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EXPERIMENTAL PROCEDURE

In the present investigation, the attenuation cross section measurements were done in a narrow beam good geometry set up. Each of the radioactive sources ^{137}Cs and ^{203}Hg in the form of the radiographic capsule were mounted inside the lead shielding and collimated as shown in fig. 3-1. The detector is properly shielded and collimated with respect to the source position. The experiment was done in two sample positions outside and inside the well of the detector which are shown as P_1 and P_2 positions respectively in the figure.

The sample position P_1 corresponds to a physical situation in which no scattered photons [except for those which undergo small angle scattering corresponding to the solid angle subtended by the source at the detector] reach the detector. Thus, while the sample is in position P_1 , the experiment is simply the conventional narrow beam good geometry set up.

At P_1 position:

In the position P_1 , the transmitted spectra with and without the sample in the path of the beam were recorded. A typical spectrum for a sample for ^{137}Cs source is shown in the fig. 4-1. The area under the photo peaks of the respective spectra were taken to be the transmitted intensities I and I_0 respectively in the equation 4.1 to calculate the attenuation cross sections for the sample in units of barn/mole.

$$\sigma_{\text{tot}} = \frac{A \ln(I_0 / I)}{0.60225 t} \quad 4.1$$

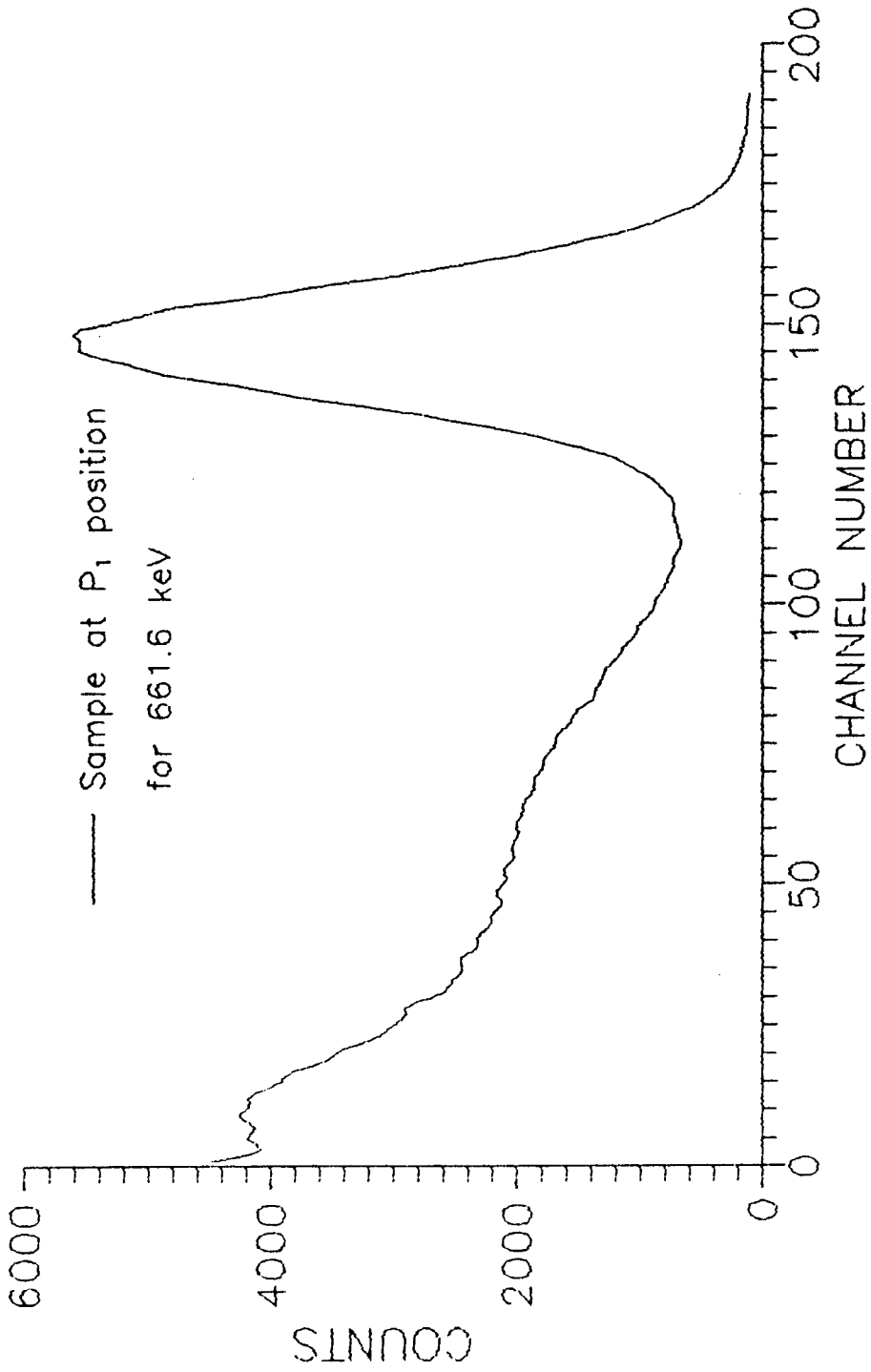


Fig 4-1. A typical transmitted spectrum for HgCl₂ in P₁ position (outside the well) for 661.6 keV

where A is the molecular weight of the sample and t is the sample thickness (mass per unit area in g/cm^2). Further, to the area of the photo peak (shaded area in fig. 4-1), intensity corresponding to ten channels to the lower energy side of the photo peak in the respective spectra were added. From these transmitted intensities corresponding to 0 to 70 channels, σ_{tot} was calculated using equation 4.1. Again the intensity corresponding to the next ten channels to the left of the earlier case were added and σ_{tot} was calculated using the transmitted intensities corresponding to 0 to 80 channels in the equation 4.1. This procedure was repeated each time adding intensities of ten channels towards the lower energy side, to the earlier till the back scattered peak was encompassed. The calculated values of σ_{tot} were plotted as a function of the number of channels used for the purpose. This procedure was extended to all the samples and the plots were obtained. A typical plot in case of HgCl_2 for ^{137}Cs source is shown in fig. 4-2. It can be noticed from this figure that even after adding the intensities corresponding to all channels up to the back scattered peak, the attenuation cross section values remains the same. Since adding intensities of the channels to the lower energy side of the shaded photo peak area amounts to including the scattering contribution in the transmitted intensity, the constancy of σ_{tot} indicates that when the sample is in position P_1 no scattered photons reach the detector.

At P_2 position:

The experiment was repeated keeping the samples inside the well of the detector.(position P_2). The spectra were recorded with empty container and the container with the sample in the path of the beam. A typical transmitted spectrum is shown in fig. 4-3. The procedure explained in the position P_1 was followed to calculate the σ_{tot} for all the samples. The values

