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THE NUCLEAR DATA COMMISSION AND THE RADIONUCLIDE DATA CENTRE IN RUSSIA

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IN RUSSIA

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THE WORK OF THE NUCLEAR DATA COMMISSION

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The Nuclear Data Commission (NDC) held its regular meeting at Obninsk on 22 December 1992 after a long break.

It may be recalled that this body was set up in the 1960s to co-ordinate the activities on nuclear data (measurements, calculations, evaluation and so on) being carried out in all the republics of the former Soviet Union. The NDC has done a lot of useful work in the past. Based on an analysis of the general situation with respect to nuclear data, it periodically made recommendations for work to be stepped up in areas of highest priority, provided both moral and material support for this work and then organized a discussion of the results. One could cite as a specific example the stir created in the mid-1960s by the values of the alpha parameter for plutonium-239. At that time, upon its recommendation, a series of control measurements were organized at various institutes and the subsequent comparison of the results obtained by them went a long way towards refining the values of this very important parameter of crucial significance for the whole future of nuclear power production based on fast reactors. The NDC paid unceasing attention to the development of an experimental infrastructure - first and foremost the design of new promising neutron sources such as the isochronic cyclotron in Kiev, the neutron target for the linear electron accelerator in Kharkov, the pulsed fast reactor at Dubna, the linear accelerator at the All-Union Scientific Research Institute for Electrophysics, the PIK reactor in St. Petersburg and many others. In order to solve more specific problems, the NDC set up co-ordination councils for neutron and non-neutron nuclear data, the testing of nuclear data and the development of multi-group constant systems, which functioned quite efficiently. All practical work on the compilation and treatment of nuclear data was carried out and continues to be carried out at centres located in various towns in the country and operating under the auspices of the NDC. One of the main results of this work was the creation of a national library of evaluated nuclear data, BROND, which occupies a distinguished place alongside other national and regional libraries such as the American ENDF, the Japanese JENDL, the European JEF and others. The NDC engages in extensive co-operation at the international level. Since 1963, its representatives have participated regularly in the work of the International Nuclear Data Committee of the IAEA and nuclear data centres exchange information on a regular basis with similar centres in various countries of the world. This all ensures that the requirements of the country's various institutions for reliable and up-to-date nuclear data are met.

After the disintegration of the former Soviet Union and the transition to a so-called market economy, individual specialists expressed doubts about the need to continue the work of the NDC, suggesting that there were other more pressing requirements. However, it is precisely at a time of general instability that it is especially important to co-ordinate efforts, to exchange experiences of work under the new conditions, and to provide mutual assistance and support. It is therefore perfectly legitimate for the activities of the NDC to be revived in a new guise.

Moreover, as has been demonstrated in practice, the need for nuclear data continues to be urgent, since the emergence of new areas of work is accompanied by specific requirements for new categories of data and more detailed information on those data. Some of these issues were examined at the last NDC meeting, where the presentations of N.S. Rabotnov and B.D. Kuz'minov dealt with the nuclear data requirements for the development of work on the transmutation of long-lived nuclear waste. V.N. Manokhin's report considered a similar problem in connection with the decommissioning of nuclear reactors that have reached the end of their lifetime. One very important problem today is the certification of nuclear data and their upgrading to the level of the State standard. This problem as applied to multi-group constant systems and the creation of a national library of recommended nuclear data was outlined in the report by M.N. Nikolaev. The meeting also heard information presented by V.P. Chechev on the organization and progress of work on radionuclide (nuclear and radiative) data at the Radium Institute (St. Petersburg) and on the status of work at the Joint Institute of Nuclear Research on the development of a new advanced neutron source.

Appropriate decisions were taken on all the matters discussed. In particular, a special commission was set up to submit proposals for a programme to establish a database for the problem of transmutation of radioactive waste. Another important decision taken by the NDC related to the reorganization of its external relations with the IAEA, with the former republics of the USSR, and with other countries.

The NDC has now prepared new draft regulations, under which it is to have the status of the Nuclear Data Commission of the Ministry of the Russian Federation for Atomic Energy. It is also proposed to simplify its routine work procedures considerably without changing the main orientations of its current activities. Furthermore, there are plans to expand the activities on providing the scientific community with information on the work and scope of the NDC. In this connection, it should be noted that contact has been established between the NDC and the international non-governmental organization "Nuclear Society" and this has also been reflected in the new draft regulations.

