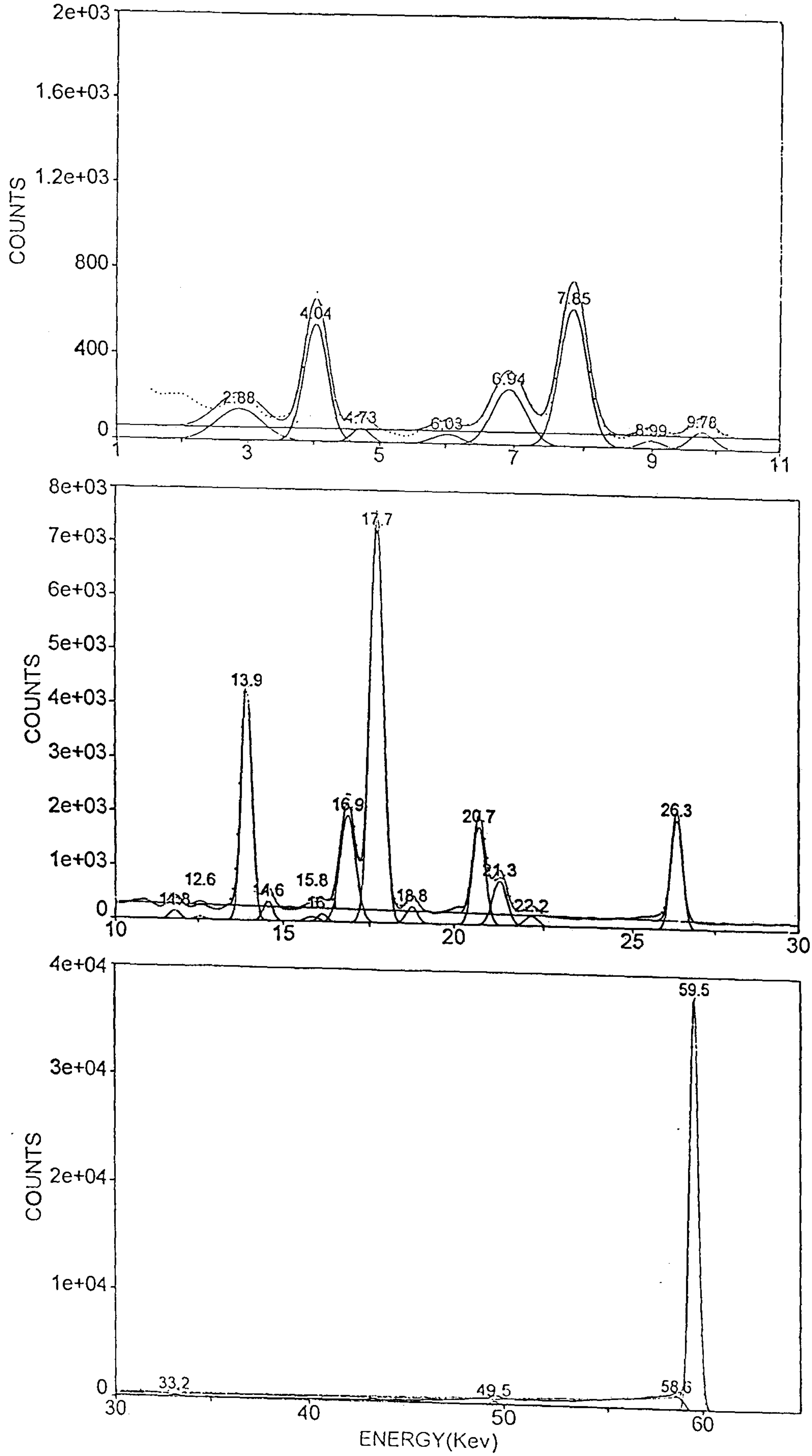

Fig. 2. Photon spectrum of Am-241 source

