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UNFOLDING OF NEUTRON SPECTRA FROM ACTIVATION DATA USING THE RFO1 AND RFO7 CODES

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UNFOLDING OF NEUTRON SPECTRA FROM ACTIVATION DATA USING THE RF01 AND RF07 CODES

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ABSTRACT

The authors describe two methods for unfolding neutron spectra from activation data. The RF01 code can be used only with threshold detectors, but the use of the RF07 code involves no such limitations; if suitable foils are used, neutron spectra can be unfolded over the whole energy range at one time.

Introduction

Knowledge of the energy distribution of neutrons plays an important part in the study of different reactor types.

The use of activation foils to measure neutron spectra has a potential that is not shared by other methods; the foils are small in size and not normally sensitive to temperature change. They are used to measure spectra as a function of position; moreover, such measurements provide information on the entire energy range at one time. The latter fact is of particular importance in that the results of measurements conducted in different energy ranges can therefore be normalized with respect to one another, and detailed energy distributions determined by other methods in various energy ranges can be fitted into the approximate spectrum obtained from the activation data. It should be noted that in processing the data we do not take into account the fact that the measurement was made with foils; the processing technique can be applied whenever one measures the rate of interaction between neutrons and matter (in fission chambers, BF_3 counters, semiconductor detectors and so on). For the sake of simplicity we will henceforth always use the expression "foil activation".

When applying the foil activation method the values one measures are certain integrals of the products of flux and foil cross-sections. The spectrum unfolded from these data is somewhat arbitrary, since we have only a small quantity of data available - namely, the measured foil activities. The spectrum should satisfy the activation equations (1)

$$A_i = \int_0^\infty \phi(E)\Sigma_i(E)\,dE \qquad (1)$$

where A_i is the measured reaction rate in the i-th foil;

$\phi(E)$ is the spectrum as a function of energy;

$\Sigma_i(E)$ is the energy-dependent cross-section for the reaction occurring during activation of the i-th foil.

There is, of course, an infinite number of spectra satisfying these equations. Hence, some more initial information is required to determine the spectrum. It can be said that, on the whole, the more measured data we have, the less initial information is required. However, the microstructure of a spectrum depends greatly on the initial information, which is therefore of great importance and is usually given in the form of an initial spectrum.

Methods of processing activation data can be divided into two groups. The first group comprises methods where it is assumed that one is dealing with a spectrum given in a simple analytical form (Maxwellian distribution, I/E, fission spectrum, some polynomial or certain combinations of these) and that it is only the parameters of this analytical form that are unknown. A method of this kind was first applied by Lanning [1], who expanded a spectrum in an orthonormalized system of functions. The limits of applicability of this method were studied by Gold [2].

In the thermal neutron region, the commonest method is the use of a Laguerre polynomial as the orthonormalized system of functions. If the spectrum is expanded in a series and only the first few terms are considered, the theoretical spectrum closely approximates the actual spectrum. In the fast and epithermal neutron region one cannot determine categorically the form in which the solution should be sought, particularly when the entire neutron energy region is taken into account. In such cases, we therefore consider it better to apply the methods belonging to the second group.

The second group comprises methods with which the spectrum is determined purely numerically by means of iteration. A method of this kind was used in Ref. [4] for the initial measurements of a fast neutron spectrum; it was assumed that the cross-section of threshold detectors was described by means of functions whose values were equal to zero up to a threshold energy, and to certain constants above that threshold. From the foil activities the integral flux was determined for each threshold energy (this quantity is taken to mean a certain flux integral between the threshold energy and infinity), after which the spectrum was determined by differentiation. The values of $\sigma_i(E)$ available at that time were only very approximate and more accurate calculations were therefore not possible.

Over the past few years, the availability of more exact cross-section values and the use of computers have made it possible to develop more accurate methods based on these principles. A typical example is the SAND-I code developed by McElroy and co-workers [4]. The SAND-II code, also developed by McElroy and co-workers, is based on different principles [5]. Both these methods have been adapted by us for use with our ICT-1905 computer.

As the SAND-I code is described in detail in Ref. [4], we give only a brief description of the RF01 code in this report. The RF07 code developed by us is similar to the SAND-II code (of which only a very short description is available) only as far as the main features are concerned.