The next meeting of the NDC will be held in May 1993 at which, among other things, its draft regulations and structure will be examined. In future, the NDC will carry out its work on a regular basis, which should be of benefit to all nuclear data activities in our country.

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RADIONUCLIDE DATA CENTRE

(Tasks and problems of obtaining the most reliable values of the nuclear physics characteristics of radionuclides and radiation physics parameters of radionuclide sources)

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ABSTRACT

Information is provided on the establishment of the Radionuclide Data Centre under the V.G. Khlopin Radium Institute. Its functions and areas of activity are discussed. The paper focuses on the procedure of obtaining the evaluated values of the decay and radiative characteristics of the widely used radionuclides.

THE FUNCTIONS AND AREAS OF ACTIVITY OF THE RADIONUCLIDE DATA CENTRE

The sectorial Radionuclide (Nuclear and Radiative) Data Centre (in short, Radionuclide Data Centre (RDC)) at the V.G. Khlopin Radium Institute is starting operation this year. Its functions are performed by the research laboratory for applied nuclear spectrometry and radiometry, which is part of the Isotope Division of the V.G. Khlopin Radium Institute. Functionally, the RDC is connected with the nuclear data centres of the Russian Federation's Ministry for Atomic Energy (Institute of Physics and Power Engineering for neutron data and the Kurchatov Institute for non-neutron data), with the Data Centre of the St. Petersburg Nuclear Physics Institute and with the State Standard Reference

Data Service through the main sectorial Standard Reference Data Centre of the Central Scientific Research Institute of Information and Technoeconomic Studies on Atomic Science and Technology (TSNIIatominform).

The RDC's main area of activity is to establish a computer data bank for the decay properties of radionuclides and the parameters of standard radionuclide sources, to refine these data on the basis of the evaluation made and necessary measurements and to prepare recommended data in order to supply the sector's enterprises with reliable reference data on the decay properties of radionuclides in practical use and on the parameters of the widely used radionuclide sources.

It is expected that the RDC's work will be performed by a staff of 10 persons divided, in accordance with the two areas of the Centre's activities, into two groups, one servicing the database for nuclear physics characteristics (NPC) of radionuclides and the other the database for radiation physics parameters (RPP) of radionuclide sources. The primary task of the Centre is to treat existing data, but where published measurement results do not exist or are of insufficient accuracy the Centre plans to perform its own measurements of the nuclear physics characteristics of radionuclides, together with measurements of radiation physics parameters of the standard radionuclide sources. Our criterion for making additional measurements to refine nuclear physics characteristics applies to cases where the uncertainties of the evaluated values exceed 5% (for a confidence probability of $P = 0.95$) or where the discrepancy in the results of published experimental studies exceeds 10% and is not attributable to the authors' declared measurement errors. The value that needs to be refined most often is the quantum yields (absolute intensities in decay percentages) of the characteristic X-ray and gamma radiation. Measurements to refine these values can be performed independently or as part of international intercomparison or co-operation with subsequent re-evaluation of the earlier recommended values of nuclear physics characteristics.

If nuclear power and isotope production engineers use nuclear and radiative data which are inaccurate or derived from different sources, unreliable results are obtained during the use of radionuclide sources, analyses of radioactive contamination of the environment and process monitoring in nuclear power production and difficulties occur in certifying radionuclide products. In the area of radionuclide metrology we can straight away mention at least three unsatisfactory situations, to the elimination of which the Centre's activities will be devoted:

- The use by the Russian Ministry for Atomic Energy personnel of outdated evaluated data for nuclear physics characteristics from Refs [1-3]. These data were obtained on the basis of studies published in the physics literature up to 1978-1979, whereas the amount of published data in the world is doubled in 8-10 years so that the evaluated values of the nuclear physics characteristics change and their accuracy is improved;
- The use of activity as the basic radiation physics parameter of the sources produced. This causes misunderstandings when the user compares the true radiation intensity with calculations based on the "input" activity, and makes it impossible to determine the advantages of a particular source design and to justify their price on the external market;
- Large data scatter during measurements of the environmental contamination level because of methodological difficulties in determining the activity of the identified radionuclides in bulk samples, in calculating dose fields and in forecasting changes in dose fields in time.

