User's Guide
WinDAS

Version 1.1 / Microsoft® Windows™

WinDAS - [EUCAL296.DAT]

File   Acquire   Calculate   caLibrate   Settings   View   Window   Help

Left: -0.016 0   Right 1.84   0   MCS   PHA   MSP

Mode: PHA   Acquisition time: 600 s
Date: 1997-11-27 18:07:02   Deadtime: 0.16 %

Eu-152 1145 Bq, 16-Dec-1996
T1/2=13.2y, Weight=54g
GDM S/N:296, Trimmer=450

For Help, press F1
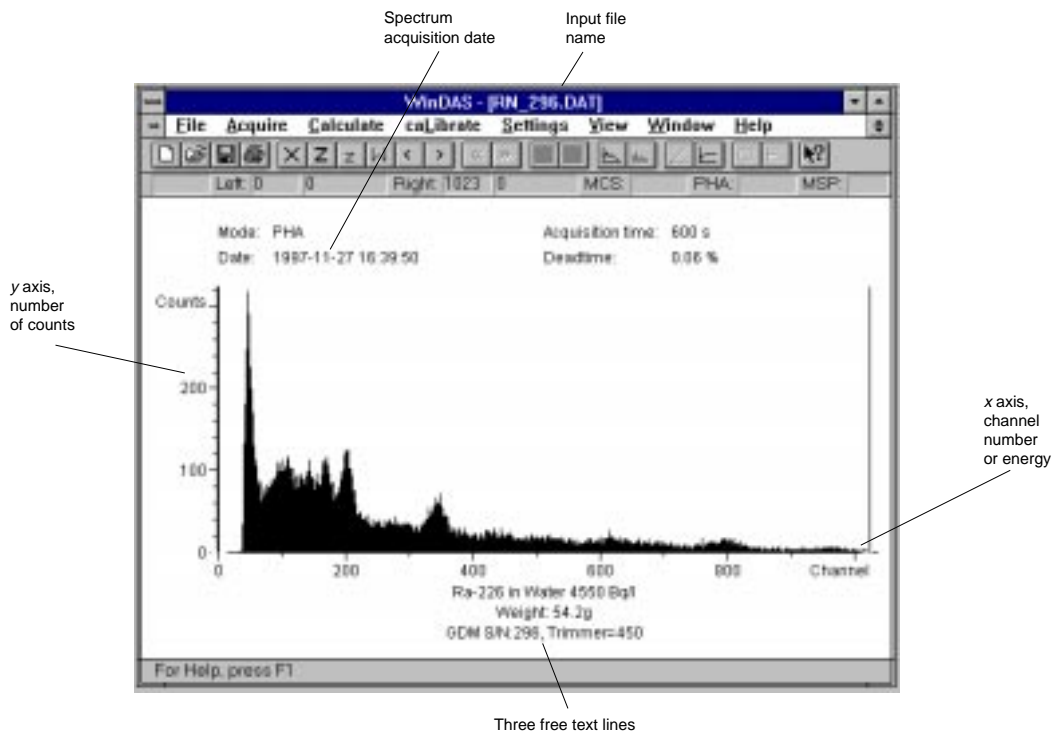
gammadata
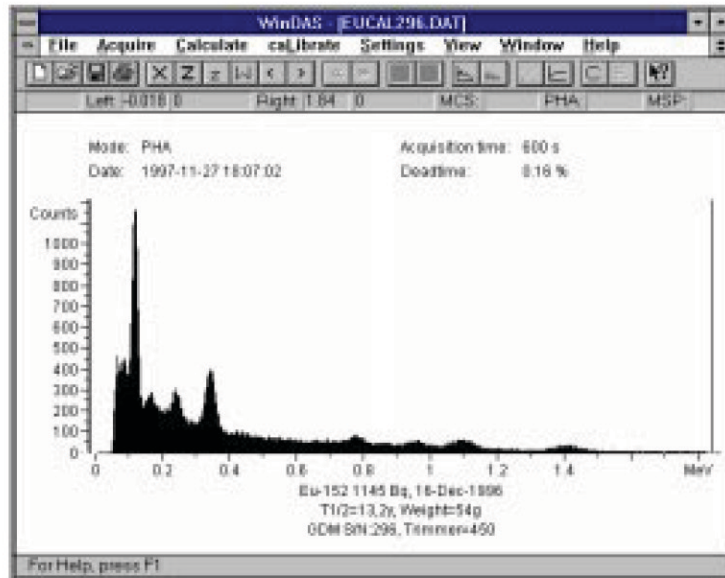
1. Introduction