Further on we describe the RF01 and RF07 codes developed by us. It should be noted that the sphere of application of the former is limited (it is used only with threshold detectors), whereas there is no limitation of this kind in the case of the RF07 code; moreover, the RF07 code gives considerably better results, so that, apart from certain special cases (for example, when no initial information on the spectrum is available), it is better to use the RF07 code. The entire energy region can be divided into a maximum of 500 points. The initial spectrum can be given in analytical or numerical form; in the latter case, it can be given for arbitrary points. The initial spectrum actually considered will consist of straight lines joining these points. During the calculations, the initial spectrum is varied until the deviation of the measured from the theoretical activities is less than a value specified in the input data.

RF01 code

Each iterative step consists of the following operations:

1. Determination of the reaction rate for each foil from the given iteration spectrum and cross-sections:

$$B_i^{(k)} = \int_0^\infty \phi^{(k)}(E)\Sigma_i(E)\,dE \quad /i=1,2,\ldots,I/ \tag{2}$$

where $B_i^{(k)}$ is the reaction rate for the i-th foil as calculated at the k-th iterative step;

$\phi^{(k)}(E)$ is the spectrum at the k-th iterative step;

I is the number of foils.

2. Assignment of a threshold energy to each foil (this value is taken to be the energy above which 95% of all reactions occur in the given spectrum) in accordance with the following equation:

$$\int_{E_{i\,thr}}^\infty \phi^{(k)}(E)\Sigma_i(E)\,dE = \beta \int_0^\infty \phi^{(k)}(E)\Sigma_i(E)\,dE \tag{3}$$

where E_{ithr} is the threshold energy of the i-th foil as determined from Eq. (3);

$\beta = 0.95$.

3. Determination of the integral flux for each foil:

$$\Phi_i^{(k)} = \int_{E_{ithr}}^{\infty} \phi^{(k)}(E)\, dE \qquad (4)$$

4. Determination of the new integral flux:

$$\Phi_i^{(k+1)} = \Phi_I^{(k)} \frac{A_i}{B_i^{(k)}} \qquad (5)$$

5. Determination of the new spectrum by differentiation of the curve fitted to the points denoting the integral flux values.

The most difficult stage of the method is the fitting of the curve to the integral points. McElroy first carried out this operation by hand. With the method we have developed, use is made of parabolas passing through three integral points. Subsequently, when differentiating, only the segment of the parabola between the first and second points is used. The curve derived in this fashion is broken, but that does not greatly spoil the shape of the spectrum, and after the sixth or seventh iterative step the curve, when corrected manually, gives approximately the same values of $B_i^{(k)}$ as an uncorrected broken curve.

The RF01 code has two substantial disadvantages: first, the integral flux is determined only at as many points as there were irradiated foils; second, if the threshold energies in two foils are close together or coincide, some of the information is lost, for the integral flux is determined only at one point by means of two foils.

RF07 code

Each iterative step consists of the following operations:

1. Determination of the reaction rates from the given spectrum:

$$B_i^{(k)} = \sum_{n=1}^{N} \phi_n^{(k)} \Sigma_{i,n} \Delta E_n \qquad /i = 1,2,\ldots,I/ \qquad (6)$$

where $\phi_n^{(k)}$ is the flux in the n-th energy range at the k-th step;

$\Sigma_{i,n}$ is the cross-section for the i-th reaction in the n-th energy range;

ΔE_n is the width of the n-th energy range;

N is the number of energy ranges.

It should be noted that this formula corresponds to formula (2). The quantities appearing in formula (6) are of the group type, but the ranges are narrow and the quantities can therefore be calculated by means of simple formulas, which we will not consider here.

2. Determination of the weight factor for each foil and each range:

$$W_{i,n}^{(k)} = \frac{1}{B_i^{(k)}} \phi_n^{(k)} \Sigma_{i,n} \Delta E_n \qquad \begin{matrix} /i = 1,2,\ldots,I; \\ n = 1,2,\ldots,N/ \end{matrix} \tag{7}$$

3. Determination of the correction factor for each range:

$$C_n^{(k)} = \frac{N}{I} \sum_{i=1}^{I} \left(W_{i,n}^{(k)} \frac{A_i - B_i^{(k)}}{A_i} \right) \tag{8}$$