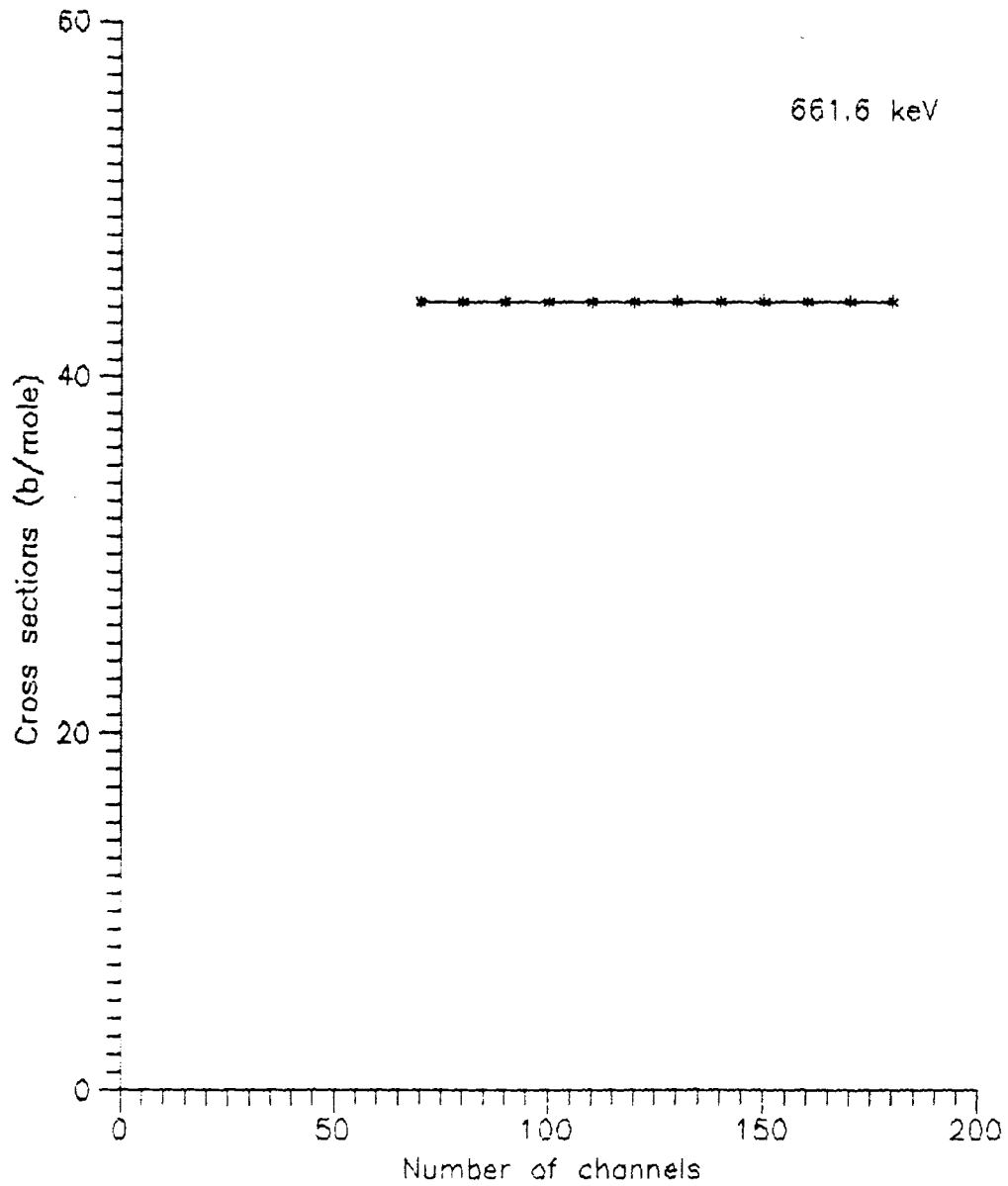


Fig 4-2. A typical plot of σ_{tot} versus number of channels for HgCl_2 in P_1 position for 661.6 keV.

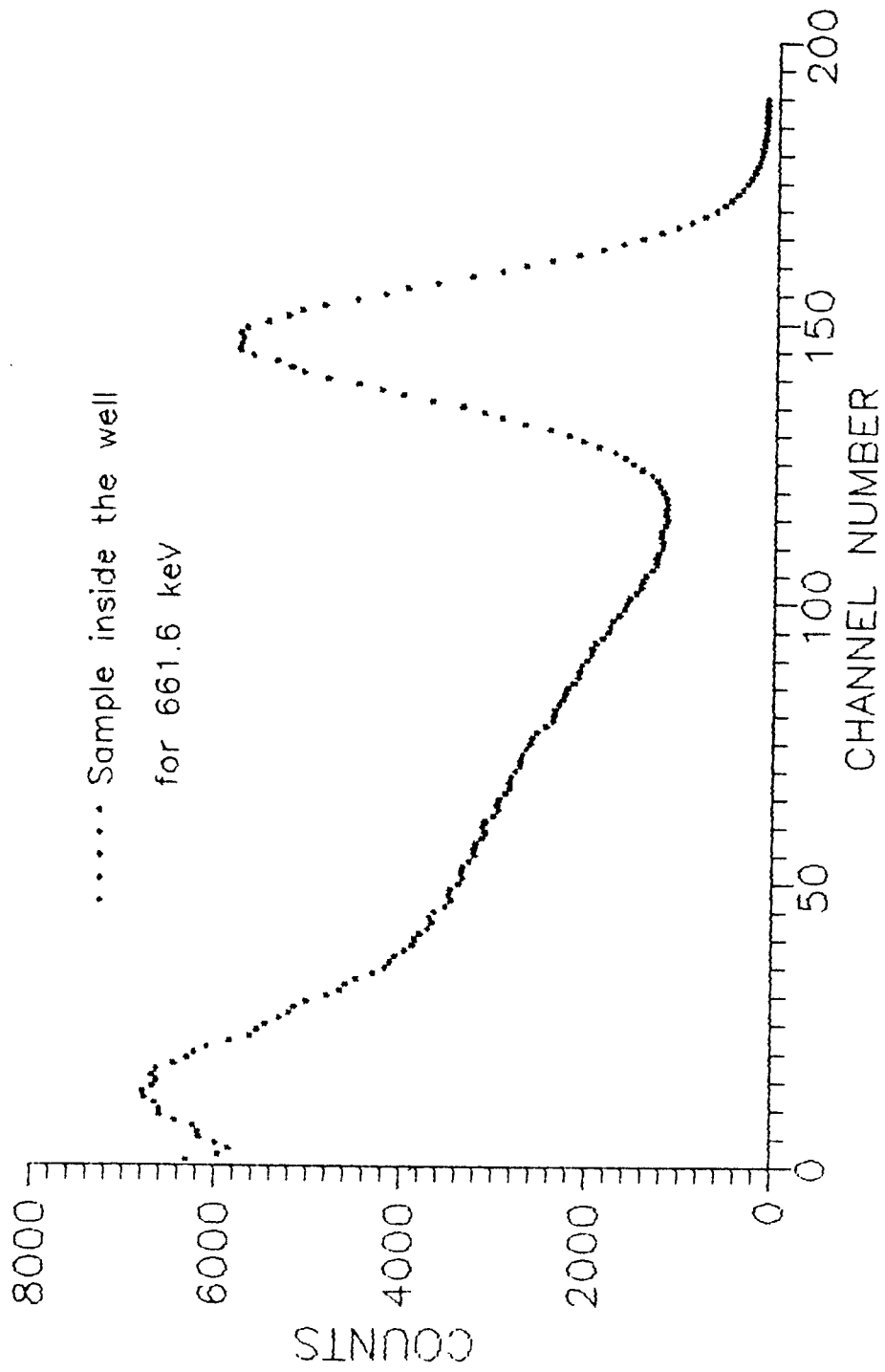


Fig 4-3. A typical transmitted spectrum for HgCl_2 in P_2 position (inside the well) for 661.6 keV

of σ_{tot} so obtained were plotted against the number of channels for all the samples used in the present investigation. A typical plot for HgCl_2 is shown in fig. 4-4. It is clear from the figure, that σ_{tot} progressively decreases with the number of channels used. This was because of the fact that while the sample was kept in position P_2 , there would be a complete contribution of scattering (single as well as plural) in all directions to the transmitted intensity. Thus, the addition of intensities corresponding to the lower energy side of the shaded photo peak area up to the back scattering peak, amounts to the progressive inclusion of the scattering contribution to the transmitted intensity. Thus, as the number of channels increases, the transmitted intensity increases resulting in the underestimation of the attenuation cross sections.

Estimation of incoherent scattering cross sections:

The spectra corresponding to both the sample positions P_1 and P_2 are shown in fig. 4-5 for 661.6 keV for comparison. It can be noticed from this figure that there will be an increase in the transmitted intensity for the sample position inside the detector well relative to that outside the well. As a result, the total cross sections for the sample position P_2 will be underestimated with respect to those calculated for sample position P_1 . This fact is made use of in the present study to evaluate the whole-atom integral incoherent scattering cross sections of samples.