Welcome to *WinDAS™* – the easy way for measuring and analysing of gamma radiation from radioactive sources or samples.

The software *WinDAS™* is designed for automatic determination of the activity of samples containing cesium-137 and cesium-134 and also for determination of the radon gas activity in houses with the aid of test canisters containing active charcoal. It is developed to facilitate the use of *GDM 10/15/20™* measurement systems in professional as well as educational contexts.

The result is presented on the screen of the computer in the form of a frequency diagram of the energy distribution of the detected gamma quanta, i.e. a spectrum. The figure below shows a normal spectrum window.

The spectra can be stored for later analysis and distribution to the other computers of the laboratory. The spectra can thus be analysed by all students/employees in the laboratory.

Part of or the whole spectrum can be plotted on a printer or printed out channel by channel.

Spectrum acquisition date   Input file name

y axis, number of counts

x axis, channel number or energy

Three free text lines

2 Installation

The program should be installed under *Windows™ version 3.1* with the file *WINDAS16.EXE* or *Windows95™* and *WindowsNT™* with the file *WINDAS32.EXE*. The software is normally installed under a directory name *windas*.

An PC with a 486 processor is recommended for the 16 bit-version and a Pentium processor for the 32 bit-version.

If you have installed the demo version of this program, you should remove it from the hard disk before installation of *WinDAS™*.

Installation:

> • First, choose the Windows directory *Main* and double-click
>   on the icon *File Manager*.

> • Create a directory on your hard disk with name *\WINDAS*.
>
> • Insert the diskette in the drive.
>
> • Next, double-click on the symbol for diskette drive A.
>
> • Now drag the symbol for *windas* to *\WINDAS* directory to the hard disk C.

NOTE
When the installation is done, terminate *File Manager* and eject the original diskette before running the program.

3 Starting the program

The program is started by double-click on the icon *WinDAS*.

When you have double-click the icon the program is loaded and you soon get the following display on the screen:
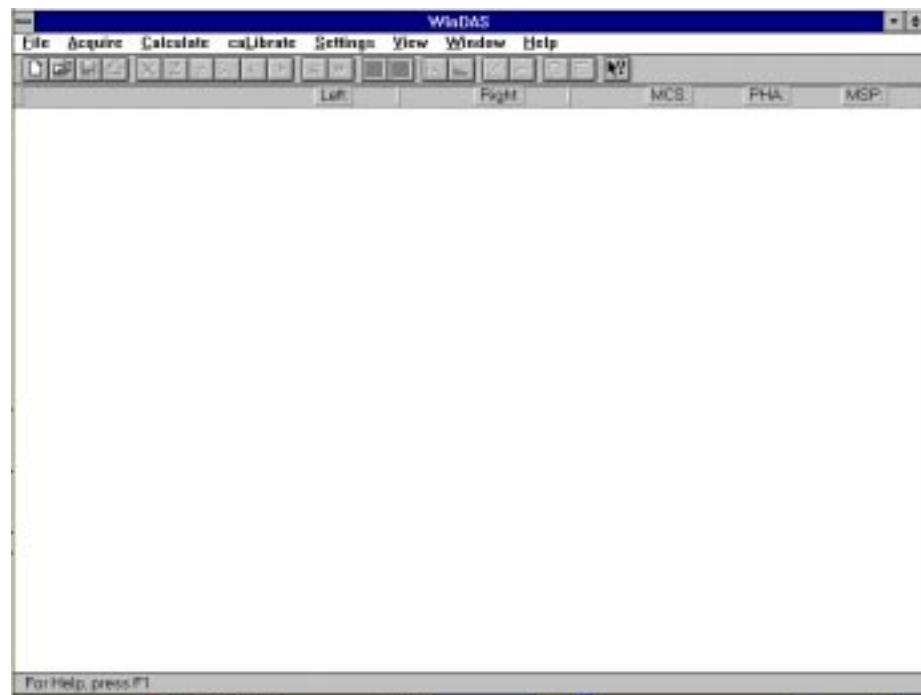
4 Menu Commands

Below are shown all the command buttoms of the *WinDAS™* program.