4. Determination of the new flux for each range:

$$\phi_n^{(k+1)} = \phi_n^{(k)} \left(1 + C_n^{(k)} \right) \tag{9}$$

After each iterative step the flux is normalized in such a way that the sum of the squares of the deviations of the measured and computed activity ratios from unity, i.e. the expression

$$\sum_{i=1}^{I} \left(\frac{B_i^{(k)}}{A_i} - 1 \right)^2$$

is at a minimum. If the flux is multiplied by a number f in each energy range, each activity increases by a factor f, so that this number should be determined in such a way as to satisfy the condition

$$\sum_{i=1}^{I} \left(\frac{f\, B_i^{(k)}}{A_i} - 1 \right)^2 = \text{minimum} \qquad (10)$$

If we differentiate this expression with respect to f, we get, after simple transformations

$$f = \frac{\sum_{i=1}^{I} \frac{B_i^{(k)}}{A_i}}{\sum_{i=1}^{I} \left(\frac{B_i^{(k)}}{A_i} \right)^2} \qquad (11)$$

This means that one should calculate this quantity after each step, and then multiply the flux by it.

Detailed examination of the code algorithm shows clearly that at those points where the cross-section of all the detectors used is zero the spectrum varies only as a result of normalization, since the detectors do not carry any information about these ranges.

The applications of the code and some of its properties, and also the interpretation of the results obtained with it, are discussed by us in detail in Ref. [6].

The cross-sections used for the calculations are recorded on RFSP-LIBRARY tape. The cross-sections of the cadmium-covered foils were calculated with the aid of a separate code. The data on the magnetic tape can be supplemented or altered as new data are received. Table 1 shows the designations of those reactions for which we have the cross-sections on tape. For the code we use RFSP-LIBRARY tape and one auxiliary magnetic tape. The input data can be inserted on 8-track punched tape or on punched cards.

Using the code, we first seek data on the foil cross-sections; after appropriate processing, these data are then recorded on the auxiliary magnetic tape. During the rest of the operation only the auxiliary tape is used. If there are no data on a particular foil (or foils) on the RFSP-LIBRARY tape, the code indicates this fact and calculates only with the data on the remaining foils. If there are no data on any of the foils, the code reads the available data for the problem being solved and then begins reading the data relating to the next problem.

Input data for programmes

All the lines of input data are compiled in accordance with the rules for the FORTRAN format. The sequence for these lines is as follows:

1st type: 2I1, I2

MI = 1 - New problem;

3 - End of punched tape.

NANAL = 1 - The initial spectrum is given in analytical form;

2 - The initial spectrum is given in numerical form.

KIRAJZ - The number of iterations after which the results should be printed out. The results of the first and last iterations are printed out irrespective of this.

2nd type: I2

NSIG - Number of foils used.

3rd type: ⌈2A8, 2E12.5⌋

- The first two data items indicate the foil designation. This designation must agree with that given in Table 1. The designation is followed by the measured reaction rates in the spectrum being studied and the calibration spectrum. The calibration spectrum need not be read, but if the foils have not been calibrated, we have to give absolute foil activities for one atom.

This type is read NSIG times.

4th type: 2 ⌈7A8, A4⌋

- Any text in two lines with 60-60 alphanumerical symbols in each.

5th type: I4, E14.5

LEPMAX - Maximum number of iterations;

DMEG - Permissible error in the activities. Iteration terminates when

$$\sum_{i=1}^{I} \frac{1}{A_i} \left| B_i^{(k)} - A_i \right| \leq \text{DMEG}$$

6th type: 2E12.5, I6	ALSO	- Lower energy limit in MeV;
	FELSÖ	- Upper energy limit in MeV;
	NOSZT	- Number of energy intervals. The intervals on a logarithmic scale are distributed uniformly.
7th type: 4E12.5 CK1 EMAXW1, CK2, CK3		- Parameters of calibration flux. CK1, CK2 and CK3 are amplitudes of Maxwellian and I/E spectra and fission spectrum, while EMAXW1 is the maximum energy of the Maxwellian spectrum. If the foils are not calibrated, the values of these parameters need not be given, but a place has to be left empty for them.
8th type: 4E12.5 CK11, EMAXW11, CK12, CK13		- The parameters of the initial spectrum are in the same sequence as in the case of the 7th type. This type is read only when NANAL = 1.
9th type: I4	NENBE	- The number of energy points at which the initial spectrum is given. This type is read only when NANAL = 2.
10th type: /6E12.5/		- Altogether 2 x NENBE numbers, E_I, $\phi_0(E_I)$, E_2, $\phi_0(E_2)$, etc. The energies must follow in descending order. This type is read as many times as required for consistency with the KIRAJZ value. It is also read only when NANAL = 2.

