PROCESSING OF γ-SPECTRA IN ACTIVATION ANALYSIS WITH A PROGRAMABLE CALCULATOR

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ABSTRACT

The use of a 9810-A Hewlett Packard programable calculator in activation analysis data processing is described.

Three independent programs have been developed:

a) Peak smoothing, area and standard deviation calculation, peak energy and statistical significance test
b) Concentration calculations, and
c) Decay curve analysis

These programs are specially usefull when the same elements must be measured in a lot of samples.

The longest program has only 884 program steps.

Program listings, user's instructions and examples have been included.

I – INTRODUCTION

The processing of γ-spectra and related data in activation analysis is a time consuming work and it is convenient to eliminate, or at least, to reduce it as much as possible, specially in routine work

Many computer programs for automatic spectra processing have been described in the last years[1,2,3,4,5,6], and they routinely used at various laboratories. Most of them require digital computers with a minimum memory capacity of 32 or 64 K bits, which are not always available

Programs for automatic spectra processing, using table computers with 8000 memory positions have also been described[7,8].

The programable calculators are limited by their small memory capacity, not being able to process complete spectra. Nevertheless, in activation analysis, most of the analysis are concerned with a small number of elements in each sample. In those cases it is possible to use programable calculators to avoid hand calculations. In the present work, the use of a mod. 9810-A HEWLETT-PACKARD programable calculator, for the routine data processing in activation analysis, is described. The calculator has 51 data storage registers, 1012 program steps, and is equiped with printer and the statistic and printer alpha ROM modules.

Due to the small memory capacity of the calculator, three independent programs have been developed:

PROGRAM A: Peak smoothing; exact peak positioning; energy, area and standard deviation calculations

PROGRAM B: Concentration and standard deviation calculation.

PROGRAM C: Decay curve analysis.

In program A, the activities must be manually introduced in the calculator. An HP 9863 A Tape Reader can be used to introduce the peak activities from a punched tape into the calculator memory, but this possibility has not been included in the program, because it depends on the type of multichannel analyzer used for the measurements.

Programs A and B are the most used in activation analysis. Sometimes it is also necessary to solve complex peaks, like the 511 keV anihilation peak, in order to get the individual components In this case, the program C is very useful To use it, an HP 9862 A calculator plotter is also necessary

II – PROGRAM DESCRIPTION

II.1 – Program A

II.1.1 – Energy calculation

In modern multichannel analyzers, equiped with linear amplifiers, the peak energy and channel number are related through the formula:

$$E_i = a\,Ci + b \qquad (1)$$

where

E_i is the energy corresponding to channel Ci. The coefficients a and b are calculated through linear regression, using energy standards, and stored in the calculator memory.

The calculator also calculates the determination coefficient, (r^2), corresponding to the regression performed

II 1.2 – Peak smoothing

The γ-ray peaks measured in activation analysis often do not have statistics as good as it would be desirable, either because the nuclides are short lived, or the number of samples to be measured are so great, that the counting time must be consequently reduced. The processing of those spectra can introduce errors, specially in the calculation of photopeak energies, because the actual peak position is not always at the channel with maximum activity. For this reason, smoothing of data before computer processing is always desirable.

Several smoothing methods have been described[9,10,11].

The technique used in this work is that from Gibbons and Shanks[10] consisting in adjust

a third order polinomial to five consecutive channels. The smoothing equation is given by

$$D_i = \frac{1}{35}\left[-3\,C_{i-2} + 12\,C_{i-1} + 17\,C_i + 12\,C_{i+1} - 3\,C_{i+2}\right] \qquad (2)$$

where

C_i and D_i are the measured and smoothed number of counts in channel i.

Due to the small capacity of the HP programable calculator, the smoothed number of counts are stored in the same memory positions they had before smoothing.

As a consequence of this, after the 5th channel, equation (2) changes to

$$D_i = \frac{1}{35}\left[-3\,D_{i-2} + 12\,D_{i-1} + 17\,C_i + 12\,C_{i+1} - 3\,C_{i+2}\right] \qquad (3)$$

This may introduce an error in the results only when the peak to be smoothed is a very narrow one, only 3 or 4 channels wide, and has big discontinuities in activity between successive channels. Such a case appears when the spectra is measured with a solid state detector and a multichannel analyzer of small capacity (e.g. 400 or 512 channels).

However, a peak with these characteristics needs no smoothing. An option for avoiding smoothing in these cases has been included in the program.

The program gives very good results when applied to γ-spectra measured with a gain calibration up to 1 keV/channel.

II.1.3 – Area calculation

The area under the peak is calculated by the Total Peak Area method[12], using the smoothed data. In that method the counts from the peak channels are added and corrected for the Compton contribution (fig. 1) The first and last peak boundary channels are identified (ch_2 - ch_3 in fig. 1). Just left and right of peak, two regions of the spectra are chosen, corresponding to the Compton continuum (ch_1 - ch_2 and ch_3 - ch_4 in fig. 1) The number of channels must be the same in both areas.

The net peak area is

$$N_P = N_T - (N_1 + N_2)\,\frac{B}{2A} \qquad (4)$$

and its standard deviation

$$\sigma_{N_P} = \left[N_T + (N_1 + N_2)\,\frac{B^2}{4A^2}\right]^{1/2} \qquad (5)$$

where

N_p = Net peak area (counts)
N_T = Gross peak area, from ch_2 to ch_3
N_1 = Compton area from ch_1 to ch_2
N_2 = Compton area from ch_3 to ch_4
B = Number of channels between ch_2 and ch_3
A = Number of channels between ch_1 - ch_2 or ch_3 - ch_4

The channels ch_1, ch_2, ch_3 and ch_4 must be identified visually by the operator from the activity read-out, or from the oscilloscope display. The data from a maximum of 37 channels can be stored in the calculator memory.

Frequently, when looking at a γ-ray spectrum, it is difficult to establish "a priori" whether a peak exists or not, in the energy range of interest. This is particularly true in the case of small peaks, because they can be masked by the statistical scattering of data points, along the Compton continuum

The problem can be solved by means of a statistical significance test for the recorded data, also included in the program.

If D_i is the maximum number of counts after smoothing in the region ch_2 - ch_3 and $\bar{N}$ the mean number of counts in the Compton continuum, the condition for the peak to be significant is meet when:

$$D_i - \bar{N} \geqslant 2\,\sigma_{\bar{N}}$$

When it is not so, the computer prints "NO SIGNIFICANT PEAK".

The net area and standard deviation are also printed. Through the last one, the detection limit for that element in the sample, can be calculated.

II.1.4 — Peak position and energy calculation

The exact peak position is obtained through the smoothed first derivative[10],

$$E_i = \frac{1}{10}\left[-2\,D_{i-2} - D_{i-1} + D_{i+1} + 2\,D_{i+2}\right] \qquad (6)$$

At D_i maximum, $E_i = 0$. For locating the peak, the computer searches for the channel where E_i takes the first negative value

If the peak is statistically significant, its exact position is calculated by linear interpolation between E_i and E_{i-1} values, using the expression

$$C_p = C_{i-1} + \frac{E_{i-1}}{E_{i-1} + E_i} \qquad (7)$$

where

C_p = exact peak position
C_{-1} = number of last channel with positive first derivative
E_{-1} = first derivative value in channel C_{-1}
E = first derivative value in channel C

The peak energy is calculated through eq. 1, replacing C_i by C_p and a and b by the corresponding values already stored in the calculator memory.

In order to test the program, a γ-spectrum of a ^{203}Hg sample was recorded with a Ge(Li) detector, accumulating approximately 500 counts at the peak. Then, without erasing the multichannel analyzer memory, a ^{22}Na spectrum was accumulated over it.

In fig. 2, the 279 keV peak of the ^{203}Hg sample is shown.

The same peak, accumulated over different intensities of ^{22}Na Compton continuum is shown in fig. 3 and 4, including the results of area calculation and the calculated peak energy in each case.

As can be seen, the calculated area is the same, between the statistical limits, for the three spectra, and the maximum variation in the calculated peak position is only 0,7 channels

II.2 — Program B: Concentration calculations

After computing the areas and the standard deviations of samples and standards, the concentration of the different elements can be calculated

$$[X] = \frac{A_M}{A_S} \cdot \frac{W_S}{W_M} \cdot 10^6 \qquad (8)$$

where

[X] = concentration of element X, in ppm
A_M = sample activity
A_S = standard activity
W_S = weight of element X in the standard
W_M = sample weight

The standard deviation is given by

$$\sigma_x = \frac{A_M}{A_S} \cdot \frac{W_S}{W_M} \left[\left(\frac{\sigma_{AM}}{A_M} \right)^2 + \left(\frac{\sigma_{AS}}{A_S} \right)^2 + \left(\frac{\sigma_{W_S}}{W_S} \right)^2 + \left(\frac{\sigma_{W_M}}{W_M} \right)^2 \right]^{1/2} 10^6 \qquad (9)$$

where

σ_{WS} and σ_{WM} refer to the errors associated with the weights of standard and sample.

A_M, A_S, σ_{AM} and σ_{AS} are calculated through

$$A_M = \frac{(N_p)_M}{t_M} - \frac{(N_p)_B}{t_B} \tag{10}$$

$$A_S = \frac{(N_p)_S}{t_S} - \frac{(N_p)_B}{t_B} \tag{11}$$

$$\sigma_{AM} = \left[\left(\frac{\sigma_{(N_p)_M}}{t_M} \right)^2 + \left(\frac{\sigma_{(N_p)_B}}{t_B} \right)^2 \right]^{1/2} \tag{12}$$

$$\sigma_{AS} = \left[\left(\frac{\sigma_{(N_p)_S}}{t_S} \right)^2 + \left(\frac{\sigma_{(N_p)_B}}{t_B} \right)^2 \right]^{1/2} \tag{13}$$

where

A = net activity
N_p = peak area
t = measuring time

Subscripts M, B and S refer to sample, background and standard, respectively. Background subtraction has been included only for those cases where the measured peak is coincident with a background peak. If this is not the case, the Compton continuum from background does not affect the net peak activity calculation.

The possibility of decay correction has also been included in the program.

II.3 – Program C: Decay curve analysis

Several decay curve analysis programs have been described[13,14,15,16,17] most of them using the least squares technique and matrix calculation.