By establishing a data bank for radiation physics parameters of radionuclide samples, which will contain not only information on the true intensity of the "operating" radiation in relation to the "input" activity of the radionuclide but also information on the whole of the actual spectrum of external radiation, it will be possible to make a correct assessment of the total effect of the action of source radiation on the environment and to evaluate the distortions in the structure of the spectra and in the intensity of their individual components which the physical processes introduce into the capsule material.

For this purpose it is expected that the radiation physics parameter bank will include the following measured and calculated parameters:

- Activity of the main radionuclide in the source (for all sources, A, Bq);
- Ratio of the activity of impurity radionuclides to A (for all sources, a_i, %);
- Energy spectrum of the main type of radiation (E_i, keV; I_i, rel. units);
- Energy flux (for sources of corpuscular radiation, heat and light, W, watts);
- Density of photon flux of a given energy (for photon radiation sources, $\Phi(E)$ s^{-1} cm^{-2} at a distance of 1 m);
- Coefficient of radiation yield of the source (K(E), %);
- External radiation (for corpuscular radiation sources, J, s^{-1});
- External photon radiation (for all sources, J(F), s^{-1});
- Exposure dose rate (dose equivalent) (for all sources, D, ΦA/kg).

POSSIBILITIES AND PROBLEMS OF PRODUCTION AND DISTRIBUTION OF EVALUATED RADIONUCLIDE DECAY DATA

The degree of reliability of the value of the radiation physics parameters of radionuclide samples is associated to a great extent with the accuracy of data on the nuclear physics characteristics for the radionuclides entering into the composition of these samples, although the problem of reliability of the nuclear physics characteristics values is of independent importance for other scientific and practical problems. In the second part of this paper we consider in detail the possibilities and present status of the procedure for obtaining the most reliable (evaluated) values of the nuclear physics characteristics for radionuclides at the Centre.

Automated evaluation systems for nuclear physics characteristics of radionuclides

During 1986-1990 the Radium Institute's applied nuclear spectrometry and radiometry laboratory (on which the RDC is based), jointly with the Moscow Engineering Physics Institute (MIFI), established a unique evaluation system for nuclear physics characteristics of radionuclides (ASIO) based on the EC-1045 computer. It is intended for routine and qualitative treatment of large data sets of different types and offers extensive decision-making possibilities to evaluators. In designing the database for this system the software of the SPEKTR and ISKRA systems were used. The database is stored on a 100 MB disk and a copy on magnetic tape.

The RAM volume needed for the ASIO is 480 K, and its software consists of 400 modules (100 000 operators) written in the PL-1 language. The ASIO sub-systems for data input/correction, statistical evaluation, calculated evaluation, balancing of energies and intensities in the decay scheme and printout of evaluated nuclear physics characteristics offer the evaluator a user-friendly environment (in the interactive mode) with a wide "template" and about 300 display terminals.

However, from the users' point of view the form of the final output of the ASIO has substantial disadvantages. The magnetic tape or listing does not allow the user to work efficiently with the obtained data in a modern information medium. For a more efficient computerization of the nuclear physics characteristics evaluation it is necessary to use IBM PC AT type personal computers or compatible systems, in which both the current and output information can be provided in the form of PC diskettes now in wide use. Therefore, using this system as a prototype, we have now designed and implemented an automated evaluation system for nuclear physics characteristics (ASO) based on IBM PC AT type personal computers.

This system is based on a specialized system of acquisition of measurement results for nuclear physics characteristics of radionuclides (SSSR in Russian) which could be used for acquisition (input), storage and evaluation of experimental values for the following nuclear physics characteristics:

- Type of radionuclide decay;
- Half-life;
- Total decay energy;
- Energies of the components of alpha, beta, gamma and X-radiation, and conversion and K-Auger electrons;
- Relative intensities of these radiation components;
- Absolute intensities of the radiation components as a percentage of radionuclide decay;
- Average energy of the given type of radiation;
- Average energy of photon radiation;
- Ionization gamma constant of the radionuclide;
- Kerma constant of the radionuclide.

The design of the SSSR provides for both manual data input using a keyboard and automatic conversion from the writing format of the different existing systems for acquisition and storage of nuclear physics characteristics into the SSSR writing format. The automatic information input presupposes receipt of information in the form of a file or electronic mail, automatic recognition of the writing format of the data received, viewing, selection and recording of these data in the SSSR. The manual input which is now in use allows the editing of input information and visualization and provides reference data for interactive operation with the input editor.