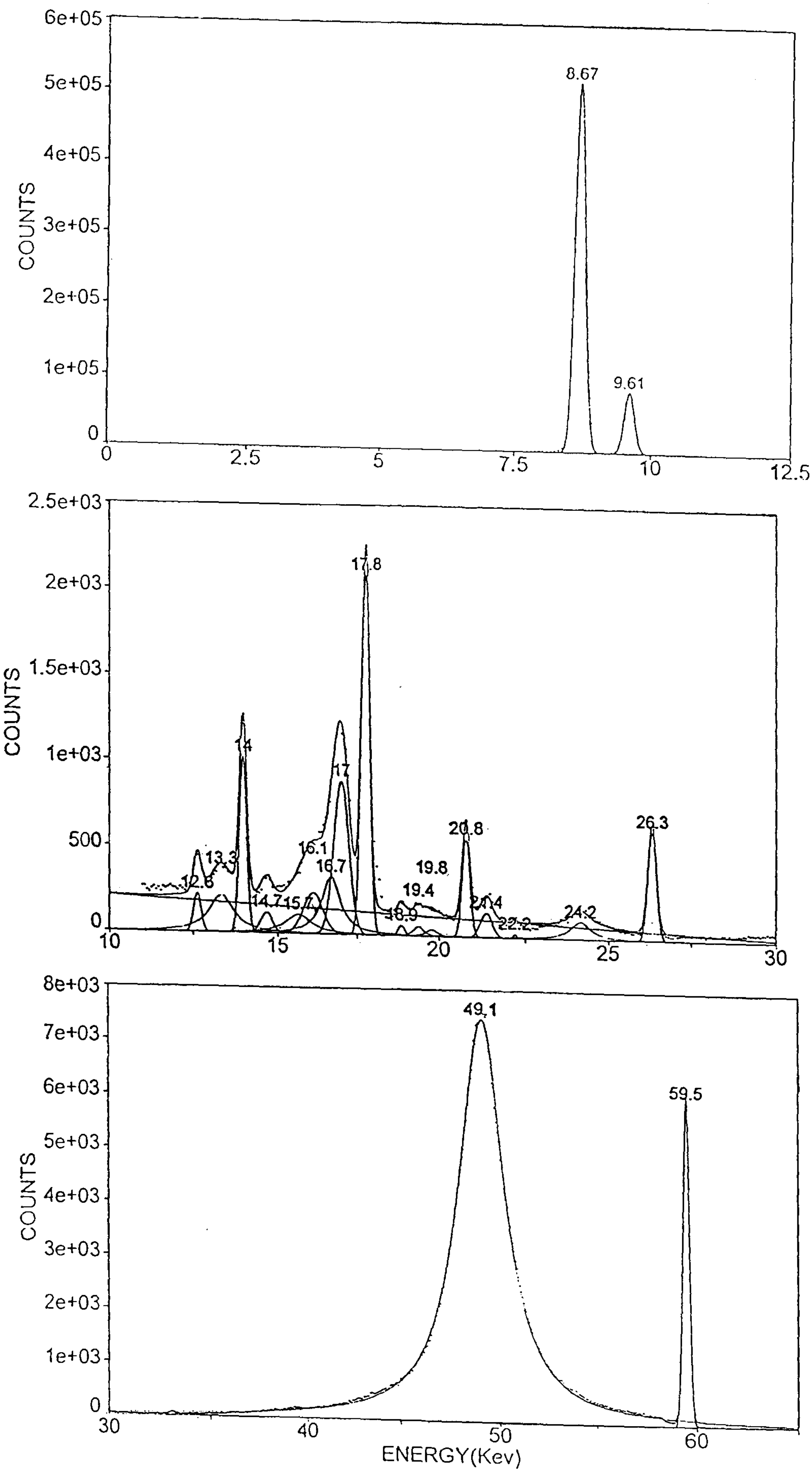

Fig. 3. Back-scattered photon spectrum of Zn