In our case, the calculator performs the same operations as in manual processing, but obviously at very much higher speed.

The operator must introduce the experimental activity and time data in the calculator. The present program will accept up to 15 pairs of activity and time data. The values are stored in the calculator memory and the decay curve is then plotted. For the correct processing of a decay curve, the sample must be counted until only the longest lived nuclide is present. The last points will be on a straight line, corresponding to the decay of that nuclide. The operator determines visually, from the plotted decay curve, the number of points that meet that condition and introduces it in the calculator.

A linear regression is then performed through those points. The extrapolated activity at t = 0 and the half life are printed.

Using the linear regression coefficients and the values of time corresponding to the different experimental points, the contribution of that nuclide is subtracted from the experimental activities. The new values replace the old ones in the same memory positions.

The new decay points are then plotted. This procedure is repeated until the last component has been obtained.

In fig. 5, a decay curve with three components, processed with this program, is shown. The sample consists of a mixture of $^{24}Na(T^{1/2} = 15\ h)$, $^{38}Cl(T^{1/2} = 37.3\ min)$ and $^{27}S(T^{1/2} = 5\ min)$.

Among the computed data in fig. 5, there are two more experimental points, at 900 and 1380 minutes, not included in the figure, but used in the calculations.

The calculated half lives are in good agreement with the theoretical values.

The program has the same limitations as hand processing: the measurements must be continued until only the longest-lived nuclide is present in the sample, and the half lives of the components must be quite different in order to be able of separating them.

Nevertheless, this program can be successfully used in many cases and is a real help in data processing.

RESUMO

É descrito no presente trabalho o uso de um calculador Hewlett Packard 9810-A no processamento de dados de analises por ativação

Três diferentes programas foram desenvolvidos:

a) Alisamento, cálculo da área e respectivo desvio padrão, energia e teste de significação estatística dos picos obtidos
b) Cálculo de concentração, e
c) Análise de curvas de decaimento

Estes programas são especialmente úteis quando os mesmos elementos devem ser medidos em grande numero de amostras.

O mais longo deles tem apenas 884 instruções. As listagens, instruções de uso e exemplos acham-se incluídos no texto

RÉSUMÉ

On décrit l'utilisation d'un calculateur programmable Hewlett Packard 9810 A pour l'étude de résultats d'analyse par activation

Trois programmes indépendents ont été développes

a) "smoothing" du pic, calcul de la surface, de la deviation standard et de la energie du pic et test de la signification statistique

b) Calculs de concentrations, et
c) Analyse de la courbe de décroissance

Ces programmes sont spécialement utilisables quand les mêmes éléments doivent être mesurés dans une série d'échantillons.

Le programme le plus long comporte seulement 884 lignes

On a inclus les listing de programme, les instructions d'utilisation et des exemples.

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III – APENDIX

Program listings and instructions

III.1 – Program A

Press FMT. GO TO
Insert program
(1) – Enter energy of standard
Press CONTINUE
Enter peak channel number
Press CONTINUE
Repeat step (1) until all calibration data are entered.
Press SET FLAG
Press CONTINUE
(2) – Enter ch_1
Press CONTINUE
(3) – Enter activity value
Press CONTINUE
Repeat step (3) until all activities are entered.
Press SET FLAG
Press CONTINUE
Enter 1 if smoothing is desired
If no, enter 0
Press CONTINUE
Enter ch_4
Press CONTINUE
Enter ch_3
Press CONTINUE
Enter ch_2
Press CONTINUE
The program goes automatically to step 2 for a new peak.

EXAMPLE A:

	Channel Number	Counts
ch_1	403	2728
	404	2743
	405	2644
	406	2651
	407	2613
ch_2	408	2603
	409	2701
	410	2768
	411	2795
	412	2846
	413	2684
	414	2703
	415	2720
	416	2585
ch_3	417	2711
	418	2689
	419	2760
	420	2527
	421	2551
ch_4	422	

ACTIVATION ANALYSIS

A) ENERGY CALCULATIONS

E = A * N + B

LEAST SQUARES FITTING

A (KEV/CHAN)
0.998

B (KEV)
0.537

CORRELATION
1.000

B)
PEAK SMOOTHING AND AREA CALCULATIONS

AREA (COUNTS)
520.132

SIGMA (COUNTS)
214.385

PEAK CHANEL
411.300

PEAK ENERGY (KEV)
411.159

EXAMPLE B:

	Channel Number	Counts
ch_1	403	2358
	404	2263
	405	2339
	406	2396
	407	2374
ch_2	408	2350
	409	2334
	410	2287
	411	2328
	412	2390
	413	2372
	414	2258
	415	2259
	416	2324
ch_3	417	2323
	418	2224
	419	2248
	420	2200
	421	2222
ch_4	422	