The following sections is made up of illustrations of all the menus that appear in *WinDAS™* and a description of what the commands in each do.

WinDAS - [PHA Empty]

File **Acquire** **Calculate** **caLibrate** **Settings** **View** **Window** **Help**

4.1 The meny File

File		
New	**Ctrl+N**	Allocate a new spectrum area and select spectrum size.
Open...	**Ctrl+O**	Open an existing spectrum.
Close		Deallocate the current spectrum area.
Save	**Ctrl+S**	Save the current spectrum.
Save MSP		Save the current series of spectra.
Clear		Clear spectrum area.
Add		Add a spectrum.
Substract		Subtract a spectrum from the current spectrum.
Staircase		Create a staircase.
Print...	**Ctrl+P**	Plot the current spectrum.
Print Preview		Display full pages.
Print Setup...		Change the printer and printing options.
1 EUCAL.DAT		Open this spectrum.
Exit		Quit the application; prompts to save the spectrum.

4.2 The menu <u>A</u>cquire

<u>A</u>cquire	
<u>S</u>tart	Start collecting data in the selected mode (green).
<u>S</u>top	Stop data collection (red).
<u>R</u>estart	Restart i.e. execute Stop, Clear, Start.
Preset Time	Setup a predufined time for PHA data collection.

4.3 The menu <u>C</u>alculate

<u>C</u>alculate	
<u>C</u>entroid	Calculate the centroid of the region between markers.
<u>S</u>um	Calculate sum between markers.
Ma<u>x</u>	Calculate max between markers.
Mi<u>n</u>	Calculate min between markers.
<u>A</u>verage	Calculate average between markers.
Cs Activity	Calculates the cesium activity of the displayed spectrum.
Rn Activity	Calculates the radon activity of the displayed spectrum.
RnH20 Activity	Calculates the radon in water activity of the displayed spectrum.

4.4 The meny Ca<u>L</u>ibrate

ca<u>L</u>ibrate	
<u>E</u>nergy	Use the last calculated centroid, or a specified channel, in the calibration.
X-unit	Specify X scale unit.
<u>F</u>rom file	Get calibration from a spectrum file.
Remove	Remove the current energy calibration.
Y-unit	Specify Y scale unit.
Cs-Intensity	Makes a calibration of the cesium activity from the displayed spectrum.

4.5 The menu **S**ettings

Settings	
Marker Position	Gives the the current position of the markers.
MCS Window	Set the channel window for the MCS mode.
MCS mode	Select Multi Channel Scaling mode.
MSP mode	Select Multi Run mode.
PHA mode	Select Pulse Height Analysis mode.
Cs mode	Select the Cesium mode.
Rn mode	Select the Radon mode.
RnH2O mode	Select the Radon in water mode.
Cs-parameters	Set the parameters for automatic analysis of cesium activity.
Rn-parameters	Set the parameters for automatic analysis of radon activity.
UserText	Let put text on 3 lines with 75 characters each.
System Setup	Set the Communication port, Baud rate and Default spectrum size.