In order to select the optimum tool for constructing the SSSR, we analysed the widely known database control systems (DBase, Fox Base, Paradox, etc.), which are built on the relational model. The relational principle is the most acceptable one for constructing nuclear databases for the EC, VAX, etc. class of computers when there are no problems with information storage capacity. However, for the purpose of the PC-based ASO the above-mentioned conventional databases have a number of drawbacks. They require a large volume of operating memory (no overlay), have a limited mathematical apparatus, and their writing format is not optimal with regard to the requirements of the SSSR (need to work with compressed files, need for a different writing format for different nuclear physics characteristics and exclusion of repeating fields). Moreover, these systems have a rather poorly developed hierarchical structure of data and do not allow modern system service. For these reasons, during the design of the ASO a specialized database was developed using the TURBO PASCAL language with integrated TURBO ASSEMBLER supplemented by a TURBO VISION software package. This database is a finished software product, and it is essentially a system of specialized sub-databases with different writing formats for different nuclear physics characteristics.

The data files forming part of the SSSR are sub-divided into primary (experimental), reference, evaluated and user files, depending on their purpose. The primary file contains the literature data published in the experimental and theoretical studies on the nuclear physics characteristic to which the given sub-database corresponds. The evaluated file contains the evaluated values of a given type of characteristic (for example, absolute intensity of gamma radiation). The reference data files contain information (tables) on auxiliary quantities (atomic masses, electron binding energies, level population fractions, etc.). The user data file contains the recommended values for a given nuclear physics characteristic which are intended for distribution among users. The module of mathematical procedures of the ASO includes sub-modules for statistical treatment of data (calculation of rare weighted and arithmetic means with corresponding errors), interpolation of internal conversion coefficients on the basis of tabulated values, calculation of average radiation energies, total energy of alpha decay, ionization gamma constant, and also absolute values of intensity based on the relative intensity of radiation. All the modules associated with data acquisition, storage and selection in the SSSR are constructed on a hierarchical model which is closest to the format in which the material is presented in reference manuals [2-5] and in the collection of decay schemes [7]: name of nuclide - types of decay - types of radiation - components of radiation - data (with key word "energy" for most sub-databases).

The hierarchical structure of the system of specialized sub-databases is expressed most clearly during work with a demonstration database. The first step in the creation of the user file is to enter in the SSSR the set (sub-database) "name of nuclide", which contains generalized information on nuclides included in the given data file. The sets added successively thereafter are types of decay, types of radiation and so on, according to the scheme given above. Since the key word in the final set of data is the value of energy of nuclear transition or radiation component, each energy value in the hierarchical structure of the user file corresponds, moving in the reverse order, to a definite transition (radiation component) number, a specific type of radiation, type of decay and name of nuclide. The diagram of user file viewing is shown in Fig. 1. In such a system of user file quick access to the necessary data, even for a large number of records, is ensured by the sorting of data groups in the sets and of data sets themselves because of the use of an object-oriented programming technique and the TURBO ASSEMBLER language.

In order to test the program package for the ASO based on the PS/2-60 personal computer, we evaluated the nuclear physics characteristics of ^{52}Cr, ^{57}Co and ^{113}Gd. We performed the evaluation, taking into account recently published data, on the basis of the procedure described below. Table 1 presents the most important refinements obtained in the values of the nuclear physics characteristics, in comparison with the data of Ref. [2].

The new evaluated data have been entered in the files of the demonstration database of the PS/2-60 personal computer and recorded on a diskette in the user form. The evaluated data were taken into account in refining the decay scheme parameters of the five radionuclides considered, which are also on the diskette.

Procedures for evaluating the values of the nuclear physics characteristics of radionuclides

A specific feature of evaluating the decay characteristics of the widely used radionuclides is that there are several, often contradictory, measurement results for one and the same characteristic. Another feature is that the decay scheme has a well-known structure (sequence of location and characteristics of the energy levels of the daughter nucleus). These two features of the decay data for radionuclides of practical use determine both difficulties and their solution in obtaining the most reliable (evaluated) values of the nuclear physics characteristics of these radionuclides. The weighted mean of a number of experimental results which agree with each other but were obtained by substantially different methods is the best evaluation of the "true" value of a characteristic and its uncertainty if the number of consistent measurement results is sufficiently large ($n \geq 5$). In practice, however, the evaluator often encounters a number of values $n < 5$, and the role of statistical criteria diminishes. Therefore, in evaluating the decay data the most important thing is to analyse the experimental technique (detection of systematic uncertainties) and the radionuclide decay scheme on the basis of the evaluated values of nuclear physics characteristics [3-8].