The code then begins the calculation, in the course (in accordance with the KIRAJZ value) and after the completion of which it prints out the result and goes on to read data relating to the next problem.

Print-out of results

After the input data have been issued as first-iteration results, the code prints out the normalized initial spectrum; the spectrum is then

printed out after each KIRAJZ iteration. The measured and calculated reaction rates, their ratios and percentage deviations, are also printed out. The spectrum is displayed schematically on a logarithmic scale.

The Appendix contains a set of input data and a photocopy of results printed out by the RF07 code.

Table 1

Reactions recorded on RFSP-LIBRARY tape
and their energy limits

U235/NF/FP-CD	$0,7.10^{-8}$ - 18 MeV
U233/NF/FP-CD	$1,0.10^{-8}$ - 18
PU239/NF/FP-CD	$0,6.10^{-8}$ - 18
NA23/NG/NA24-CD	$0,5.10^{-8}$ - 18
MG24/NP/NA24	0,05 - 18
IN115/NN/IN115M	0,05 - 18
S32/NP/P32	0,05 - 18
AL27/NP/MG27	0,05 - 18
AL27/NHE/NA24	0,05 - 18
RH103/NN/RH103M	0,05 - 18
FE56/NP/MN56	0,05 - 18
NI58/NP/CO58	0,05 - 18
P31/NP/SI31	0,05 - 18
PU239/NF/FP	$0,5.10^{-10}$ - 10^{-5}
DY164/NG/DY165	$0,33.10^{-10}$ - 10^{-5}
LU176/NG/LU177	$0,5.10^{-10}$ - 10^{-5}
EU151/NG/EU152	$0,5.10^{-10}$ - 10^{-5}
IN115/NG/IN116	$0,5.10^{-10}$ - 10^{-5}
AU197/NG/AU198	$0,5.10^{-10}$ - 2.10^{-5}

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[2] GOLD, R., Nucl. Sci. Eng. 20 (1964) 493.

[3] HUGHES, D.J., Pile Neutron Research, Cambridge (Mass.) (1953).

[4] McELROY, W.N. et al., Nucl. Sci. Eng. 27 (1967) 533.

[5] McELROY, W.N. et al., AFWL-TR-67-41 (September 1967).

[6] FISCHER, A., TURI, L., to be published.

```
22 2
 5
PU239(NF)FP       8.76059E 02
DY164(NG)DY165    1.80564E+03
LU176(NG)LU177    4.21792E+03
EU151(NG)EU152    2.46769E+03
IN115(NG)IN116    6.08475E+02
   - TEST CASE FOR REPORT -
- 15 JULY 1970. -
 100   0.01000E 00
 1.00000E-09 3.00000E-06   100
 0.0          0.0          0.0          0.0
  39
 3.     E-06 1.7    E-02 2.75   E-06 1.925  E-02 2.2    E-06 2.32   E-02
 1.9    E-06 2.68   E-02 1.6    E-06 3.19   E-02 1.4    E-06 3.64   E-02
 1.2    E-06 4.25   E-02 1.05   E-06 4.85   E-02 0.9    E-06 5.67   E-02
 0.85109E-06 6.8781 E-02 0.68412E-06 6.8781 E-02 0.68411E-06 9.1563 E-02
 0.51234E-06 9.1563 E-02 0.51233E-06 1.2353 E-01 0.38482E-06 1.2353 E-01
 0.38481E-06 1.658  E-01 0.27553E-06 1.658  E-01 0.27552E-06 2.4184 E-01
 0.21278E-06 2.4184 E-01 0.21277E-06 3.4906 E-01 0.17104E-06 3.4906 E-01
 0.17103E-06 4.8664 E-01 0.13385E-06 4.8664 E-01 0.13384E-06 8.3368 E-01
 0.10121E-06 8.3368 E-01 0.10120E-06 1.3658 E 00 7.31180E-08 1.3658 E 00
 7.31170E-08 2.139  E-00 4.95890E-08 2.139  E 00 4.95880E-08 2.6911 E-00
 3.0614 E-08 2.6911 E 00 3.06130E-08 2.684  E 00 1.7853 E-08 2.687  E 00
 1.7852 E-08 2.1198 E 00 9.1081 E-09 2.1198 E 00 9.1080 E-09 1.318  E 00
 4.0481 E-09 1.318  E 00 4.0480 E-09 2.8335 E-01 1.0    E-09 2.8335 E-01
3
```