4.6 The menu <u>V</u>iew

View	
<u>D</u>ot mode	Show spectrum in Dot mode.
<u>F</u>ill mode	Show spectrum in Fill mode.
<u>A</u>utoscale	Autoscaling the Y-axis.
Fixed scale	Set the full scale of the Y-axis.
Li<u>N</u>ear	Select linear Y axis.
Lo<u>G</u>arithmic	Select logarithmic Y axis.
Smooth	Smooth spectrum (On display only!).
Nosmooth	Disable smoothing.
e<u>X</u>pand	Expand region between markers.
zoom <u>I</u>n	Zoom in.
zoom <u>O</u>ut	Zoom out.
<u>W</u>hole spectrum	Show whole spectrum.
Pan <u>L</u>eft	Pan left.
Pan <u>R</u>ight	Pan right.
<u>E</u>nergy Scale	Show X scale as a Energy Scale.
<u>C</u>hannel Scale	Show X scale as a Channel Scale.
MSP Part	Show a part of a MSP file.

4.7 The menu <u>W</u>indow

Window	
<u>C</u>ascade	Arrange windows so they overlap.
<u>T</u>ile	Arrange windows as non-overlapping tiles
Arrange Icons	Arrange icons at the bottom of the window.
✓<u>1</u> RNDECAY.DAT	Activate this window.

4.8 The menu <u>H</u>elp
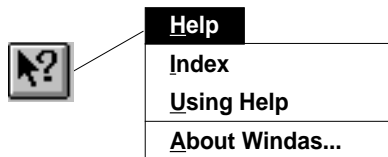
<u>H</u>elp	
<u>I</u>ndex	List Help topics.
<u>U</u>sing Help	Display instructions about how to use help.
<u>A</u>bout Windas...	Display program information, version number and copyright.

5 Gain adjustment

The gain can be adjusted with the knob on the detector box (it supplies high voltage to the photo multiplier tube; the high voltage determines the gain). On delivery the adjustment is such that it is suitable for most measuring situations (about 480 on the potentiometer scale).

To make sure that the gain is correct, one can collect a spectrum of a sample of ^{137}Cs. Start the data acquisition by **Acquire Start** after you have allocated a new spectrum with the command **File New**. Then place a sample of ^{137}Cs near the crystal of the NaI detector. Look for the photo peak, which should be located between channels 340 and 380. This location of the photo peak corresponds to an energy window (= the energy region that is accepted by the electronics) of about 2 MeV for the whole spectrum. The position of the photo peak can be adjusted by changing the high voltage. An example of a ^{137}Cs spectrum is given in figure 1.
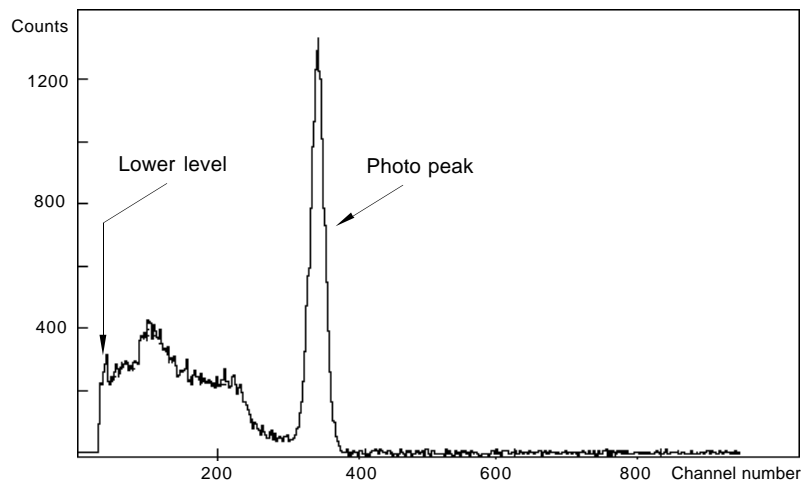

Figure 1.

Pulses from low-energy gamma quanta and from the electronic noise are discriminated (removed) with the 10-turn knob on the amplifier box. In figure 1 the discriminator is adjusted to about 70 keV. How to store and analyse the spectra is dιscribed in chapters 6, 7 and 8.

6 Collecting and Storing a Gamma-Ray Spectrum

When the different parts of the GDM-system have been assembled and connected to the computer according to the _User's Guide_ and the software have been installed everything is ready for collecting a spectrum and storing it on a floppy disc or a hard disc.