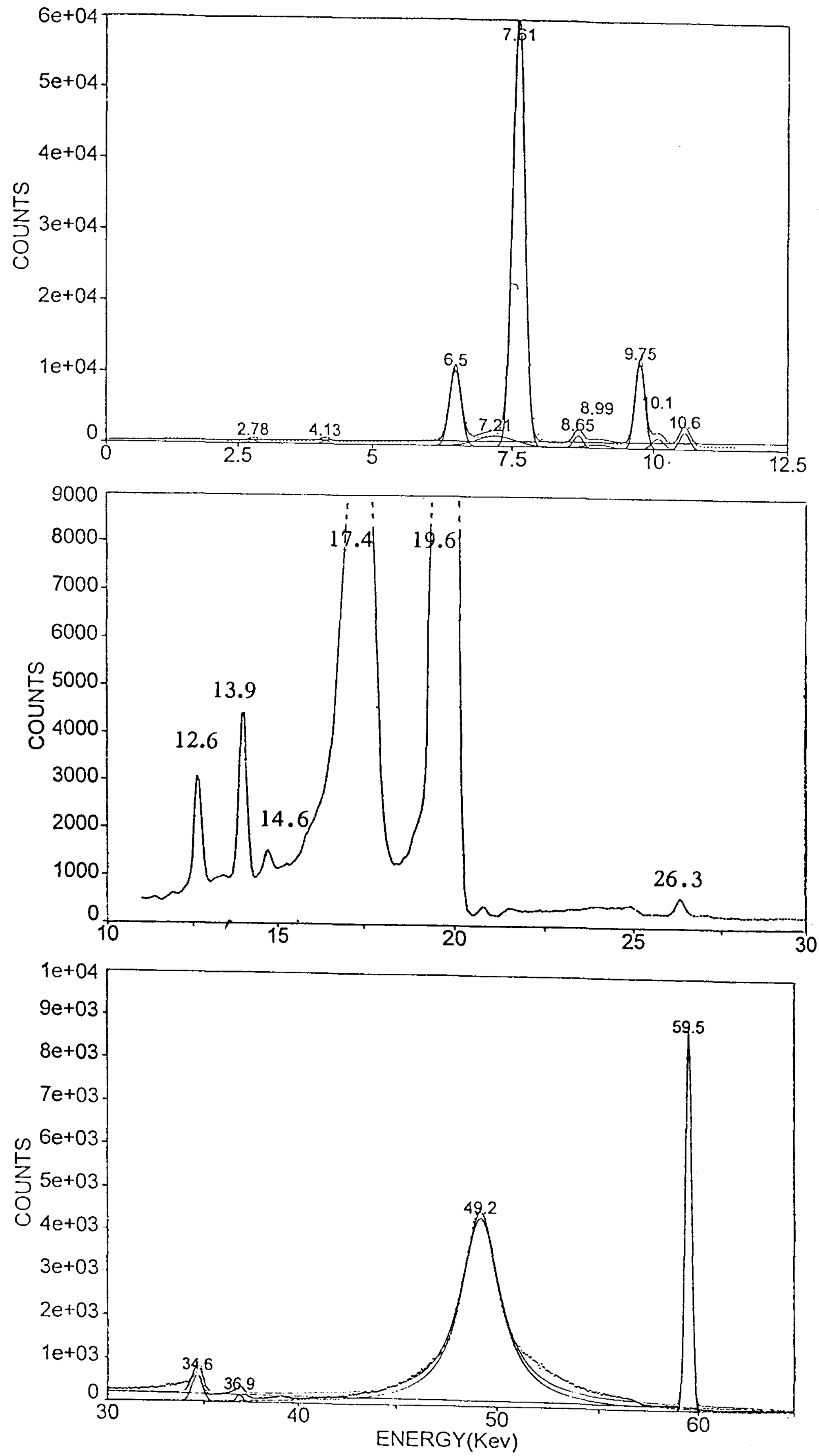

Fig. 4. Back-scattered photon spectrum of Mo