ACTIVATION ANALYSIS

A) ENERGY CALCULATIONS

$E = A * N + B$

LEAST SQUARES FITTING

A (KEV/CHAN)
0.998

B (KEV)
0.537

CORRELATION
1.000

B)
PEAK SMOOTHING AND AREA CALCULATIONS

AREA (COUNTS)
295.736

SIGMA (COUNTS)
198.664

NO SIGNIFICANT PEAK

PROGRAM A — LIstings

```
0000--CLR---20
0001--FMT---42
0002--FMT---42
0003-- A ---62
0004-- C ---61
0005--XTO---23
0006-- I ---65
0007--INT---64
0008-- H ---62
0009--XTO---23
0010-- I ---65
0011-- O ---71
0012-- N ---73
0013--CLR---20
0014--CNT---47
0015--CNT---47
0016--CNT---47
0017--CNT---47
0018-- A ---62
0019-- N ---73
0020-- A ---62
0021-- L ---72
0022--NFE---67
0023--YTO---40
0024-- I ---65
0025--YTO---40
0026--CLR---20
0027--CLR---20
0028-- A ---62
0029--PSE---57
0030--CNT---47
0031-- E ---60
0032-- N ---73
0033-- E ---60
0034-- 0 ---13
0035-- G ---15
0036--NFE---67
0037--CLR---20
0038-- C ---61
0039-- H ---62
0040-- L ---72
0041-- I ---65
0042-- O ---71
0043-- L ---72
0044-- N ---73
0045-- O ---71
0046-- C ---61
0047-- E ---60
0048-- I ---65
0049--YTO---40
0050--CLR---20
0051--CLR---20
0052--CNT---47
0053--CNT---47
0054--CNT---47
0055-- I ---65
0056 SFI 54
0057 A -- 62
0058 X -- 36
0059 N 73
```

```
0060-- + ---33
0061-- B ---66
0062--CLR---20
0063--CLR---20
0064-- L ---72
0065-- E ---60
0066-- A ---62
0067--YTO---40
0068--XTO---23
0069--CNT---47
0070--YTO---40
0071-- 6 ---14
0072--INK---17
0073-- A ---62
0074-- 0 ---13
0075-- E ---60
0076--YTO---40
0077--CLR---20
0078-- F ---16
0079-- I ---65
0080--XTO---23
0081--XTO---23
0082-- I ---65
0083-- N ---73
0084-- G ---15
0085--CLR---20
0086--CLR---20
0087-- A ---62
0088--CNT---47
0089--KEY---52
0090-- I ---55
0091-- E ---60
0092--INT---64
0093--DIM---35
0094-- C ---61
0095-- L ---72
0096-- A ---62
0097-- N ---73
0098--PSE---57
0099--PNT---45
0100--PNT---45
0101--FMT---42
0102--FMT---42
0103-- B ---66
0104 PSE 57
0105--CLR---20
0106-- N ---56
0107-- E ---60
0108-- A ---62
0109-- L ---52
0110--CNT---47
0111--YTO---40
0112-- N ---73
0113-- O ---71
0114-- N ---73
0115 XTO 23
0116 H 72
0117--GTO---44
0118 B 51
0119 H 62
```

```
0120--LBL---51
0121-- B ---66
0122-- E ---60
0123--PNT---45
0124--PNT---45
0125--FMT---42
0126--FMT---42
0127-- B ---66
0128--CNT---47
0129--KEY---52
0130-- K ---55
0131-- E ---60
0132--INT---64
0133--PSE---57
0134--FMT---42
0135--KEY---30
0136--PNT---45
0137--PNT---45
0138--YTO---40
0139-- 4 ---04
0140-- 7 ---07
0141--XTO---23
0142-- 4 ---04
0143-- 8 ---10
0144-- B ---66
0145--FMT---42
0146--FMT---42
0147-- C ---61
0148-- O ---71
0149-- 0 ---13
0150-- 0 ---13
0151-- E ---60
0152-- L ---72
0153-- A ---62
0154--XTO---23
0155-- I ---65
0156-- O ---71
0157-- N ---73
0158--FMT---42
0159--PNT---45
0160--PNT---45
0161--FMT---42
0162--FMT---42
0163-- B ---66
0164 PSE 57
0165--CLR---20
0166-- N ---56
0167-- E ---60
0168-- A ---62
0169-- L ---52
0170--CNT---47
0171--YTO---40
0172-- N ---73
0173-- O ---71
0174-- N ---73
0175 XTO 23
0176 H 72
0177 I 65
0178 N 73
0179 G 15
```

```
0180--CLR---20
0181-- A ---62
0182-- N ---73
0183-- D ---63
0184--CNT---47
0185-- A ---62
0186-- α ---13
0187-- E ---60
0188-- A ---62
0189--CLR---20
0190-- C ---61
0191-- A ---62
0192-- L ---72
0193-- C ---61
0194--1/X---17
0195-- L ---72
0196-- A ---62
0197--XTO---23
0198-- I ---65
0199-- O ---71
0200-- N ---73
0201--YTO---40
0202--CLR---20
0203--CLR---20
0204-- A ---62
0205-- α ---13
0206-- E ---60
0207-- A ---62
0208--CNT---47
0209--X<Y---52
0210-- C ---61
0211-- O ---71
0212--1/X---17
0213-- N ---73
0214--XTO---23
0215--YTO---40
0216--PSE---57
0217--FMT---42
0218--CLR---20
0219-- 1 ---01
0220--XTO---23
0221-- α ---13
0222--STP---41
0223--XTO---23
0224-- 0 ---00
0225--STP---41
0226--IFG---43
0227--GTO---44
0228--LBL---51
0229-- C ---61
0230--CNT---47
0231--XTO---23
0232--IND---31
0233-- α ---13
0234-- 1 ---01
0235--XTO---23
0236-- + ---33
0237-- α ---13
0238--GTO---44
0239-- 2 ---02
0240-- 2 ---02
0241-- 5 ---05
0242--LBL---51
0243-- C ---61
0244--XTO---23
0245-- - ---34
0246-- α ---13
0247-- α ---13
0248--XTO---23
0249-- 0 ---00
0250-- 4 ---04
0251-- 6 ---06
0252-- 0 ---00
0253--XTO---23
0254-- b ---14
0255--STP---41
0256--XTO---23
0257-- 4 ---04
0258-- 5 ---05
0259--X=Y---50
0260--GTO---44
0261--LBL---51
0262-- G ---15
0263--CNT---47
0264--LBL---51
0265-- D ---63
0266-- 1 ---01
0267--XTO---23
0268-- α ---13
0269--LBL---51
0270-- E ---60
0271--XFR---67
0272--IND---31
0273-- α ---13
0274-- UP---27
0275-- 3 ---03
0276--CHS---32
0277-- H ---36
0278-- 1 ---01
0279--XTO---23
0280-- + ---33
0281-- α ---13
0282-- 1 ---01
0283-- 2 ---02
0284--XFR---67
0285-- IND---31
0286-- X ---36
0287-- α ---13
0288-- + ---33
0289-- 1 ---01
0290--XTO---23
0291-- + ---33
0292-- α ---13
0293-- 1 ---01
0294-- 7 ---07
0295--XFR---67
0296--IND---31
0297-- 3 ---03
0298 - α ---13
0299-- + ---33
0300-- 1 ---01
0301--XTO---23
0302-- + ---33
0303-- α ---13
0304-- 1 ---01
0305-- 2 ---02
0306--XFR---67
0307--IND---31
0308-- X ---36
0309-- α ---13
0310-- + ---33
0311-- 1 ---01
0312--XTO---23
0313-- + ---33
0314-- α ---13
0315-- 3 ---03
0316--XFR---67
0317--IND---31
0318-- X ---36
0319-- α ---13
0320-- - ---34
0321-- 3 ---03
0322-- 5 ---05
0323--DIV---35
0324-- 2 ---02
0325--XTO---23
0326-- - ---34
0327-- α ---13
0328--YTO---40
0329--IND---31
0330-- α ---13
0331-- UP---27
0332-- α ---13
0333-- + ---33
0334--XFR---67
0335-- 4 ---04
0336-- 6 ---06
0337--X=Y---50
0338--GTO---44
0339--LBL---51
0340-- F ---15
0341--CNT---47
0342-- 1 ---01
0343--XTO---23
0344-- - ---34
0345-- α ---13
0346--GTO---44
0347--LBL---51
0348-- E ---60
0349--LBL---51
0350-- F ---15
0351-- 1 ---01
0352--XTO---23
0353-- + ---33
0354-- b ---14
0355-- b ---14
0356-- UP---27
0357--XFR---67
0358-- 4 ---04
0359-- 9 ---09
```

```
0360--X=Y---50
0361--GTO---44
0362--LBL---51
0363-- G ---15
0364--CNT---47
0365--GTO---44
0366--LBL---51
0367-- D ---63
0368--LBL---51
0369-- G ---15
0370--STP---41
0371-- UP---27
0372--STP---41
0373-- - ---34
0374-- UP---27
0375--STP---41
0376-- - ---34
0377-- DN---25
0378--XTO---23
0379-- 4 ---04
0380-- 4 ---04
0381--YTO---40
0382-- 0 ---00
0383-- 4 ---04
0384-- 3 ---03
0385-- 1 ---01
0386--XTO---23
0387-- α ---13
0388-- 0 ---00
0389-- UP---27
0390--LBL---51
0391-- H ---74
0392--XFR---67
0393--IND---31
0394-- α ---13
0395-- + ---33
0396-- α ---13
0397-- UP---27
0398--XFR---67
0399-- 4 ---04
0400-- 3 ---03
0401--X=Y---50
0402--GTO---44
0403--LBL---51
0404-- I ---65
0405--CNT---47
0406-- 1 ---01
0407-- + ---33
0408--YTO---40
0409-- α ---13
0410-- DN---25
0411--GTO---44
0412--LBL---51
0413-- H ---74
0414--LBL---51
0415-- I ---65
0416-- DN---25
0417--YTO---40
0418-- 0 ---00
0419-- 4 ---04
```

```
0420-- 2 ---02
0421-- 1 ---01
0422--XTO---23
0423-- + ---33
0424-- α ---13
0425--XFR---67
0426-- 4 ---04
0427-- 3 ---03
0428-- UP---27
0429--XFR---67
0430-- 4 ---04
0431-- 4 ---04
0432-- + ---33
0433--YTO---40
0434-- 0 ---00
0435-- 4 ---04
0436-- 1 ---01
0437-- 0 ---00