The values of the σ_{tot} calculated in the case of each sample at position P_2 were plotted as a function of number of channels (fig. 4-4). It was noticed that σ_{tot} decreased progressively up to a certain value beyond which it remains constant irrespective of the number of channels. This saturation value

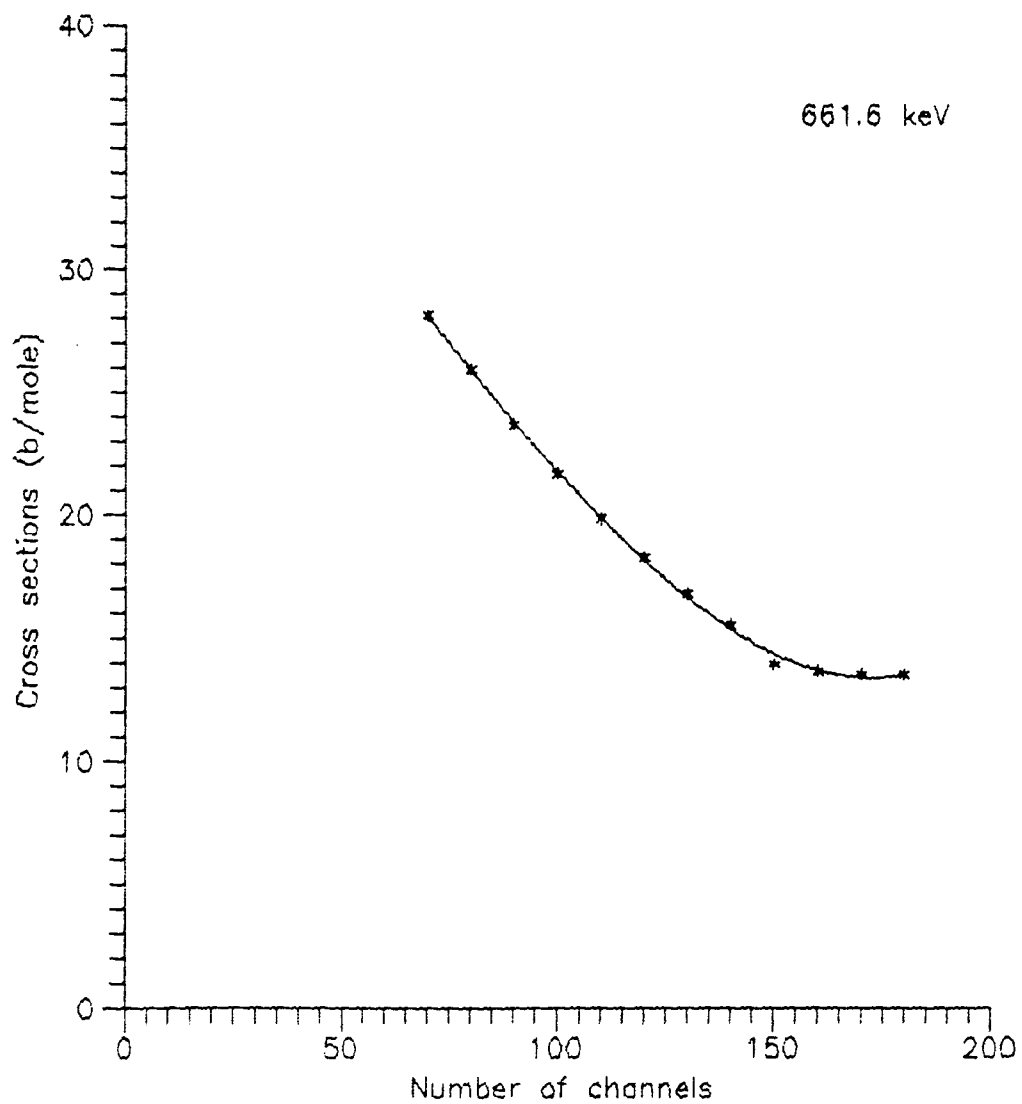


Fig 4-4. A typical plot of σ_{tot} versus number of channels for HgCl_2 in P_2 position for 661.6 keV.

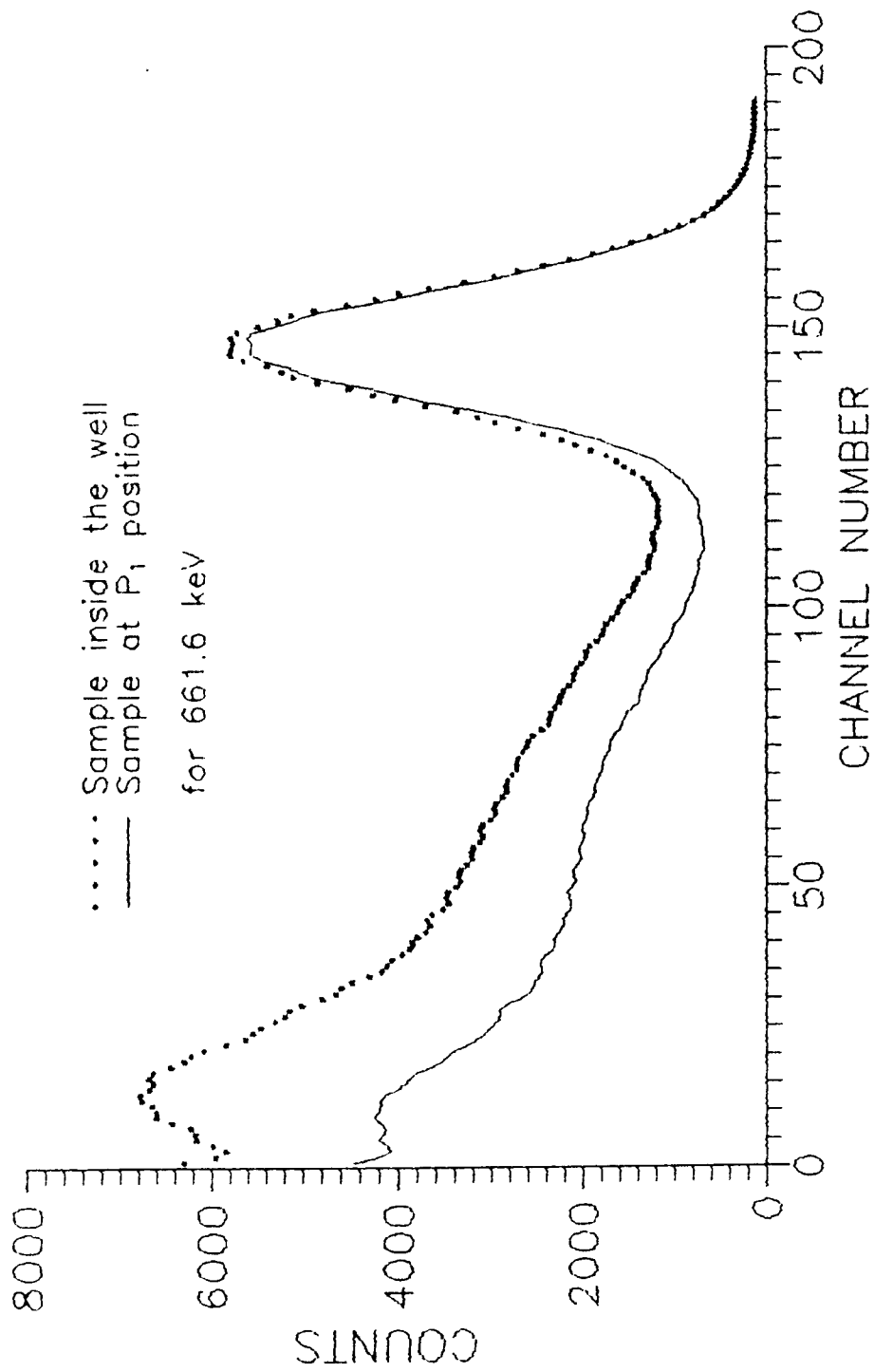


Fig 4-5. Typical transmitted spectra for HgCl₂ in both P₁ and P₂ positions for 661.6 keV

(constant value) of the σ_{tot} can be attributed to the absence of any further scattering contribution to the transmitted intensity. As such, the saturation value σ_s would represent that value of σ_{tot} which would have been obtained when all the incoherently scattered photons reach the detector. Similarly, when the plot is extrapolated to the zero channel number, this extremum value of the σ_{tot} should correspond to a value σ_0 which would have been obtained when no incoherently scattered (energy degraded) photons could reach the detector. The difference ($\sigma_0 - \sigma_s$) should yield the whole-atom integral incoherent scattering cross section of the sample.