Set of input data

```
* * *  RF07  * * *

 - TEST CASE FOR REPORT -                          - 15 JULY 1970. -

PU239(NF)FP        8.76059E 02   0.00000E-01
DY164(NG)DY165     1.80564E 03   0.00000E-01
LU176(NG)LU177     4.21792E 03   0.00000E-01
IN115(NG)IN116     6.08475E 02   0.00000E-01
EU151(NG)EU152     2.46769E 03   0.00000E-01

 Number of foils  5

 Number of steps                100
 Number of division points      100
 Error limit                    1.000E-02
 Energy limits                  1.000E-09 . ES  3.000E-06  MEV

 Non-calibrated foils
```


Results printed out by the RF07 programme (I)

Number of iterations: 1

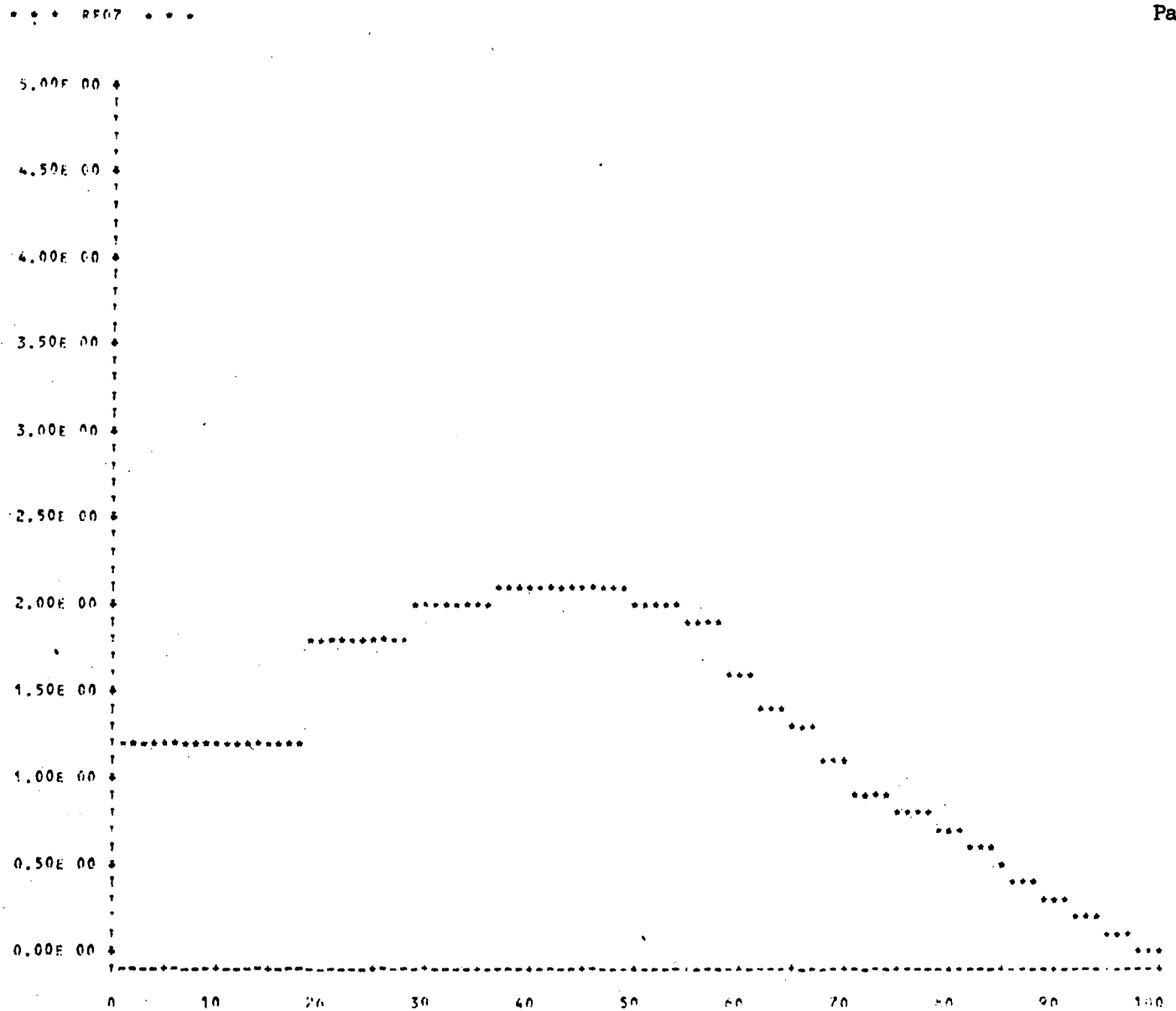
Differential flux printout 1 Point-wise

E	F(E)	E	F(E)	E	F(E)	E	F(E)	E	F(E)
1.000E-09	1.013E 06	1.084E-09	1.013E 06	1.176E-09	1.013E 06	1.275E-09	1.013E 06	1.382E-09	1.013E 06
1.498E-09	1.013E 06	1.625E-09	1.013E 06	1.761E-09	1.013E 06	1.910E-09	1.013E 06	2.071E-09	1.013E 06
2.245E-09	1.013E 06	2.434E-09	1.013E 06	2.639E-09	1.013E 06	2.861E-09	1.013E 06	3.103E-09	1.013E 06
3.364E-09	1.013E 06	3.647E-09	1.013E 06	3.954E-09	1.013E 06	4.287E-09	4.710E 06	4.649E-09	4.710E 06
5.040E-09	4.710E 06	5.465E-09	4.710E 06	5.925E-09	4.710E 06	6.424E-09	4.710E 06	6.965E-09	4.710E 06
7.552E-09	4.710E 06	8.188E-09	4.710E 06	8.878E-09	4.710E 06	9.626E-09	7.575E 06	1.044E-08	7.575E 06
1.132E-08	7.575E 06	1.227E-08	7.575E 06	1.330E-08	7.575E 06	1.442E-08	7.575E 06	1.564E-08	7.575E 06
1.695E-08	7.575E 06	1.838E-08	9.602E 06	1.993E-08	9.601E 06	2.161E-08	9.599E 06	2.343E-08	9.598E 06