0438-- UP---27
0439--LBL---51
0440-- J ---75
0441--XFR---67
0442--IND---31
0443-- α ---13
0444-- + ---33
0445-- α ---13
0446-- UP---27
0447--XFR---67
0448-- 4 ---04
0449-- 1 ---01
0450--X=Y---50
0451--GTO---44
0452--LBL---51
0453-- K ---55
0454--CNT---47
0455-- 1 ---01
0456-- + ---33
0457--YTO---40
0458-- α ---13
0459-- DN---25
0460--GTO---44
0461--LBL---51
0462-- J ---75
0463--LBL---51
0464-- K ---55
0465-- DN---25
0466--YTO---40
0467-- 0 ---00
0468-- 4 ---04
0469-- 0 ---00
0470-- 1 ---01
0471--XTO---23
0472-- + ---33
0473-- α ---13
0474--XFR---67
0475-- 4 ---04
0476-- 3 ---03
0477--XTO---23
0478-- + ---33
0479-- 0 ---00
```

```
0480-- 4 ---04
0481-- 1 ---01
0482-- 0 ---00
0483-- UP---27
0484--LBL---51
0485-- L ---72
0486--XFR---67
0487--IND---31
0488-- α ---13
0489-- + ---33
0490-- α ---13
0491-- UP---27
0492--XFR---67
0493-- 4 ---04
0494-- 1 ---01
0495--X=Y---50
0496--GTO---44
0497--LBL---51
0498-- M ---70
0499--CNT---47
0500-- 1 ---01
0501-- + ---33
0502--YTO---40
0503-- α ---13
0504-- DN---25
0505--GTO---44
0506--LBL---51
0507-- L ---72
0508--LBL---51
0509-- M ---70
0510-- DN---25
0511--YTO---40
0512-- 3 ---03
0513-- 9 ---11
0514--XFR---67
0515-- 4 ---04
0516-- 2 ---02
0517-- + ---33
0518--YTO---40
0519-- 3 ---03
0520-- 8 ---10
0521--XFR---67
0522-- 4 ---04
0523-- 4 ---04
0524-- X ---36
0525-- 2 ---02
0526--XFR---67
0527-- X ---36
0528-- 4 ---04
0529-- 3 ---03
0530--DIV---35
0531--XFR---67
0532-- 4 ---04
0533-- 0 ---00
0534--XEY---30
0535-- - ---34
0536-- DN---25
0537--PNT---45
0538--ENT---45
0539--ENT---45
```

```
0540--FMT---42
0541--YTO---40
0542-- I ---65
0543-- G ---15
0544-- M ---70
0545-- A ---62
0546--CNT---47
0547--X<Y---52
0548-- C ---61
0549-- 0 ---71
0550--1/X---17
0551-- N ---73
0552--XTO---23
0553--YTO---40
0554--PSE---57
0555--FMT---42
0556--XFR---67
0557-- 3 ---03
0558-- 8 ---10
0559-- UP---27
0560--XFR---67
0561-- 4 ---04
0562-- 4 ---04
0563--XS0---12
0564-- X ---36
0565-- 2 ---02
0566--XFR---67
0567-- X ---36
0568-- 4 ---04
0569-- 3 ---03
0570--XS0---12
0571--DIV---35
0572--XFR---67
0573-- 4 ---04
0574-- 0 ---00
0575-- + ---33
0576-- DN---25
0577-- r ---76
0578--PNT---45
0579--PNT---45
0580-- 1 ---01
0581--CHS---32
0582--XFR---67
0583-- + ---33
0584-- 4 ---04
0585-- 3 ---03
0586--XTO---23
0587-- a ---13
0588--LBL---51
0589-- N ---73
0590-- 2 ---02
0591--XFR---67
0592--IND---31
0593-- X ---36
0594-- a ---13
0595--CHS---32
0596-- UP---27
0597-- 1 ---01
0598--XTO---23
0599-- + ---33
```

```
0600-- a ---13
0601--XFR---67
0602--IND---31
0603-- a ---13
0604-- - ---34
0605-- 2 ---02
0606--XTO---23
0607-- + ---33
0608-- a ---13
0609--XFR---67
0610--IND---31
0611-- a ---13
0612-- + ---33
0613-- 1 ---01
0614--XTO---23
0615-- + ---33
0616-- a ---13
0617-- 2 ---02
0618--XFR---67
0619--IND---31
0620-- X ---36
0621-- a ---13
0622-- + ---33
0623-- 1 ---01
0624-- 0 ---00
0625--DIV---35
0626-- 2 ---02
0627--XFR---67
0628-- + ---33
0629-- 4 ---04
0630-- 3 ---03
0631--XTO---23
0632-- - ---34
0633-- a ---13
0634--YTO---40
0635--IND---31
0636-- a ---13
0637-- UP---27
0638-- 0 ---00
0639--BUP---22
0640--X=Y---50
0641--GTO---44
0642--LBL---51
0643--1/X---17
0644--CNT---47
0645--X<Y---52
0646--GTO---44
0647--LBL---51
0648--XS0---12
0649--CNT---47
0650--LBL---51
0651-- a ---13
0652-- 2 ---02
0653--XFR---67
0654-- + ---33
0655-- 4 ---04
0656-- 3 ---03
0657--XFR---67
0658-- + ---33
0659-- a ---13
```

```
0660-- UP---27
0661--XFR---67
0662-- 4 ---04
0663-- 6 ---06
0664--X=Y---50
0665--GTO---44
0666--LBL---51
0667-- 0 ---71
0668--CNT---47
0669-- 1 ---01
0670--CHS---32
0671--XFR---67
0672-- + ---33
0673-- 4 ---04
0674-- 3 ---03
0675--XTO---23
0676-- + ---33
0677-- a ---13
0678--GTO---44
0679--LBL---51
0680-- N ---73
0681--LBL---51
0682--1/X---17
0683--SFL---54
0684--LBL---51
0685--XS0---12
0686-- DN---25
0687-- 2 ---02
0688-- - ---34
0689-- a ---13
0690-- + ---33
0691--YTO---40
0692-- b ---14
0693--XFR---67
0694--IND---31
0695-- b ---14
0696-- UP---27
0697--XFR---67
0698-- 4 ---04
0699-- 2 ---02
0700--XFR---67
0701--DIV---35
0702-- 4 ---04
0703-- 3 ---03
0704-- UP---27
0705-- r ---76
0706-- + ---33
0707-- + ---33
0708-- DN---25
0709--X<Y---52
0710--GTO---44
0711--LBL---51
0712-- b ---14
0713--CNT---47
0714-- UP---27
0715-- 1 ---01
0716--XTO---23
0717-- - ---34
0718-- b ---14
0719--XFR---67
```

```
0720--IND---31
0721-- b ---14
0722--KEY---52
0723--GTO---44
0724--LBL---51
0725-- b ---14
0726--CNT---47
0727--GTO---44
0728--LBL---51
0729-- a ---13
0730--LBL---51
0731-- b ---14
0732--IFG---43
0733--GTO---44
0734--LBL---51
0735--INT---64
0736--CNT---47
0737--XFR---67
0738--IND---31
0739-- a ---13
0740--CHS---32
0741-- UP---27
0742-- 1 ---01
0743--XTO---23
0744-- - ---34
0745-- a ---13
0746--XFR---67
0747--IND---31
0748-- a ---13
0749-- + ---33
0750--XEY---30
0751--DIV---35
0752-- a ---13
0753-- + ---33
0754--XFR---67
0755-- 4 ---04
0756-- 3 ---03
0757-- + ---33
0758-- 1 ---01
0759-- - ---34
0760-- DN---25
0761--XFR---67
0762-- + ---33
0763-- 0 ---00
0764--GTO---44
0765--LBL---51
0766--RUP---22
0767--LBL---51
0768--INT---64
0769-- a ---13
0770--XFR---67
0771-- + ---33
0772-- 4 ---04
0773-- 3 ---03
0774--XFR---67
0775-- + ---33
0776-- 0 ---00
0777-- UP---27
0778   1 ---01
0779   - ---34
```

```
0780-- DN---25
0781--LBL---51
0782--RUP---22
0783--FMT---42
0784--FMT---42
0785-- π ---56
0786-- E ---60
0787-- A ---62
0788-- K ---55
0789--CNT---47
0790-- C ---61
0791-- H ---74
0792-- A ---62
0793-- N ---73
0794-- E ---60
0795-- L ---72
0796--FMT---42
0797--PNT---45
0798--PNT---45
0799--XFR---67
0800-- [illegible] ---36
0801-- 4 ---04
0802-- 7 ---07
0803--XFR---67
0804-- + ---33
0805-- 4 ---04
0806-- 8 ---10
0807--FMT---42
0808--FMT---42
0809-- π ---56
0810-- E ---60
0811-- A ---62
0812-- K ---55
0813--CLR---20
0814-- E ---60
0815-- N ---73
0816-- E ---60
0817-- a ---13
0818-- G ---15
0819--XFR---67
0820--CNT---47
0821--KEY---52
0822-- K ---55
0823-- E ---60
0824--INT---64
0825--PSE---57
0826--FMT---42
0827--PNT---45
0828--PNT---45
0829--GTO---44
0830--LBL---51
0831-- DN---25
0832--CNT---47
0833--LBL---51
0834-- Q ---71
0835--FMT---42
0836--FMT---42
[illegible]    H    [illegible]
[illegible]    A    [illegible]
[illegible]    C    [illegible]
```

```
0840--YTO---40
0841-- I ---65
0842-- G ---15
0843-- N ---73
0844-- I ---65
0845-- F ---16
0846-- I ---65
0847-- C ---61
0848-- A ---62
0849-- N ---73
0850--XTO---23
0851--CLR---20
0852-- π ---56
0853-- E ---60
0854-- A ---62
0855-- K ---55
0856--FMT---42
0857--LBL---51
0858-- DN---25
0859--FMT---42
0860--FMT---42
0861--CLR---20
0862--CLR---20
0863--SFL---54
0864--SFL---54
0865--SFL---54
0866--SFL---54
0867--SFL---54
0868--SFL---54
0869--SFL---54
0870--SFL---54
0871--SFL---54
0872--SFL---54
0873--SFL---54
0874--SFL---54
0875--SFL---54
0876--SFL---54
0877--CLR---20
0878--CLR---20
0879--FMT---42
0880--GTO---44
0881-- 1 ---01
0882-- 6 ---06
0883-- 1 ---01
0884--END---46
```