The extrapolation to zero channel number was done by fitting a polynomial to the plot of attenuation cross sections obtained using the equation 4.1 versus the number of channels. Typical plots in the case of compounds containing a low-, medium- and a high-Z element are given in figs. 4-6 to 4-8. It was interesting to note from the figures that polynomial of the same degree did not uniquely fit all the curves. For example, in the case of the low-Z compound NaNO_3 , a first degree polynomial fitted the curve. However, a second degree polynomial represented the trend of the curve for Cr_2O_3 which is a medium-Z compound. The curve for the high-Z compound PbO could be fitted with a third degree polynomial. The polynomial fitting was done by performing the regression analysis on a personal computer. Thus, the whole-atom integral incoherent scattering cross sections for all the samples were calculated using the best fit values of σ_0 and σ_s .

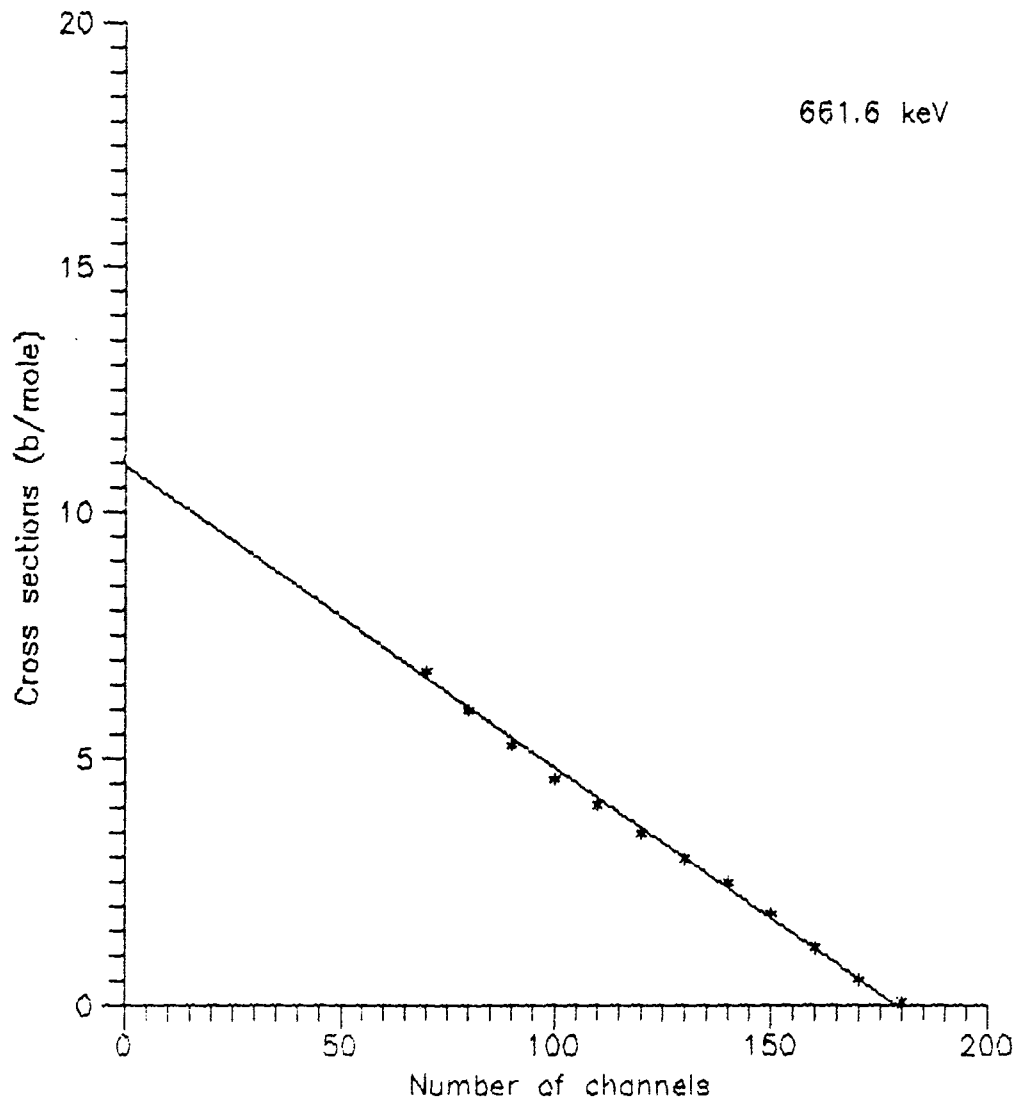


Fig 4-6. A typical plot of σ_{tot} versus number of channels for NaNO_3 in P_2 position for 661.6 keV