2.540E-08	9.596E 06	2.754E-08	9.594E 06	2.986E-08	9.592E 06	3.238E-08	9.617E 06	3.511E-08	9.617E 06
3.806E-08	9.617E 06	4.127E-08	9.617E 06	4.475E-08	9.617E 06	4.852E-08	9.617E 06	5.260E-08	7.644E 06
5.703E-08	7.644E 06	6.184E-08	7.644E 06	6.705E-08	7.644E 06	7.269E-08	7.644E 06	7.882E-08	4.881E 06
8.545E-08	4.881E 06	9.265E-08	4.881E 06	1.005E-07	4.881E 06	1.089E-07	2.979E 06	1.181E-07	2.979E 06
1.280E-07	2.979E 06	1.388E-07	1.739E 06	1.505E-07	1.739E 06	1.632E-07	1.739E 06	1.769E-07	1.247E 06
1.918E-07	1.247E 06	2.080E-07	1.247E 06	2.255E-07	8.643E 05	2.445E-07	8.643E 05	2.651E-07	8.643E 05
2.875E-07	5.925E 05	3.117E-07	5.925E 05	3.379E-07	5.925E 05	3.664E-07	5.925E 05	3.972E-07	4.415E 05
4.307E-07	4.415E 05	4.670E-07	4.415E 05	5.063E-07	4.415E 05	5.490E-07	3.272E 05	5.952E-07	3.272E 05
6.453E-07	3.272E 05	6.997E-07	2.458E 05	7.586E-07	2.458E 05	8.225E-07	2.458E 05	8.918E-07	2.098E 05
9.670E-07	1.895E 05	1.048E-06	1.736E 05	1.137E-06	1.609E 05	1.232E-06	1.483E 05	1.336E-06	1.370E 05
1.449E-06	1.262E 05	1.571E-06	1.163E 05	1.703E-06	1.077E 05	1.847E-06	9.902E 04	2.002E-06	9.139E 04
2.171E-06	8.416E 04	2.354E-06	7.896E 04	2.552E-06	7.388E 04	2.767E-06	6.825E 04	3.000E-06	6.075E 04

Measured and counted activities, activity ratios and percentage errors

	A(I)	B(I)	B(I)/A(I)	B(I)/A(I) - 1
D = 3.948E-02				
PU239(NF)FP	8.76059E 02	8.68173E 02	9.90998E-01	-0.9002
DY164(NG)DY165	1.80564E 03	1.88585E 03	1.04442E 00	4.4419
LU176(NG)LU177	4.21792E 03	3.91247E 03	9.27583E-01	-7.2417
IN115(NG)IN116	6.08475E 02	6.38400E 02	1.04918E 00	4.9181
EU151(NG)EU152	2.46769E 03	2.41241E 03	9.77600E-01	-2.2400