III.2 — Program B

Concentration calculations

This program is self-explaining, as can be seen below

Example: Cooper Analysis

```
ACTIVATION
ANALYSIS

CONCENTRATION
CALCULATIONS

ENTER DATA -

A) BACKGROUND

***COUNTS
        1345.00*

***TIME
       10000.00*

***SIGMA
          42.00*

B) STANDARD

***COUNTS
       15832.00*

***TIME
         100.00*

***SIGMA
          85.00*

***WEIGHT-MG.
           3.26*

***SIGMA-MG.
           0.01*
```

```
C) SAMPLE

***COUNTS
       2861.00*

***TIME
       2000.00*

***SIGMA
         31.00*

***WEIGHT-MG.
        465.00*

***SIGMA-MG
          1.00*

DECAY TIME-MIN
        127.00*

CONCENTRATION
IN PPM.
         50.45

(SIGMA-PPM)
          2.00
```

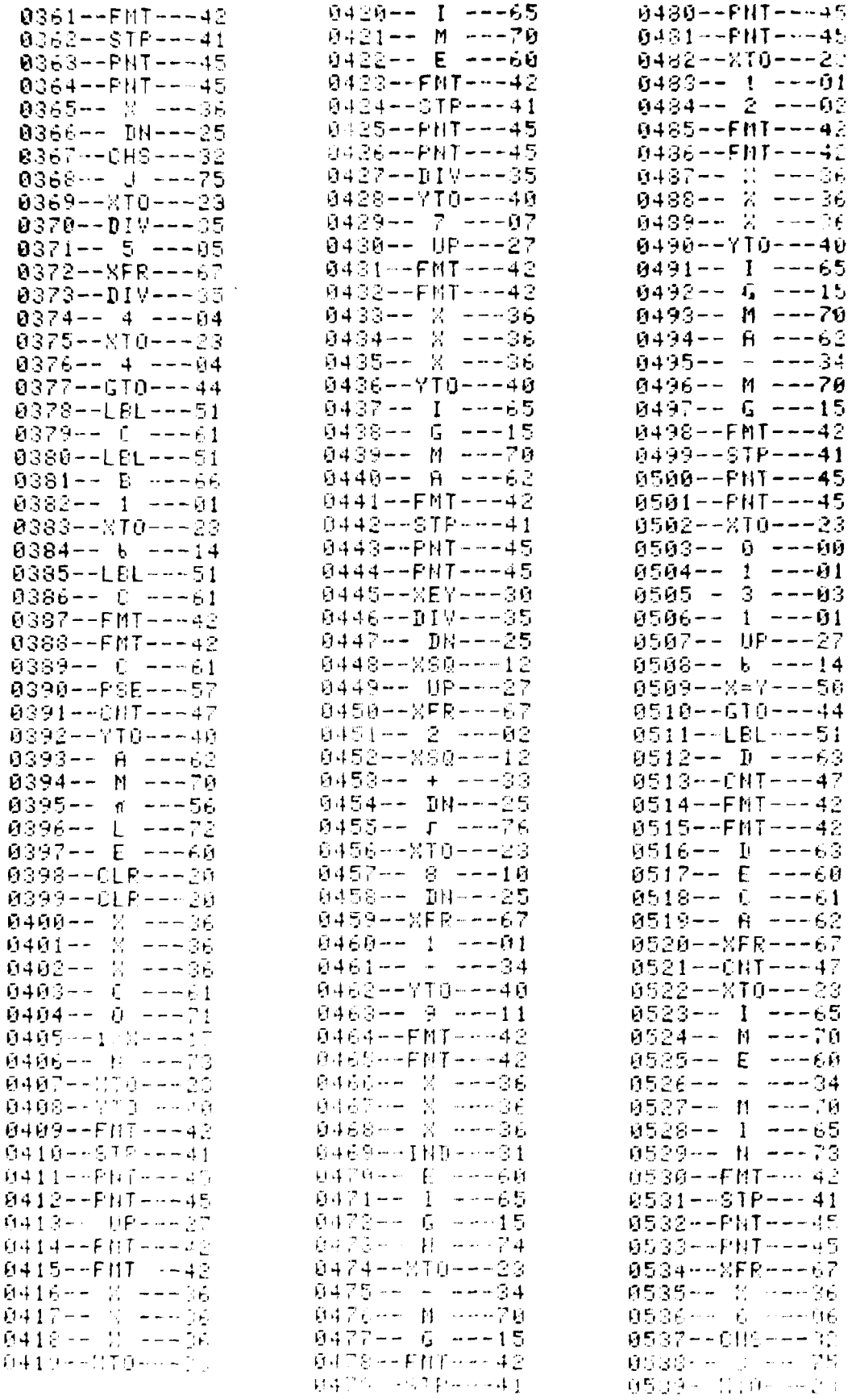
PROGRAM B – Listings

```
0000--CLR---20
0001--FMT---42
0002--FMT---42
0003-- A ---62
0004-- C ---61
0005--XTO---23
0006-- I ---65
0007--INT---64
0008-- A ---62
0009--XTO---23
0010-- I ---65
0011-- O ---71
0012-- N ---73
0013--CLR---20
0014-- A ---62
0015-- N ---73
0016-- A ---62
0017-- L ---72
0018--EXP---67
0019--YTO---40
0020-- I ---65
0021--YTO---40
0022--CLR---20
0023--CLR---20
0024-- C ---61
0025-- O ---71
0026-- N ---73
0027-- C ---61
0028-- E ---60
0029-- N ---73
0030--XTO---23
0031-- a ---13
0032-- A ---62
0033--XTO---23
0034-- I ---65
0035-- O ---71
0036-- N ---73
0037--CLR---20
0038-- C ---61
0039-- A ---62
0040-- L ---72
0041-- C ---61
0042--1/X---17
0043-- L ---72
0044-- A ---62
0045--XTO---23
0046-- I ---65
0047-- O ---71
0049-- N ---73
0049--YTO---40
0050--CLR---20
0051--CLR---20
0052-- E ---60
0053-- N ---73
0054--XTO---23
0055-- E ---60
0056-- a ---13
0057--CNT---47
[illegible]
[illegible]
0060--XTO---23
0061-- A ---62
0062--CNT---47
0063--EEX---26
0064--CLR---20
0065--CLR---20
0066--CLR---20
0067-- A ---62
0068--PSE---57
0069--CNT---47
0070-- B ---66
0071-- A ---62
0072-- C ---61
0073-- K ---55
0074-- G ---15
0075-- a ---13
0076-- O ---71
0077--1/X---17
0078-- N ---73
0079-- D ---63
0080--CLR---20
0081--CLR---20
0082-- X ---36
0083-- X ---36
0084-- X ---36
0085-- C ---61
0086-- O ---71
0087--1/X---17
0088-- N ---73
0089--XTO---23
0090--YTO---40
0091--FMT---42
0092--STP---41
0093--PNT---45
0094--PNT---45
0095--X⇄Y---50
0096--GTO---44
0097--LBL---51
0098-- A ---62
0099--CNT---47
0100-- UP---27
0101--FMT---42
0102--FMT---42
0103-- X ---36
0104-- X ---36
0105-- X ---36
0106--XTO---23
0107-- I ---65
0108-- M ---70
0109-- E ---60
0110--FMT---42
0111--STP---41
0112--PNT---45
0113--PNT---45
0114--DIV---35
0115--YTO---40
0116-- 1 ---01
0117-- UP---27
0118--FMT---42
0119--FMT---42
0120-- X ---36
0121-- X ---36
0122-- X ---36
0123--YTO---40
0124-- I ---65
0125-- G ---15
0126-- M ---70
0127-- A ---62
0128--FMT---42
0129--STP---41
0130--PNT---45
0131--PNT---45
0132--KEY---30
0133--DIV---35
0134--YTO---40
0135-- 2 ---02
0136--GTO---44
0137--LBL---51
0138-- E ---60
0139--LBL---51
0140-- A ---62
0141--XTO---23
0142-- 1 ---01
0143--XTO---23
0144-- 2 ---02
0145--LBL---51
0146-- E ---60
0147--FMT---42
0148--FMT---42
0149-- B ---66
0150--PSE---57
0151--CNT---47
0152--YTO---40
0153--XTO---23
0154-- A ---62
0155-- N ---73
0156-- D ---63
0157-- A ---62
0158-- a ---13
0159-- D ---63
0160--CLR---20
0161--CLR---20
0162-- X ---36
0163-- X ---36
0164-- X ---36
0165-- C ---61
0166-- O ---71
0167--1/X---17
0168-- N ---73
0169--XTO---23
0170--YTO---40
0171--FMT---42
0172--STP---41
0173--PNT---45
0174--PNT---45
0175-- UP---27
0176--FMT---42
0177--FMT---42
0178-- X ---36
0179-- X ---36
```

```
0180-- X ---36
0181--XTO---23
0182-- I ---65
0183-- M ---70
0184-- E ---60
0185--FMT---42
0186--STP---41
0187--PNT---45
0188--PNT---45
0189--DIV---35
0190--YTO---40
0191-- 3 ---03
0192-- UP---27
0193--FMT---42
0194--FMT---42
0195-- X ---36
0196-- X ---36
0197-- X ---36
0198--YTO---40
0199-- I ---65
0200-- G ---15
0201-- M ---70
0202-- A ---62
0203--FMT---42
0204--STP---41
0205--PNT---45
0206--PNT---45
0207--XEY---30
0208--DIV---35
0209-- DN---25
0210--YSQ---12
0211-- UP---27
0212--XFR---67
0213-- 2 ---02
0214--XSQ---12
0215-- + ---33
0216-- DN---25
0217-- F ---76
0218--XTO---23
0219-- 4 ---04
0220-- DN---25
0221--XFR---67
0222-- 1 ---01
0223-- - ---34
0224--YTO---40
0225-- 5 ---05
0226--FMT---42
0227--FMT---42
0228-- X ---36
0229-- X ---36
0230-- X ---36
0231--IND---31
0232-- E ---60
0233-- I ---65
0234-- G ---15
0235-- H ---74
0236--XTO---23
0237-- - ---34
0238-- M ---70
0239-- G ---15
```

```
0240-- . ---21
0241--FMT---42
0242--STP---41
0243--PNT---45
0244--PNT---45
0245--XTO---23
0246-- 1 ---01
0247-- 0 ---00
0248--FMT---42
0249--FMT---42
0250-- X ---36
0251-- X ---36
0252-- X ---36
0253--YTO---40
0254-- I ---65
0255-- G ---15
0256-- M ---70
0257-- A ---62
0258-- - ---34
0259-- M ---70
0260-- G ---15
0261-- . ---21
0262--FMT---42
0263--STP---41
0264--PNT---45
0265--PNT---45
0266--XTO---23
0267-- 1 ---01
0268-- 1 ---01
0269--FMT---42
0270--FMT---42
0271--CLR---20
0272-- I ---65
0273-- F ---16
0274--CNT---47
0275-- N ---73
0276-- O ---71
0277--CNT---47
0278-- D ---63
0279-- E ---60
0280-- C ---61
0281-- A ---62
0282--XFR---67
0283--CLR---20
0284-- C ---61
0285-- O ---71
0286-- 6 ---13
0287-- 6 ---13
0288-- E ---60
0289-- C ---61
0290--XTO---23
0291-- I ---65
0292-- O ---71
0293-- N ---73
0294--CLX---37
0295--CLR---20
0296--YTO---40
0297-- I ---65
0298--[illegible]
0299--CNT---47
```

```
0300-- F ---16
0301-- L ---72
0302-- A ---62
0303-- G ---15
0304--CNT---47
0305--EEX---26
0306--CLR---20
0307--CLR---20
0308--FMT---42
0309--STP---41
0310--LBL---51
0311-- * ---56
0312--IFG---43
0313--GTO---44
0314--LBL---51
0315-- B ---66
0316--CNT---47
0317--FMT---42
0318--FMT---42
0319-- H ---74
0320-- A ---62
0321-- L ---72
0322-- F ---16
0323--CNT---47
0324-- L ---72
0325-- I ---65
0326-- F ---16
0327-- E ---60
0328-- - ---34
0329-- M ---70
0330-- I ---65
0331-- N ---73
0332--FMT---42
0333--STP---41
0334--PNT---45
0335--PNT---45
0336-- UP---27
0337-- . ---21
0338-- 6 ---06
0339-- 9 ---11
0340-- 3 ---03
0341--XEY---30
0342--DIV---35
0343--YTO---40
0344-- 6 ---06
0345--FMT---42
0346--FMT---42
0347-- D ---63
0348-- E ---60
0349-- C ---61
0350-- A ---62
0351--XFR---67
0352--CNT---47
0353--XTO---23
0354-- I ---65
0355-- M ---70
0356-- E ---60
0357-- - ---34
0358-- M ---70
0359-- I ---65
0360-- N ---73
```