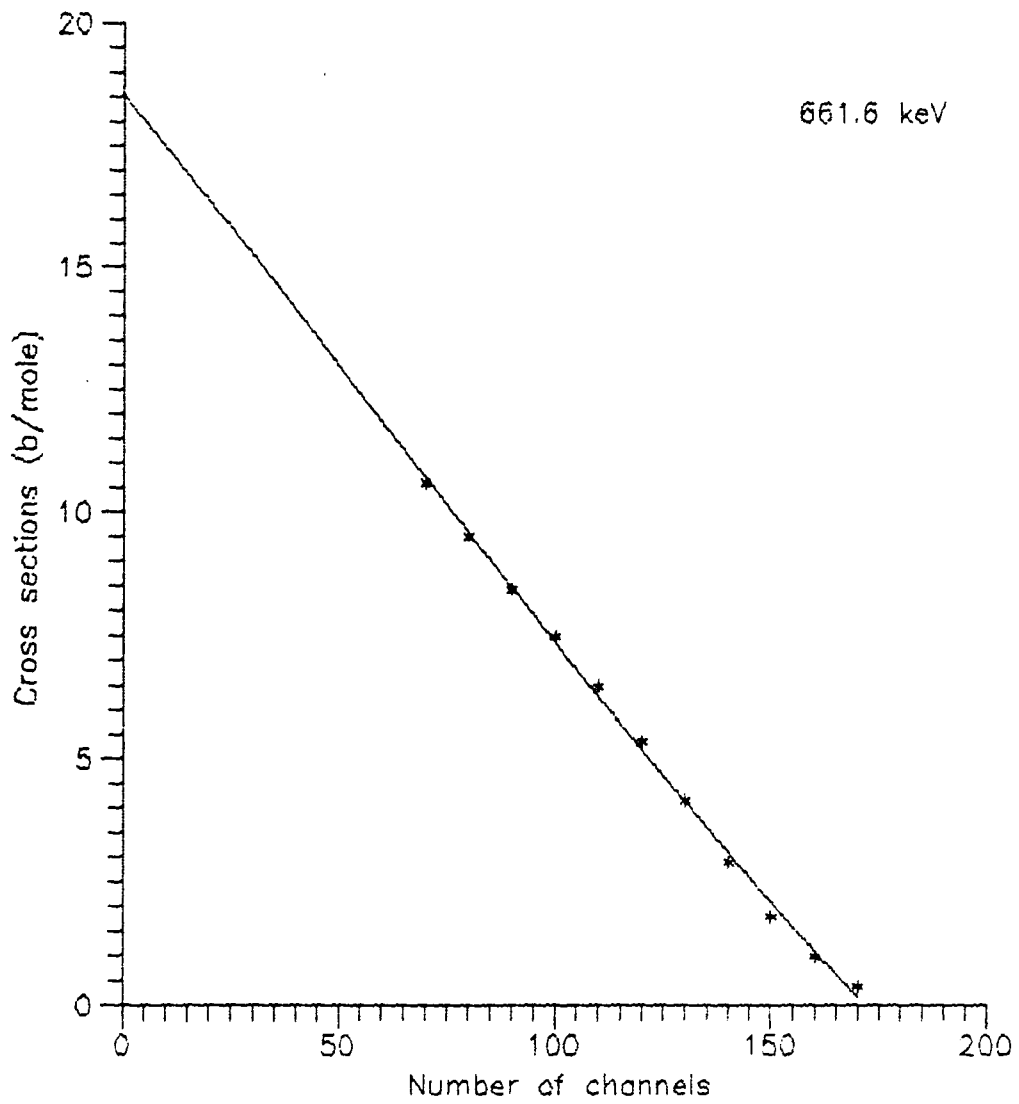


Fig 4-7. A typical plot of σ_{tot} versus number of channels for Cr_2O_3 in P_2 position for 661.6 keV

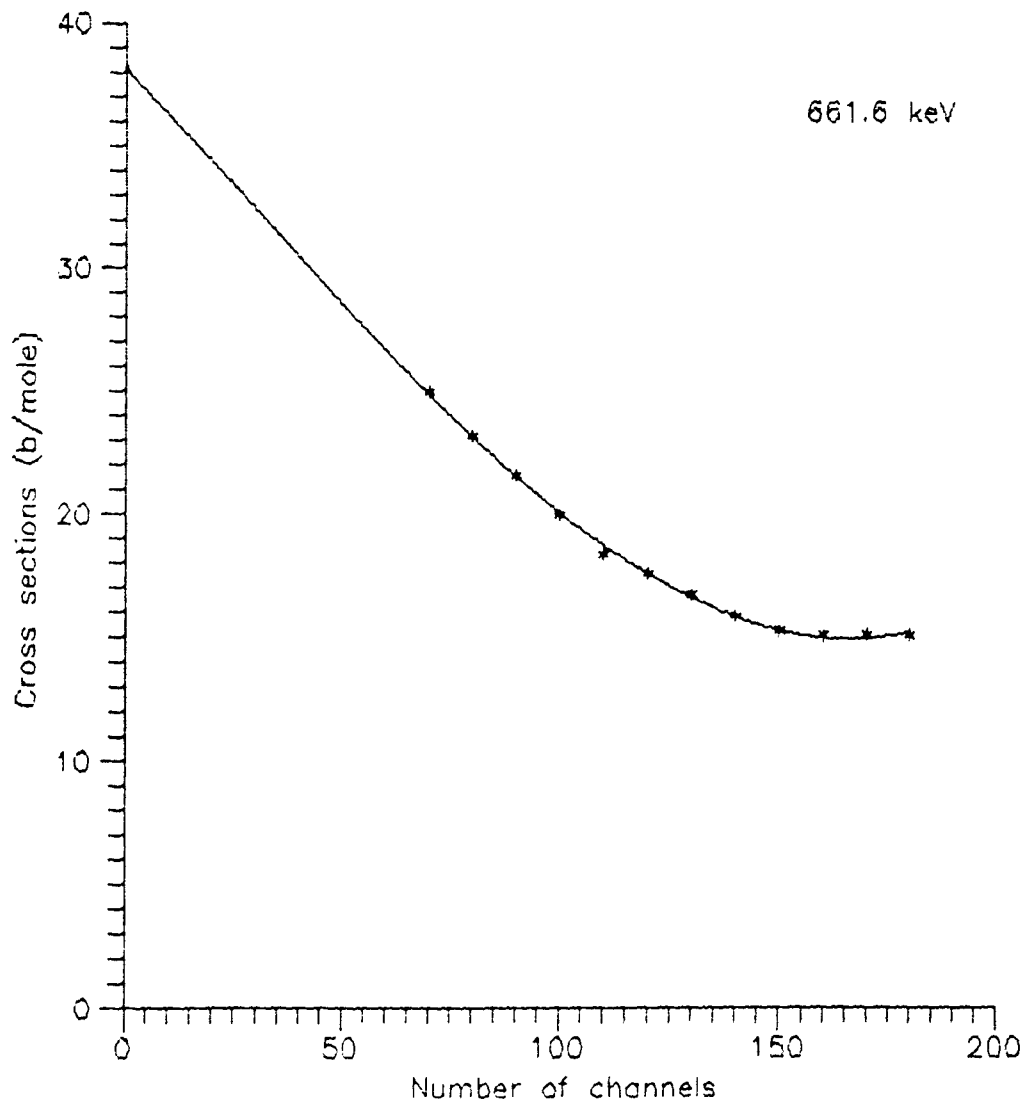


Fig 4-8. A typical plot of σ_{tot} versus number of channels for PbO in P_2 position for 661.6 keV

Using the method described above, the whole-atom integral incoherent scattering cross sections for all the samples were also obtained at 279.2 keV. Typical transmitted spectra in sample positions P₁ and P₂ are given in fig. 4-9. Plots of attenuation cross sections calculated using equation 4.1 versus the number of channels are shown in figs. 4-10 to 4-14. These plots were also found to show a trend similar to those obtained at 661.6 keV for the respective samples.

Errors associated with the measured cross sections

The experimental errors in the present method are mainly due to the following possible sources

- 1) Counting statistics
- 2) Non uniformity of the sample
- 3) Sample impurity
- 4) Photon dose build up effects
- 5) Dead time of the counting instrument.

Counting statistics:

In the transmission experiment, the counting time was chosen such that at least 10⁵ to 10⁶ counts were recorded within the photo peak area. Thus the error due to counting statistics was less than 0.3 % in all cases.