Results printed out by the RF07 programme (II)



Results printed out by the RF07 programme (III)

Number of iterations: 51

Differential flux printout 1 Point-wise

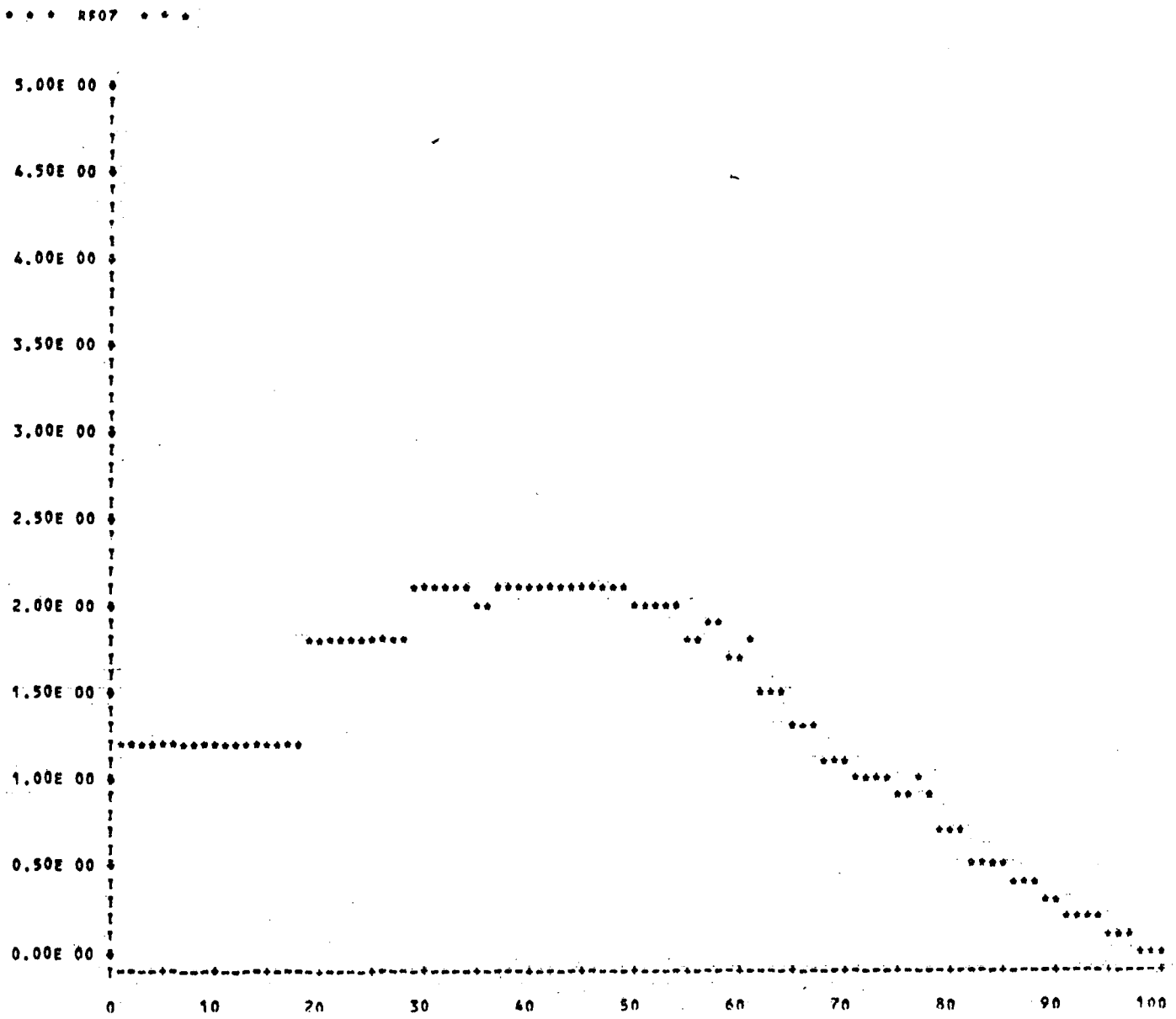
E	F(E)	E	F(E)	E	F(E)	E	F(E)	E	F(E)
1.000E-09	1.011E 06	1.084E-09	1.012E 06	1.176E-09	1.012E 06	1.275E-09	1.012E 06	1.382E-09	1.012E 06
1.498E-09	1.012E 06	1.625E-09	1.012E 06	1.761E-09	1.012E 06	1.910E-09	1.013E 06	2.071E-09	1.013E 06
2.245E-09	1.013E 06	2.434E-09	1.013E 06	2.639E-09	1.013E 06	2.861E-09	1.013E 06	3.103E-09	1.013E 06
3.364E-09	1.013E 06	3.647E-09	1.013E 06	3.954E-09	1.013E 06	4.287E-09	4.778E 06	4.649E-09	4.777E 06
5.040E-09	4.779E 06	5.465E-09	4.778E 06	5.925E-09	4.780E 06	6.424E-09	4.777E 06	6.965E-09	4.775E 06
7.552E-09	4.775E 06	8.188E-09	4.772E 06	8.878E-09	4.769E 06	9.624E-09	7.732E 06	1.044E-08	7.714E 06
1.132E-08	7.699E 06	1.227E-08	7.678E 06	1.330E-08	7.651E 06	1.442E-08	7.628E 06	1.564E-08	7.592E 06
1.695E-08	7.561E 06	1.838E-08	9.522E 06	1.993E-08	9.446E 06	2.161E-08	9.358E 06	2.343E-08	9.276E 06
2.540E-08	9.176E 06	2.754E-08	9.067E 06	2.986E-08	8.980E 06	3.238E-08	8.921E 06	3.511E-08	8.799E 06
3.806E-08	8.708E 06	4.127E-08	8.616E 06	4.475E-08	8.511E 06	4.852E-08	8.432E 06	5.260E-08	6.823E 06
5.703E-08	6.780E 06	6.184E-08	6.759E 06	6.705E-08	6.754E 06	7.269E-08	6.793E 06	7.882E-08	4.55?E 06