0361--FMT---42
0362--STP---41
0363--PNT---45
0364--PNT---45
0365-- X ---36
0366-- DN---25
0367--CHS---32
0368-- J ---75
0369--XTO---23
0370--DIV---35
0371-- 5 ---05
0372--XFR---67
0373--DIV---35
0374-- 4 ---04
0375--XTO---23
0376-- 4 ---04
0377--GTO---44
0378--LBL---51
0379-- C ---61
0380--LBL---51
0381-- B ---66
0382-- 1 ---01
0383--XTO---23
0384-- 6 ---14
0385--LBL---51
0386-- C ---61
0387--FMT---42
0388--FMT---42
0389-- C ---61
0390--PSE---57
0391--CNT---47
0392--YTO---40
0393-- A ---62
0394-- M ---70
0395-- n ---56
0396-- L ---72
0397-- E ---60
0398--CLR---20
0399--CLR---20
0400-- X ---36
0401-- X ---36
0402-- X ---36
0403-- C ---61
0404-- O ---71
0405--1/X---17
0406-- N ---73
0407--XTO---23
0408--YTO---40
0409--FMT---42
0410--STP---41
0411--PNT---45
0412--PNT---45
0413-- UP---27
0414--FMT---42
0415--FMT---42
0416-- X ---36
0417-- X ---36
0418-- X ---36
0419--XTO---23
0420-- I ---65
0421-- M ---70
0422-- E ---60
0423--FMT---42
0424--STP---41
0425--PNT---45
0426--PNT---45
0427--DIV---35
0428--YTO---40
0429-- 7 ---07
0430-- UP---27
0431--FMT---42
0432--FMT---42
0433-- X ---36
0434-- X ---36
0435-- X ---36
0436--YTO---40
0437-- I ---65
0438-- G ---15
0439-- M ---70
0440-- A ---62
0441--FMT---42
0442--STP---41
0443--PNT---45
0444--PNT---45
0445--XEY---30
0446--DIV---35
0447-- DN---25
0448--X≤0---12
0449-- UP---27
0450--XFR---67
0451-- 2 ---02
0452--X≤0---12
0453-- + ---33
0454-- DN---25
0455-- ∫ ---76
0456--XTO---23
0457-- 8 ---10
0458-- DN---25
0459--XFR---67
0460-- 1 ---01
0461-- - ---34
0462--YTO---40
0463-- 9 ---11
0464--FMT---42
0465--FMT---42
0466-- X ---36
0467-- X ---36
0468-- X ---36
0469--IND---31
0470-- E ---60
0471-- I ---65
0472-- G ---15
0473-- H ---74
0474--XTO---23
0475-- - ---34
0476-- M ---70
0477-- G ---15
0478--FMT---42
0479--STP---41
0480--PNT---45
0481--PNT---45
0482--XTO---23
0483-- 1 ---01
0484-- 2 ---02
0485--FMT---42
0486--FMT---42
0487-- X ---36
0488-- X ---36
0489-- X ---36
0490--YTO---40
0491-- I ---65
0492-- G ---15
0493-- M ---70
0494-- A ---62
0495-- - ---34
0496-- M ---70
0497-- G ---15
0498--FMT---42
0499--STP---41
0500--PNT---45
0501--PNT---45
0502--XTO---23
0503-- 0 ---00
0504-- 1 ---01
0505 - 3 ---03
0506-- 1 ---01
0507-- UP---27
0508-- 6 ---14
0509--X=Y---50
0510--GTO---44
0511--LBL---51
0512-- D ---63
0513--CNT---47
0514--FMT---42
0515--FMT---42
0516-- D ---63
0517-- E ---60
0518-- C ---61
0519-- A ---62
0520--XFR---67
0521--CNT---47
0522--XTO---23
0523-- I ---65
0524-- M ---70
0525-- E ---60
0526-- - ---34
0527-- M ---70
0528-- 1 ---65
0529-- N ---73
0530--FMT---42
0531--STP---41
0532--PNT---45
0533--PNT---45
0534--XFR---67
0535-- X ---36
0536-- G ---15
0537--CHS---32
0538-- J ---75
0539-- LBL---51

```
0540--DIV---35
0541-- 9 ---11
0542--XTO---23
0543--DIV---35
0544-- 8 ---10
0545--LCL---51
0546-- D ---63
0547--XFR---67
0548-- 9 ---11
0549--XFR---67
0550--DIV---35
0551-- 5 ---05
0552--XFR---67
0553-- X ---36
0554-- 1 ---01
0555-- 0 ---00
0556--XFR---67
0557--DIV---35
0558-- 1 ---01
0559-- 2 ---02
0560-- UP---27
0561--EEX---26
0562-- 6 ---06
0563-- X ---36
0564-- DN---25
0565--FMT---42
0566--FMT---42
0567--CLR---20
0568-- - ---34
0569-- - ---34
0570-- - ---34
0571-- - ---34
0572-- - ---34
0573-- - ---34
0574-- - ---34
0575-- - ---34
0576-- - ---34
0577-- - ---34
0578-- - ---34
0579-- - ---34
0580-- - ---34
0581-- - ---34
0582--CLR---20
0583-- C ---61
0584-- O ---71
0585-- N ---73
0586-- C ---61
0587-- E ---60
0588-- N ---73
0589--XTO---23
0590-- a ---13
0591-- A ---62
0592--XTO---23
0593-- I ---65
0594-- O ---71
0595-- N ---73
0596--CLR---20
0597-- I ---65
0598-- N ---73
0599--CNT---47
0600-- π ---56
0601-- π ---56
0602-- M ---70
0603-- . ---21
0604--FMT---42
0605--PNT---45
0606--PNT---45
0607-- UP---27
0608--XFR---67
0609-- 8 ---10
0610--XFR---67
0611--DIV---35
0612-- 9 ---11
0613--XSO---12
0614-- UP---27
0615--XFR---67
0616-- 4 ---04
0617--XFR---67
0618--DIV---35
0619-- 5 ---05
0620--XSO---12
0621-- + ---33
0622--XFR---67
0623-- 1 ---01
0624-- 1 ---01
0625--XFR---67
0626--DIV---35
0627-- 1 ---01
0628-- 0 ---00
0629--XSO---12
0630-- + ---33
0631--XFR---67
0632-- 1 ---01
0633-- 3 ---03
0634--XFR---67
0635--DIV---35
0636-- 1 ---01
0637-- 2 ---02
0638--XSO---12
0639-- + ---33
0640-- DN---25
0641-- Γ ---76
0642-- X ---36
0643-- DN---25
0644--FMT---42
0645--FMT---42
0646--YTO---40
0647-- I ---65
0648-- G ---15
0649-- M ---70
0650-- A ---62
0651--CNT---47
0652--X<Y---52
0653-- π ---56
0654-- π ---56
0655-- M ---70
0656--PSE---57
0657--FMT---42
0658--PNT---45
0659--PNT---45
0660--FMT---42
0661--FMT---42
0662-- - ---34
0663-- - ---34
0664-- - ---34
0665-- - ---34
0666-- - ---34
0667-- - ---34
0668-- - ---34
0669-- - ---34
0670-- - ---34
0671-- - ---34
0672-- - ---34
0673-- - ---34
0674-- - ---34
0675-- - ---34
0676--CLR---20
0677--CLR---20
0678--CLR---20
0679--CLR---20
0680--CLR---20
0681--FMT---42
0682--GTO---44
0683--LBL---51
0684-- C ---61
0685--END---46
```

III.3 – Program C

Press: FMT, GO TO

Insert Program

Enter Y max

Press CONTINUE

Enter Y min

Press CONTINUE

Enter X max

Press CONTINUE

Enter X min

Press CONTINUE

Step 1: Enter activity value

Press CONTINUE

Enter time

Press CONTINUE

Repeat step 1 until all data is entered (maximum 15 activity values)

Press CONTINUE

Step 2: Enter number of points to be used for linear regression

Press CONTINUE

Repeat step 2 until the plotted points are on a straight line

EXAMPLE

Xmin = 0 Ymin = 1

Xmax = 120 Ymax = 10^3

t (min)	A (cps)	t (min)	A (cps)
4,0	170,6	17,5	65,7
5,5	141,2	30,6	50,5
6,8	124,2	36,5	47,1
8,0	111,1	61,0	35,7
9,0	103,6	109,5	25,2
10,1	96,5	900,0	9,7
12,5	82,4	1380,0	6,7
15,2	73,1	–	–