The final selection of evaluated values and uncertainties of quantities like energy, intensity, internal conversion coefficient, etc. should preferably be made not only on the basis of accepted evaluation rules but also by taking into account the balancing of the decay scheme. Some characteristics can be calculated directly from the balancing relations. An example is evaluation of the absolute intensity of the characteristic KX-radiation. Its total intensity can be calculated from the evaluated values of intensity of K-capture and K-conversion electrons and the tabulated values of K-fluorescence yield. If the calculated value of IKX thus obtained agrees with the set of experimental values of IKX, we can speak about the reliability of evaluation of gamma ray intensity, internal conversion coefficients and other nuclear physics characteristics. The importance of taking account of the relationships imposed by the decay scheme for the reliability of evaluation has been pointed out in a recent study [9].

Our evaluation rules, including the statistical criteria, are intended to increase the objectivity of evaluation in cases where the number of published measurements is small and they agree with each other to different degrees. The evaluation procedure here is as follows. In simple cases, in order to obtain an evaluated value, we calculate the weighted mean, using, as weights, squares of measurement errors in the form of standard deviations (one σ).

At the same time, we analyse the consistency of data with respect to criterion χ^2 at a 0.05 significance level:

$$\chi^2 = [(n-1)/\sigma^2]\, S^2 \le (\chi^2)^{0.05}_{n-1}.$$

Here n is the number of measurements, $\sigma_{int} = \left[\sum_{i=1}^{n} (\Delta a_i)^{-2}\right]^{-1/2}$ the "internal" uncertainty of the weighted mean, $a_i \pm \Delta a_i$ the measurement results of various authors with uncertainties in the form of standard deviations, $S = \left\{\frac{1}{n-1}\left[\sum_{i=1}^{n} \omega_i a_i^2 - (\sum_{i=1}^{n} \omega_i a_i)^2\right]\right\}^{1/2}$ the "external" uncertainty of the weighted mean determined by the scatter of results (where $\omega_i = (\Delta a_i)^{-2}\left[\sum_{j=1}^{n} (\Delta a_j)^{-2}\right]^{-1}$ is the weight of the i-th measurement result) and $(\chi^2)^{0.05}_{n-1}$ the tabulated value.

If criterion χ^2 is satisfied, the weighted mean $\tilde{a} = \sum_{j=1}^{n} \omega_i a_i$ is taken as the evaluation result with ascribed uncertainty

$$\Delta\tilde{a} = \begin{cases} t_n^{0.68} S, \ if \ S \succ \sigma_{int} \\ \sigma_{int}, \ if \ \sigma_{int} \geq S \end{cases}$$

Here t_n is Student's coefficient for a confidence probability of 0.68. The use of this coefficient ($t_2 = 1.82$; $t_3 = 1.31$; $t_4 = 1.19$ and so on) gives the necessary increase in the evaluated uncertainty when the number of measurements is small.

We also use the rule that the evaluated uncertainty should not be lower than the minimum measurement error which is possible at the contemporary experimental level (σ_{min}). If σ_{min} is difficult to evaluate, the uncertainty of the recommended value is taken to be not less than the minimum uncertainty $(\Delta a_i)_{min}$ of experimental results $a_i \pm \Delta a_i$ reported by the authors.

When criterion χ^2 is not satisfied, we make use of the following options for further treatment of data: (a) change the weight; (b) use a non-weighted mean; (c) exclude some values on the basis of evaluated or subjective criteria; (d) use, as the objective value, one of the experimental results with its uncertainty increased in relation to that reported by the authors.

We use rule (b) when non-consistent data have uncertainties reported by the authors which are close to each other. We use rule (c) only when doubtful data were obtained by outdated methods or instruments or when it is necessary to choose between two divergent groups of measurement. Rule (d) is applied when there is no alternative or when the choice is dictated by the entire set of data on the decay scheme of a radionuclide. In the last case, the uncertainty of the evaluated value can be calculated as

$$\Delta\tilde{a} = t_n^{0.68}\left\{\sum_{i=1}^{n}(a_i - a_k)^2/[n(n-1)]\right\}^{1/2},$$

where a_k is the value taken as the evaluated value.