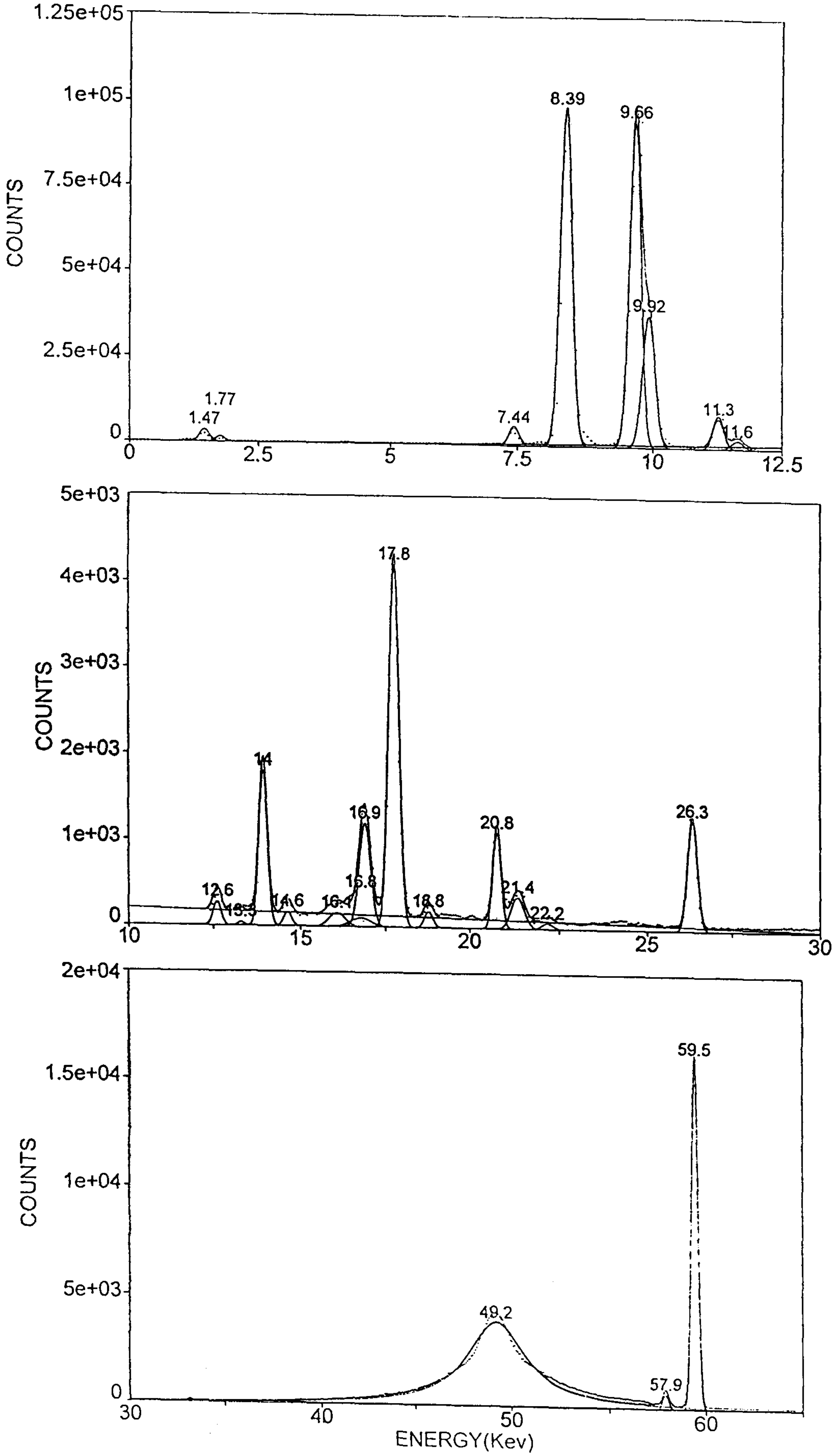

Fig. 5. Back-scattered photon spectrum of W