PROGRAM C — Listings

```
0000--CLR---20
0001-- K ---55
0002-- 2 ---02
0003--STP---41
0004-- I ---65
0005--XTO---23
0006-- 4 ---04
0007-- 6 ---06
0008-- UP---27
0009--STP---41
0010-- I ---65
0011--XTO---23
0012-- 4 ---04
0013-- 5 ---05
0014-- - ---34
0015-- 9 ---11
0016-- 9 ---11
0017-- 9 ---11
0018-- 9 ---11
0019--XTO---23
0020-- α ---13
0021--XEY---30
0022--DIV---35
0023--YTO---40
0024-- 4 ---04
0025-- 6 ---06
0026--STP---41
0027--XTO---23
0028-- 4 ---04
0029-- 8 ---10
0030-- UP---27
0031--STP---41
0032--XTO---23
0033-- 4 ---04
0034-- 7 ---07
0035-- - ---34
0036-- α ---13
0037--XEY---30
0038--DIV---35
0039--YTO---40
0040-- 0 ---00
0041-- 4 ---04
0042-- 8 ---10
0043-- 6 ---06
0044--XTO---23
0045-- α ---13
0046--STP---41
0047--LBL---51
0048-- 0 ---00
0049--XTO---23
0050--IND---31
0051-- α ---13
0052-- I ---65
0053-- UP---27
0054-- 1 ---01
0055--XTO---23
0056-- + ---33
0057-- α ---13
0058--STP---41
0059--XTO---23
0060--IND---31
0061-- α ---13
0062--GTO---44
0063--S/R---77
0064--LBL---51
0065--XS0---12
0066-- 1 ---01
0067--XTO---23
0068-- + ---33
0069-- α ---13
0070--STP---41
0071--IFG---43
0072--GTO---44
0073--LBL---51
0074--EEX---26
0075--CNT---47
0076--GTO---44
0077--LBL---51
0078-- 0 ---00
0079--LBL---51
0080--EEX---26
0081--XTO---23
0082-- - ---34
0083-- α ---13
0084--GTO---44
0085--LBL---51
0086-- 3 ---03
0087--LBL---51
0088-- 1 ---01
0089-- α ---13
0090--XTO---23
0091-- 0 ---00
0092-- 4 ---04
0093-- 2 ---02
0094-- 6 ---06
0095--XTO---23
0096-- b ---14
0097--LBL---51
0098-- 2 ---02
0099--XFR---67
0100--IND---31
0101-- b ---14
0102-- I ---65
0103-- UP---27
0104-- 1 ---01
0105--XTO---23
0106-- + ---33
0107-- b ---14
0108--XFR---67
0109--IND---31
0110-- b ---14
0111--GTO---44
0112--S/R---77
0113--LBL---51
0114--XS0---12
0115--XFR---67
0116-- b ---14
0117-- UP---27
0118--XFR---67
0119-- 4 ---04
0120-- 2 ---02
0121--X=Y---50
0122--GTO---44
0123--LBL---51
0124-- 3 ---03
0125--CNT---47
0126-- 1 ---01
0127--XTO---23
0128-- + ---33
0129-- b ---14
0130--GTO---44
0131--LBL---51
0132-- 2 ---02
0133--LBL---51
0134-- 3 ---03
0135-- α ---13
0136--XTO---23
0137-- 0 ---00
0138-- 4 ---04
0139-- 2 ---02
0140--XTO---23
0141-- b ---14
0142--STP---41
0143-- UP---27
0144-- 2 ---02
0145-- X ---36
0146-- 1 ---01
0147-- - ---34
0148--YTO---40
0149-- 4 ---04
0150-- 1 ---01
0151--YTO---40
0152-- - ---34
0153-- b ---14
0154--LBL---51
0155-- 4 ---04
0156-- A ---62
0157-- 0 ---71
0158--LBL---51
0159-- 5 ---05
0160--XFR---67
0161--IND---31
0162-- b ---14
0163-- I ---65
0164-- UP---27
0165-- 1 ---01
0166--XTO---23
0167-- + ---33
0168-- b ---14
0169--XFR---67
0170--IND---31
0171-- b ---14
0172-- 0 ---71
0173-- α ---13
0174-- UP---27
0175-- b ---14
0176--X=Y---50
0177--GTO---44
0178--LBL---51
0179-- 6 ---06
```

```
0180--CNT---47
0181-- 1 ---01
0182--XTO---23
0183-- + ---33
0184-- b ---14
0185--GTO---44
0186--LBL---51
0187-- 5 ---05
0188--LBL---51
0189-- 6 ---06
0190-- E ---60
0191--XTO---23
0192-- 4 ---04
0193-- 0 ---00
0194--YTO---40
0195-- 3 ---03
0196-- 9 ---11
0197-- UP---27
0198-- . ---21
0199-- 6 ---06
0200-- 9 ---11
0201-- 3 ---03
0202--XEY---30
0203--DIV---35
0204-- DN---25
0205--CHS---32
0206--FMT---42
0207--FMT---42
0208--XTO---23
0209--CNT---47
0210-- 1 ---01
0211--DIV---35
0212-- 2 ---02
0213--CNT---47
0214--CNT---47
0215--CNT---47
0216--CNT---47
0217--CNT---47
0218--CNT---47
0219--FMT---42
0220--PNT---45
0221--PNT---45
0222--FMT---42
0223--FMT---42
0224-- A ---62
0225-- - ---34
0226-- 0 ---00
0227--FMT---42
0228--RUP---22
0229-- J ---75
0230--PNT---45
0231--PNT---45
0232--XFR---67
0233-- 4 ---04
0234-- 1 ---01
0235-- UP---27
0236-- 1 ---01
0237-- + ---33
0238--YTO---40
0239-- - ---34
```

```
0240-- a ---13
0241-- 7 ---07
0242--XTO---23
0243-- b ---14
0244--LBL---51
0245-- 7 ---07
0246--XFR---67
0247--IND---31
0248-- b ---14
0249--XFR---67
0250-- X ---36
0251-- 4 ---04
0252-- 0 ---00
0253--XFR---67
0254-- + ---33
0255-- 3 ---03
0256-- 9 ---11
0257-- J ---75
0258-- UP---27
0259-- 1 ---01
0260--XTO---23
0261-- - ---34
0262-- b ---14
0263--YTO---40
0264--IND---31
0265-- - ---34
0266-- b ---14
0267--XTO---23
0268-- + ---33
0269-- b ---14
0270-- b ---14
0271-- UP---27
0272-- a ---13
0273--X=Y---50
0274--GTO---44
0275--LBL---51
0276-- 8 ---10
0277--CNT---47
0278-- 2 ---02
0279--XTO---23
0280-- + ---33
0281-- b ---14
0282--GTO---44
0283--LBL---51
0284-- 7 ---07
0285--LBL---51
0286-- 8 ---10
0287--SBL---54
0288-- 0 ---00
0289--XTO---23
0290-- 3 ---03
0291-- 6 ---10
0292--LBL---51
0293-- 9 ---11
0294--XFR---67
0295-- 3 ---03
0296-- 8 ---10
0297-- D ---07
0298--YTO---67
0299-- 3 ---36
```

```
0300-- 4 ---04
0301-- 0 ---00
0302--XFR---67
0303-- + ---33
0304-- 3 ---03
0305-- 9 ---11
0306-- UP---27
0307--RUP---22
0308--GTO---44
0309--S/R---77
0310--LBL---51
0311--XFR---67
0312--IFG---43
0313--FMT---42
0314-- UP---27
0315--FMT---42
0316-- DN---25
0317--FMT---42
0318-- DN---25
0319-- UP---27
0320-- 9 ---11
0321-- 9 ---11
0322-- 9 ---11
0323-- 9 ---11
0324--X<Y---52
0325--GTO---44
0326--LBL---51
0327-- A ---62
0328--CNT---47
0329-- 0 ---00
0330--RUP---22
0331--X<Y---52
0332--GTO---44
0333--LBL---51
0334-- A ---62
0335--CNT---47
0336-- 1 ---01
0337--CNT---47
0338--XTO---23
0339-- + ---33
0340-- 3 ---03
0341-- 8 ---10
0342--GTO---44
0343--LBL---51
0344-- 9 ---11
0345--LBL---51
0346-- A ---62
0347--FMT---42
0348-- UP---27
0349--STP---41
0350--GTO---44
0351--LBL---51
0352-- 1 ---01
0353--LBL---51
0354--USR---13
0355--YTO---40
0356-- 3 ---03
0357-- J ---75
0358--XFR---67
0359-- - ---34
```

```
0360-- 4 ---04
0361-- 7 ---07
0362--XFR---67
0363-- X ---36
0364-- 4 ---04
0365-- 8 ---10
0366-- UP---27
0367-- YE---24
0368-- 3 ---03
0369-- 7 ---07
0370-- DN---25
0371--XFR---67
0372-- - ---34
0373-- 4 ---04
0374-- 5 ---05
0375--XFR---67
0376-- X ---36
0377-- 4 ---04
0378-- 6 ---06
0379-- UP---27
0380--XFR---67
0381-- 3 ---03
0382-- 7 ---07
0383--FMT---42
0384-- UP---27
0385--FMT---42
0386-- DN---25
0387--FMT---42
0388-- UP---27
0389--S/R---77
0390--LBL---51
0391--XFR---67
0392--YTO---40
0393-- 3 ---03
0394-- 7 ---07
0395--XFR---67
0396-- - ---34
0397-- 4 ---04
0398-- 7 ---07
0399--XFR---67
0400-- X ---36
0401-- 4 ---04
0402-- 8 ---10
0403-- UP---27
0404-- YE---24
0405-- 3 ---03
0406-- 7 ---07
0407-- DN---25
0408--XFR---67
0409-- - ---34
0410-- 4 ---04
0411-- 5 ---05
0412--XFR---67
0413-- X ---36
0414-- 4 ---04
0415-- 6 ---06
0416-- UP---27
0417--XFR---67
0418-- 3 ---03
0419-- 7 ---07
0420--S/R---77
0421--END---46
```

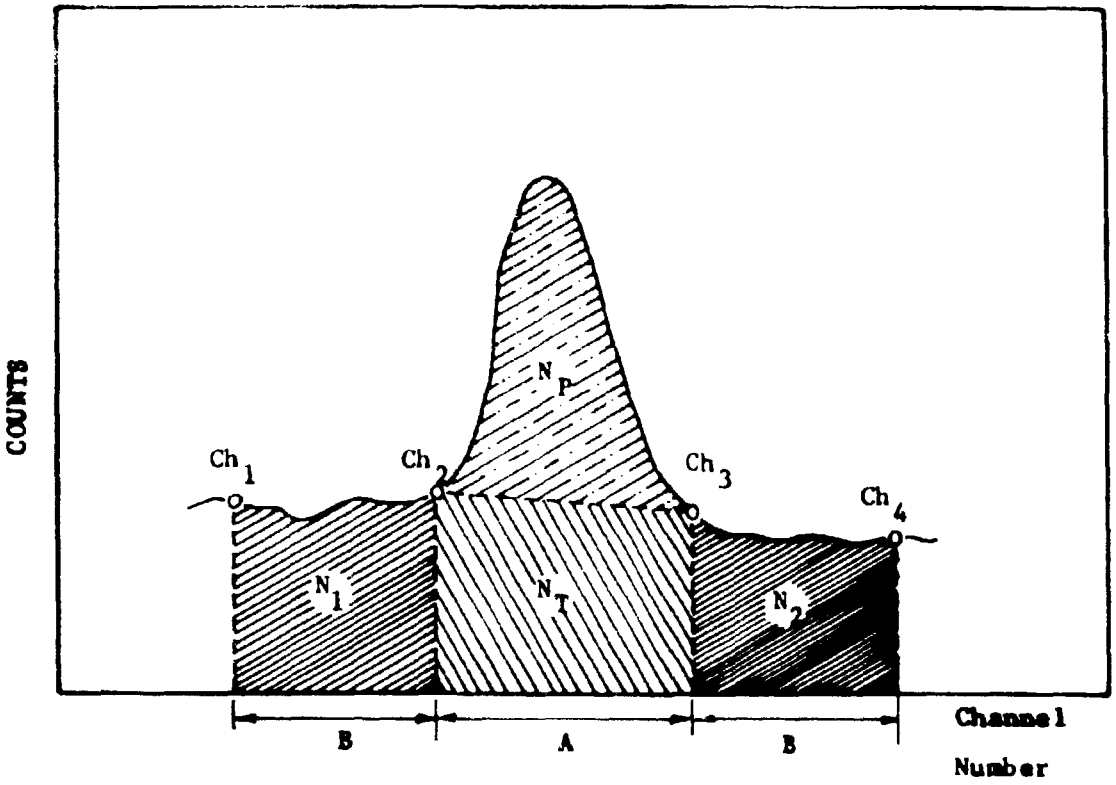


FIG 1 – AREAS USED FOR PEAK INTEGRATION.

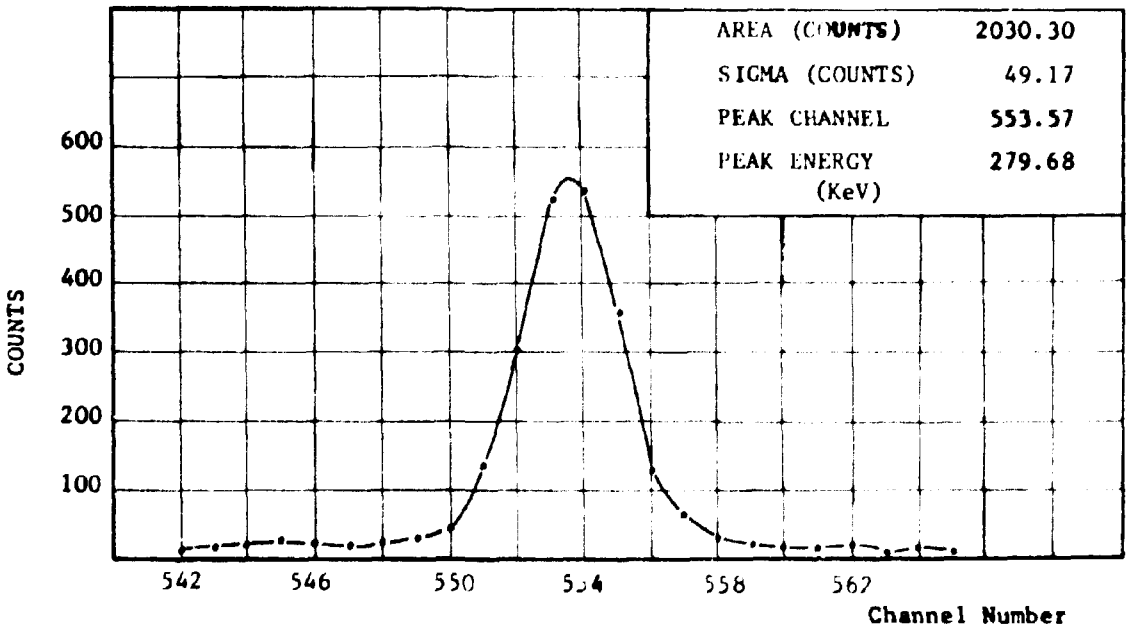


FIG 2 – PEAK AREA CALCULATION. WELL DEFINED PEAK.