CONCLUSION

The automated systems of evaluation of nuclear physics characteristics provide the evaluator with an efficient and convenient tool and supply the users with evaluated data in a modern form of data distribution. The Radionuclide Data Centre is planning to send the available data to users in the form of PC diskettes in contrast to the long and cumbersome procedure of publishing and republishing reference manuals and rarely updated catalogues. However, these plans can be implemented only after completing the extremely laborious work of revising, updating and supplementing the set of recommended data contained in Refs [2-5], and improving the program package of the ASO and the procedure of interactive evaluation based on a computer with a larger RAM. Moreover, a bank of measured radiation physics parameters for reference radionuclide sources can only be generated if there is permanent metrological certification of the spectrometers and facilities available to the Centre. All these activities require specific financial support from the Russian Federation's Ministry for Atomic Energy.

REFERENCES

[1] Decay Schemes of Radioactive Nuclides. Radiation Energy and Intensity (Publication 38 RZ, in 2 parts), Ehnergoatomizdat, Moscow (1987) 480 pp (translated from English).

[2] KHOL'NOV, Yu.V., CHECHEV, V.P., KAMYNOV, Sh.V., et al., Radiation Characteristics of Radionuclides Used in the National Economy. A Reference Manual, Atomizdat, Moscow (1980) (in Russian).

[3] KHOL'NOV, Yu.V., CHECHEV, V.P., KAMYNOV, Sh.V., et al., Evaluated Values of Nuclear Physics Characteristics of Radioactive Nuclides Used in the National Economy. A Reference Manual, Ehnergoatomizdat, Moscow (1982) (in Russian).

[4] KHOL'NOV, Yu.V., CHECHEV, V.P., KAMYNOV, Sh.V., et al., Evaluated Values of Nuclear Plysics Characteristics of Radioactive Nuclides Used in Technology and Medicine. A Reference Manual, Ehnergoatomizdat, Moscow (1984) (in Russian).

[5] CHECHEV, V.P., KUZ'MENKO, N.K., SERGEEV, V.O., et al., Evaluated Values of Nuclear Physics Characteristics of Transuranium Radionuclides. A Reference Manual, Ehnergoatomizdat, Moscow (in Russian).

[6] CHECHEV, V.P., CHUKREEV, F.E., The Decay and Radiation Characteristics of Long-Lived Radionuclides Used in the National Economy and in Scientific Research (Evaluated Data). A Reference Manual, Kurchatov Institute of Atomic Energy, Moscow (1990) (in Russian).

[7] LEDERER, C.M., SHIRLEY, V., Table of Isotopes, John Wiley and Sons, New York (1978).

[8] CHECHEV, V.P., EGOROV, A.G., Nucl. Instr. Meth. in Phys. Res: A312 1, 2 (1992) 378-384.

[9] CHUKREEV, F.E., in: Problems of Atomic Science and Technology. Ser. Nuclear Constants, No. 2 (1992) 92-96 (in Russian).

Table 1. New evaluated values of decay and radiative characteristics

Nuclide	Nucl. phys. characteristics	1980 [2]	1992 (Present study)
^{51}Cr	I_{γ}, % per decay	9,83 (14)	9,86 (9)
	E_{γ}, keV	-	31,56 (29)
	I_{XK}, %	22,33 (42)	22,9 (3)
	$I_{ЭAK}$, %	67,01 (18)	66,4 (3)
^{57}Co	$T_{1/2}$, day	271,5 (3)	271,81 (5)
	$E_{\gamma 1}$, keV	14,4147 (25)	14,4127 (4)
	$I_{\gamma 2}$, %	85,4 (2)	85,60 (17)
	$I_{\gamma 3}$, %	10,7 (2)	10,68 (8)
	I_{XK}, %	56,3 (23)	57,9 (4)
^{60}Co	$T_{1/2}$, years	5,273 (2)	5,2710 (6)
	$E_{\gamma 8}$, keV	2505,81 (3)	2505,738 (6)
	$I_{\gamma 4}$, %	99,89 (4)	99,857 (22)
^{113}Sn	$T_{1/2}$, day	115,1 (1)	115,09 (4)
	Q_{e}, keV	1027 (7)	1039 (4)
	$E_{\gamma 1}$, keV	255,13 (1)	255,07 (5)
	I_{XK}, %	96,4 (15)	96,8 (10)
^{153}Gd	See Ref. [8].		