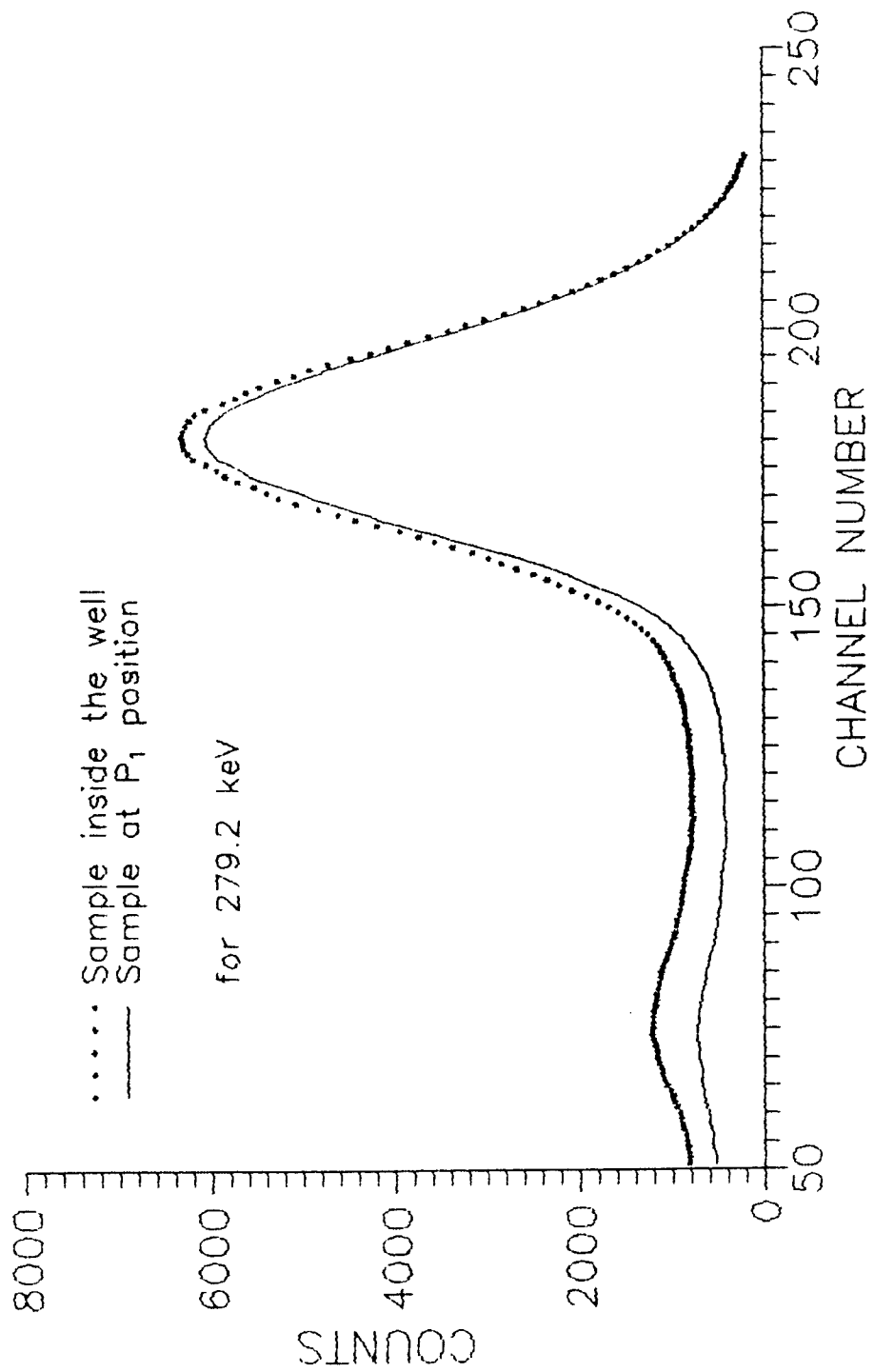


Fig 4-9. Transmitted spectra for a HgCl₂ in both P₁ and P₂ positions for 279.2 keV

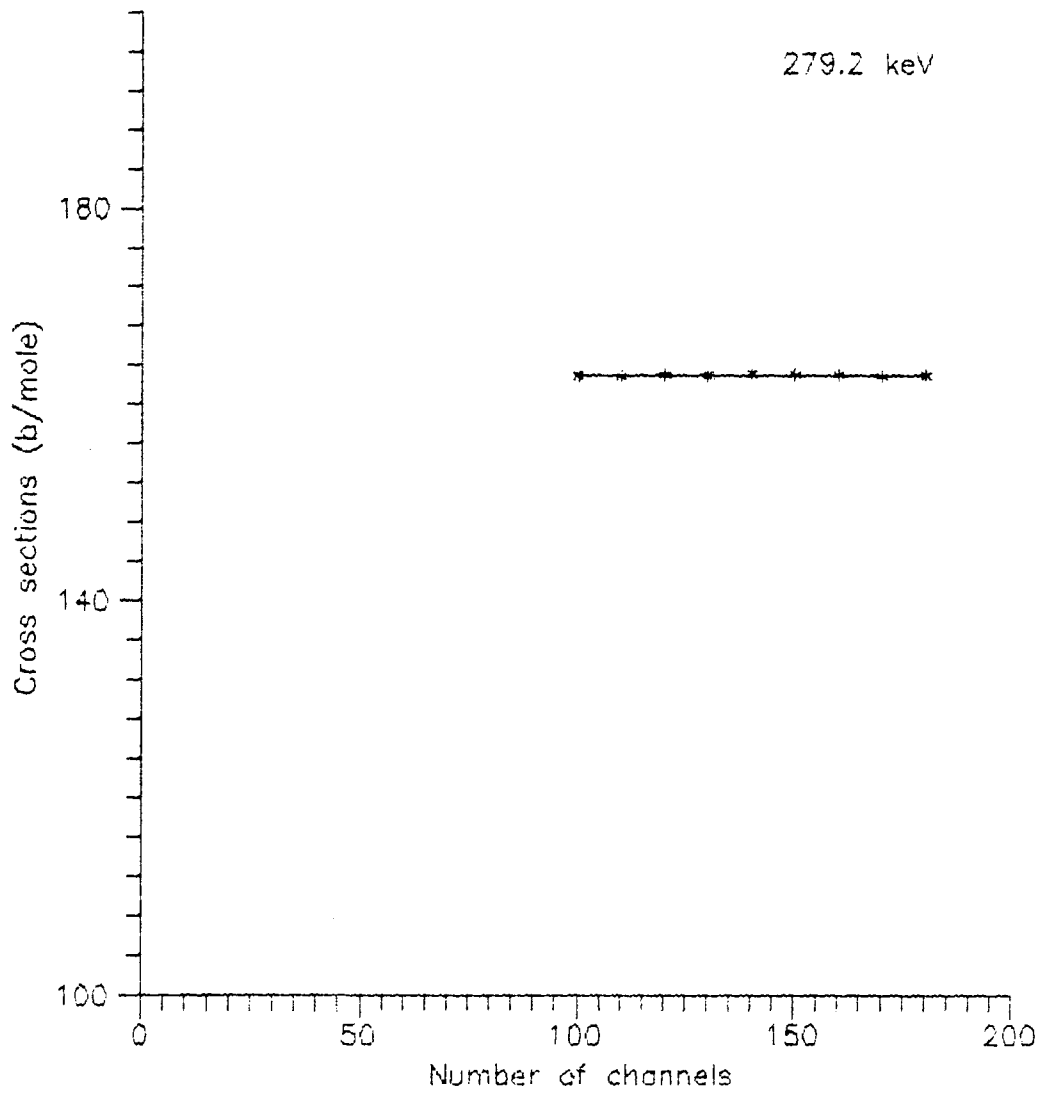


Fig 4-10. A typical plot of σ_{tot} versus number of channels for HgCl_2 in P_1 position for 279.2 keV.