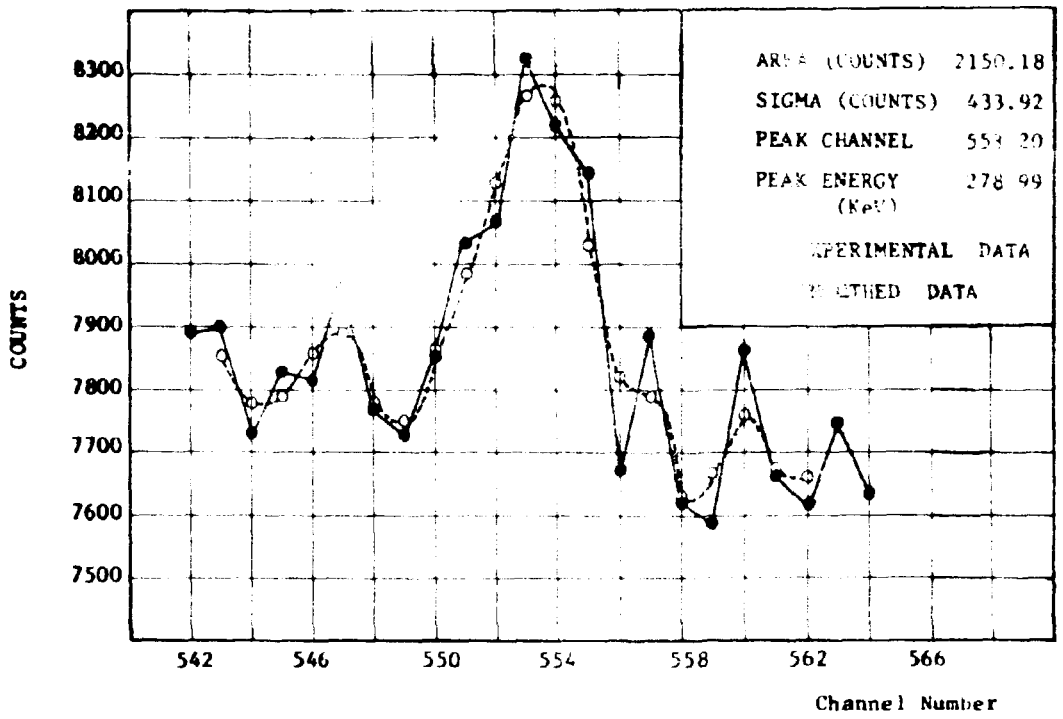


FIG. 3 – SMALL PEAK ON A MEDIUM COMPTON CONTINUUM.

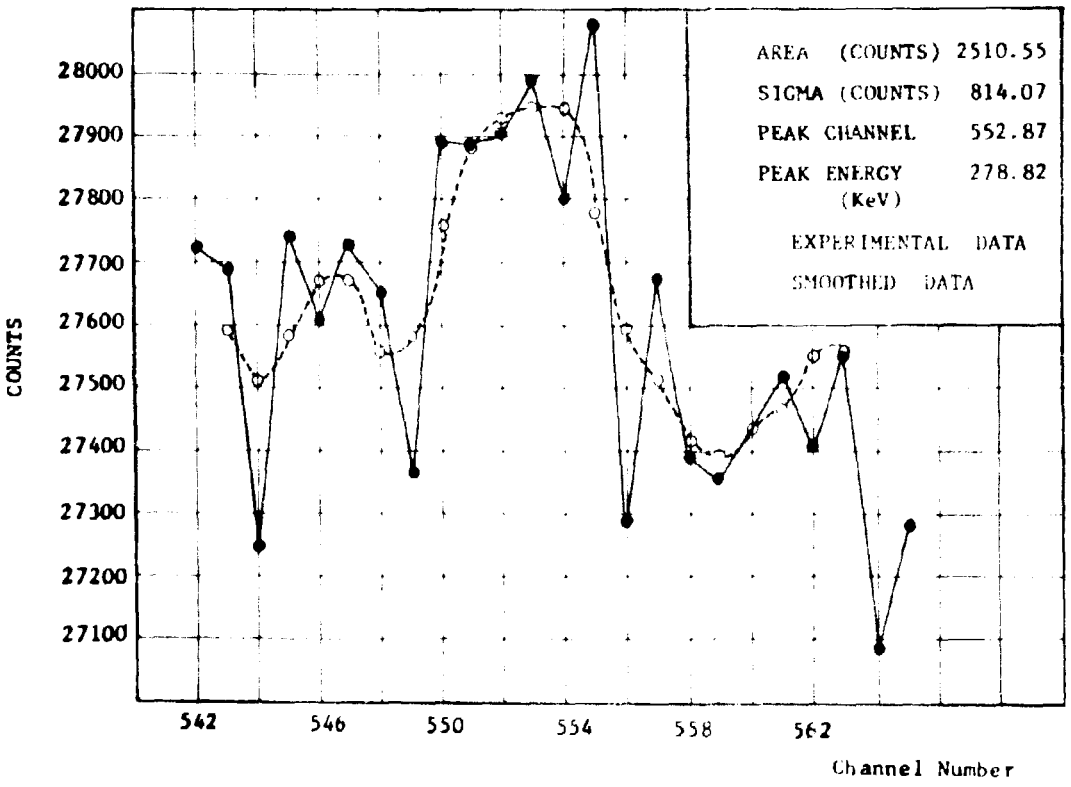


FIG. 4 – SMALL PEAK ON A HIGH COMPTON CONTINUUM.

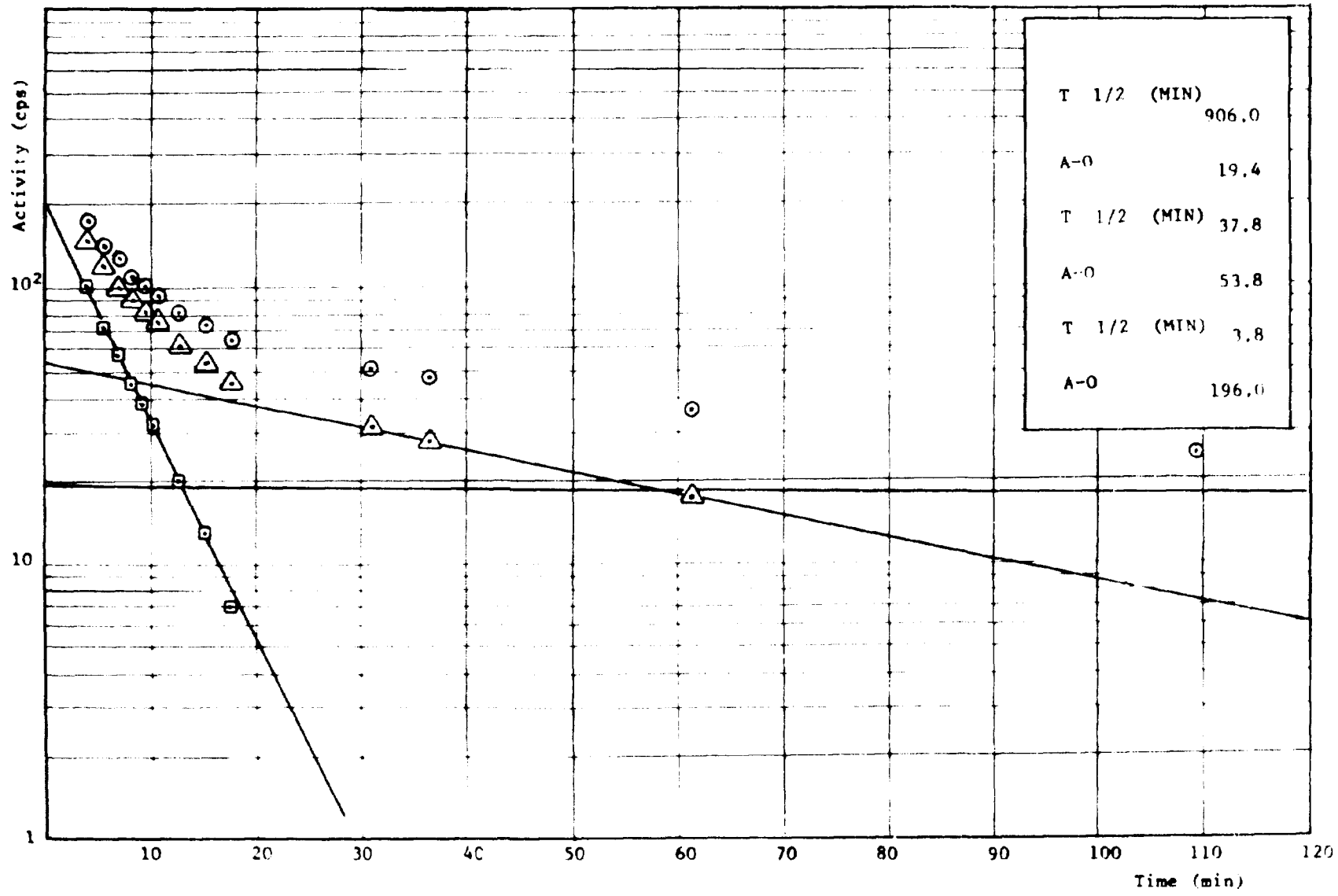


FIG 5 – DECAY CURVE ANALYSIS.