8.545E-08	4.640E 06	9.265E-08	4.812E 06	1.005E-07	5.107E 06	1.089E-07	3.257E 06	1.181E-07	3.616E 06
1.280E-07	4.225E 06	1.388E-07	2.256E 06	1.505E-07	2.226E 06	1.632E-07	2.031E 06	1.769E-07	1.304E 06
1.918E-07	1.249E 06	2.080E-07	1.223E 06	2.255E-07	8.482E 05	2.445E-07	8.544E 05	2.651E-07	8.762E 05
2.875E-07	6.188E 05	3.117E-07	6.475E 05	3.379E-07	6.498E 05	3.664E-07	6.413E 05	3.972E-07	4.888E 05
4.307E-07	5.695E 05	4.670E-07	6.420E 05	5.063E-07	5.188E 05	5.490E-07	3.348E 05	5.952E-07	3.236E 05
6.453E-07	3.192E 05	6.997E-07	2.399E 05	7.586E-07	2.395E 05	8.225E-07	2.395E 05	8.918E-07	2.057E 05
9.670E-07	1.880E 05	1.048E-06	1.292E 05	1.137E-06	1.604E 05	1.232E-06	1.460E 05	1.336E-06	1.329E 05
1.449E-06	1.123E 05	1.571E-06	1.169E 05	1.703E-06	1.083E 05	1.847E-06	9.823E 04	2.002E-06	9.064E 04
2.171E-06	8.353E 04	2.354E-06	7.844E 04	2.552E-06	7.345E 04	2.767E-06	6.791E 04	3.000E-06	6.053E 04

Measured and counted activities, activity ratios and percentage errors

	A(I)	B(I)	B(I)/A(I)	B(I)/A(I) - 1
D = 9.932E-03				
PU239(NF)FP	8.76059E 02	8.76215E 02	1.00018E 00	0.0178
DY164(NG)DY165	1.80564E 03	1.84918E 03	1.02411E 00	2.4115
LU176(NG)LU177	4.21792E 03	4.19866E 03	9.95435E-01	-0.4565
IN115(NG)IN116	6.08479E 02	6.08487E 02	1.00002E 00	0.0020
EU151(NG)EU152	2.46769E 03	2.41641E 03	9.79219E-01	-2.0781

Good spectrum

Results printed out by the RF07 programme (IV)



Results printed out by the RF07 programme (V)