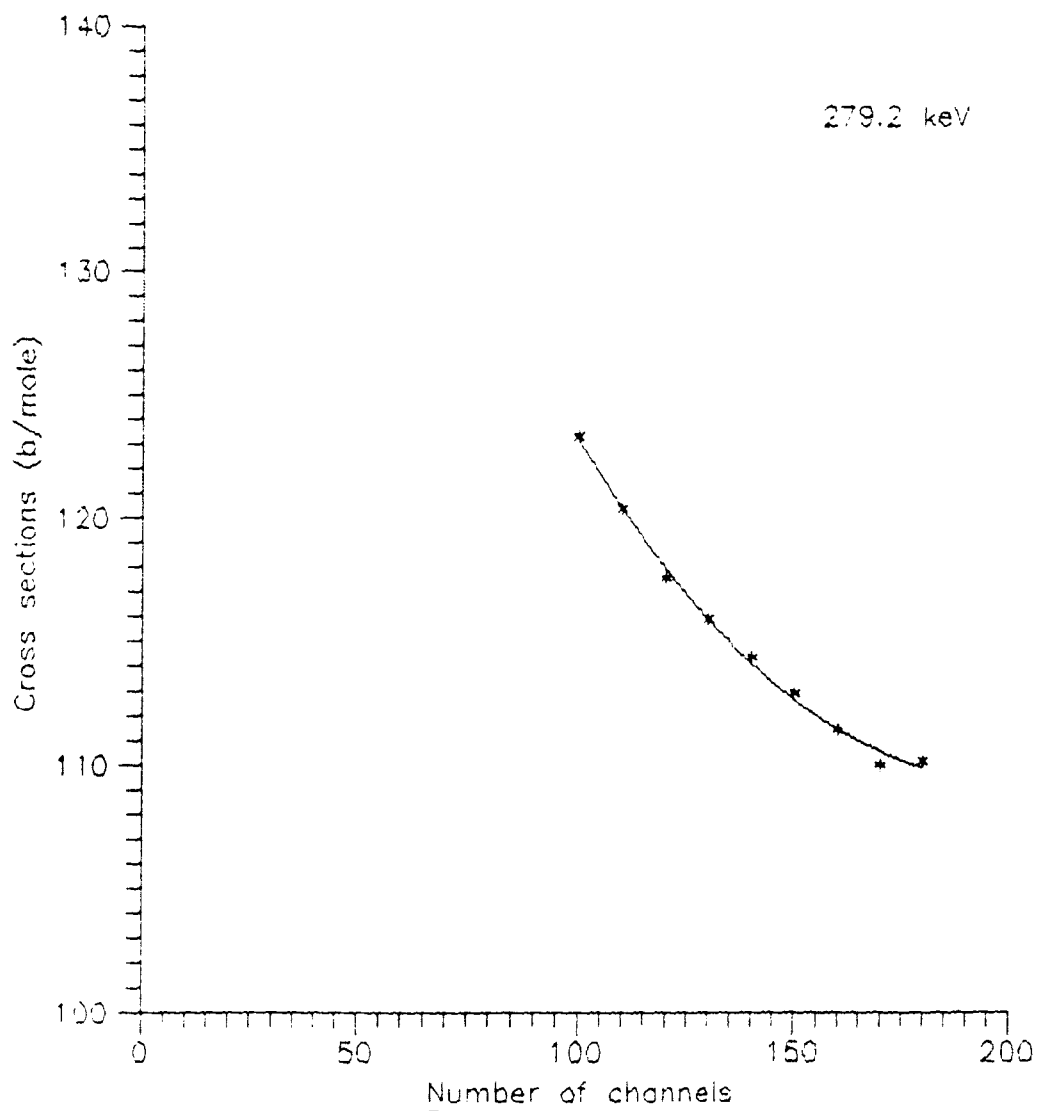


Fig 4-11. A typical plot of σ_{tot} versus number of channels for HgCl_2 in P_2 position for 279.2 keV.

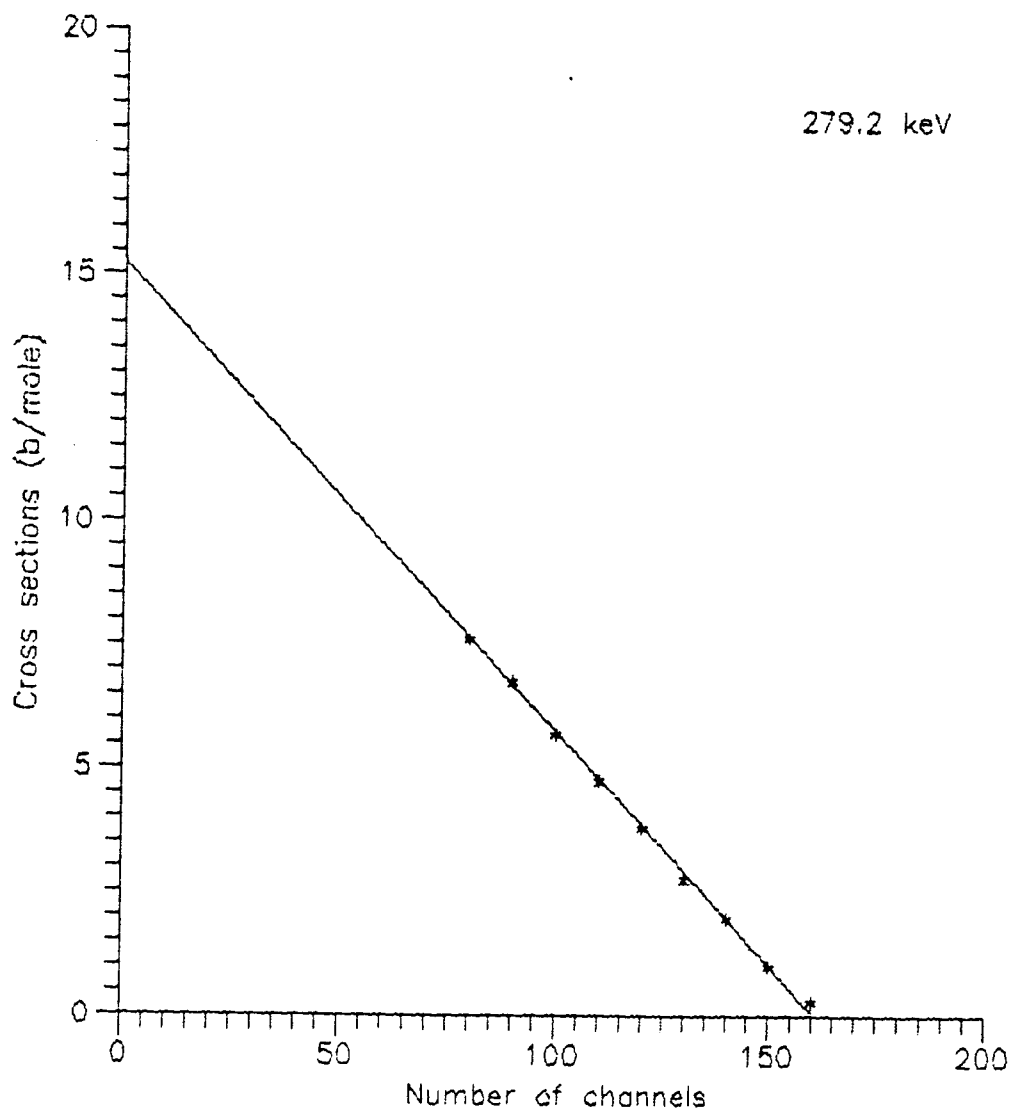


Fig 4-12. A typical plot of σ_{tot} versus number of channels for NaNO_3 in P_2 position for 279.2 keV