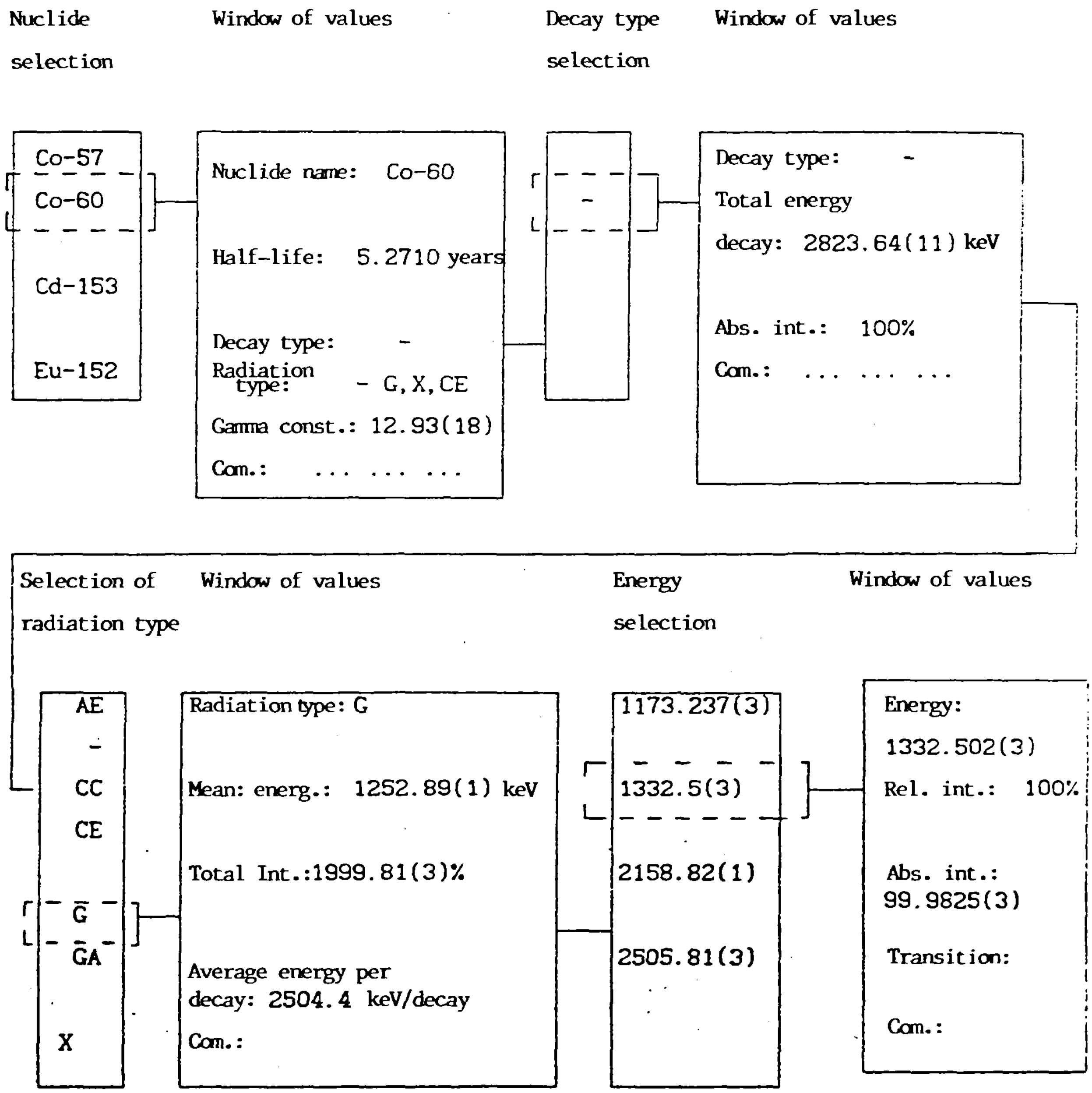

Fig. 1. User file viewing diagram

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