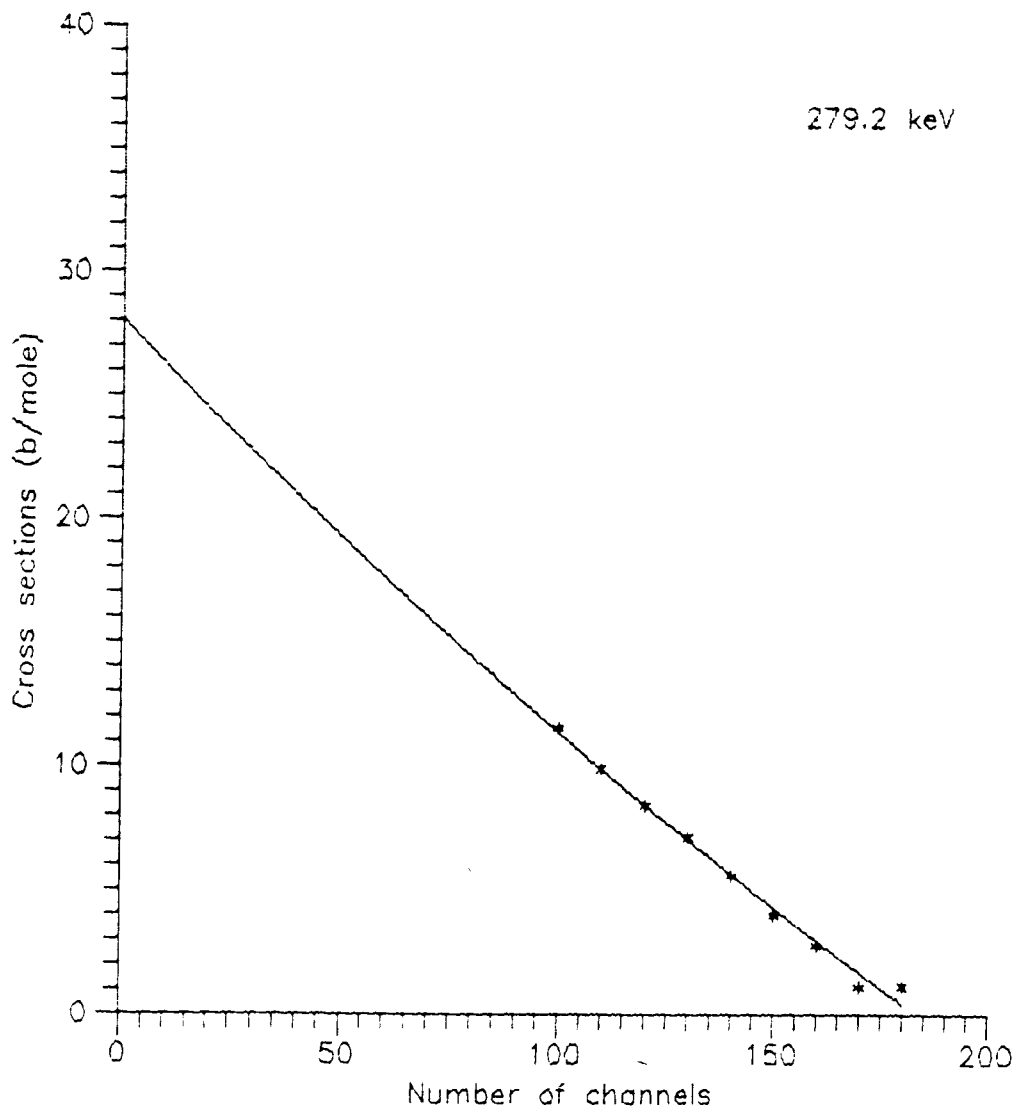


Fig 4-13. A typical plot of σ_{tot} versus number of channels for Cr_2O_3 in P_2 position for 279.2 keV

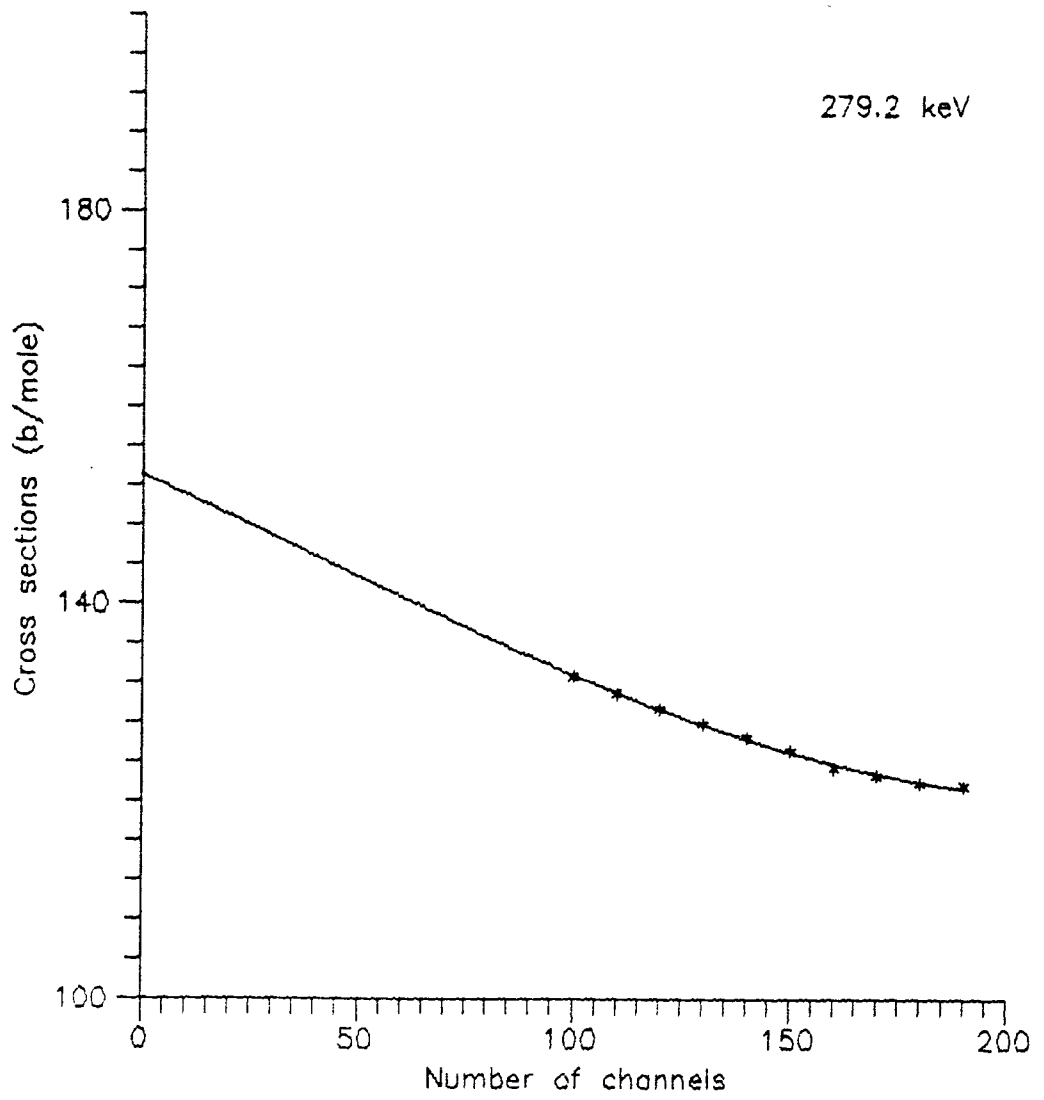


Fig 4-14. A typical plot of σ_{tot} versus number of channels for PbO in P_2 position for 279.2 keV

Non uniformity of the sample

Non uniformity of the sample introduces a fractional error of about half the root mean square deviation in mass/unit area. Carter et al (1969) gives a relation for the calculation of the error in mass absorption coefficient μ/ρ due to absorber non uniformity as

$$\left(\frac{\Delta\mu}{\rho}\right) = \frac{[\ln(\rho/a)\sinh\{a\mu/\rho\}]}{\ln \bar{R}} \quad 4.2$$

where $\Delta\mu/\rho$ is the error in mass absorption coefficient, \bar{R} is the mean transmission ratio for obtaining the value μ/ρ , a is the maximum deviation of absorber thickness from the mean thickness and a/ρ is the thickness in cm. Since, in the present investigation the uncertainty in the mass per unit area was less than 0.05 %, the error in the cross section due to non uniformity of the sample calculated using equation was found to be less than 0.05 % for all the samples at both the energies.

Non uniformity of the sample material was checked by exposing different portions of the sample to the incident beam. Since the intensities obtained were well within the counting statistics, no corrections were applied to the measured data.

Sample impurity

The errors due to sample impurity can be a significant factor only when large percentages of high Z impurities are present in the sample. In all the compounds used in the present investigation, the content of high Z impurities was less than 0.005%. The purity of the foils used were estimated to be better

than 99.9 %. Hence, the impurity corrections were not applied to the measured data.

Photon dose build up effects

This is a common phenomenon whenever thicker samples are employed in experiments. Photon dose build up is due to the multiple scattering of photons inside the sample material. Due to the larger thickness of the sample material, it offers an effective mean free path for the incident photons to be scattered and re scattered inside the sample thus resulting in several degraded photons. Obviously, these contribute to the lower energy side of the photo peak, thus overestimating the intensity I . Hence, the photon dose build up is a function of the sample thickness, atomic number and the incident photon energy. In the present study, the effect of dose build up is kept to a minimum by choosing a sample thickness such that the transmission ratio is in the range 0.1 to 0.4.

Dead time of the counting instrument

There is a built-in provision for dead time correction in the multi channel analyzer.

Another issue of concern is the bremsstrahlung from electrons ejected from the atom due to Compton scattering and photo effect. But in the present study, during spectral analysis only the region up to the back scattered peak is considered. Therefore the contribution of the Bremsstrahlung photons is negligible.