The data collection is started with **Acquire Start**. During data collection it is possible to find out how much time has passed by repeating the command STA. The data collection is stopped with **Acquire Stop**. In order to reset the spectrum, i.e. to clear the frequency diagram and remove the spectrum from the memory area in the main memory (= working area in the central unit of the computer), make the command **File Clear**.

To restart the data collection with an automatic reset, give **Acquire Restart**.

In order to measure for a predetermined time interval, use **Acquire Preset Time**, which means that the spectrum will be cleared and a new data collection will start and go on for desired time interval. The end of the measuring time will be indicated on the screen.

It is also possible to collect a whole series of measurements with a constant measuring time, which is particularly suitable for determination of short half lives. You move to MSP mode by giving the command **Settings MSP mode**, a dialogue is initiated on the screen, where the user can give the number of spectra and the measuring time for each spectrum to be recorded. When the data collection has stopped, the spectrum series is stored with the **Save MSP** command.

There is also a possibility to add comments to the spectrum that is stored by using the command **Settings UserText**. These can be comments like the location from where the sample is taken, its weight etc. There is no need, however, to add the measurement time, as it is registered automatically together with the start time for the data collection.

As soon as the spectrum has been stored a new collection of data can start. Do not forget to reset the old spectrum!

Stored spectra can be loaded into the computer by the **File Open** command. Also spectra from a measuring series are read with the command **File Open**.

The programme execution is stopped with **File Exit**.

6.1 Summary: Collecting and Storing a Gamma-Ray Spectrum

Acquire Start	Starts the data collection
Acquire Stop	Stops the data collectiom
File Exit	Ends the programme execution
File Save	Stores the spectrum
File Save MSP	Stores a series of spectra collected with the command
File Clear	Resets a spectrum
Acquire Restart	Restarts the data collection with an automatic reset
Acquire Preset Time	Data collection during a predetermined time interval in seconds
Settings MSP mode	Automatic data collection for a series of spectra
File Open	Loads an already stored spectrum
Settings UserText	Edding comments to the spectrum

6.2 Acquisition Modes

6.2.1 Commands for automatic analysis

The old software autoDAS (MS-DOS version) was designed for automatic determination of the activity of samples containing 137Cs and 134Cs and also for determination of the radon gas activity in houses with the aid of test canisters containing active charcoal. It was developed to facilitate the use of GDM 10/20 measurement systems in professional as well as educational contexts. The program was an extension of the DAS software, which was developed for use with GDM 10/20 in a school environment and which therefore lacks automatic spectrum-analysis capabilities. We have included the autoDAS commands in our new WinDAS software. Below are shown those commands of the WinDAS program that are used to automatically determine the radon or cesium contents of a known sample. In the menu **Settings** you can move to different acquisition modes.

| *Command*	*What it does*
Cs-parameters	Set the Left, Middle and Right limit for the Cs-137 and Cs-134 energy windows. The accuracy is given in percent of the measured value. Within the Cs-mode, only the uncertainty of Cs-137 peak is considered. Max Time(s) detemines the maximum acquisition time if the accuracy not is fulfilled.
Cs-Activity	Calculates the cesium content of the displayed spectrum.
Cs Mode	Automatic data acquisition and cesium determination. After you have chosen this mode you are obliged to give the name of the background file and the weight of the sample before you can start the data acquisition. It stops the acquisition automatically when a predefined accuracy demand is fulfilled. The accuracy is set by the **Cs-parameter** in the menue **settings**. The cesium activity is determined and printed on the screen.
H2ORn-activity	Calculates the radon content of the displayed spectrum (radon in water).
H2ORn Mode	Automatic data acquisition and radon in water determination. After you have chosen this mode you are obliged to give the name of the background file, weight and time after finished exposure (in hours) before you can start the data acquisition. It stops the acquisition automatically when a predefined accuracy demand is fulfilled. The accuracy is set by the **H2ORn-parameter** in the menue **settings**. The radon in water activity is determined and printed on the screen.
Cs-Intensity	Performs intensity calibration with the aid of a spectrum with known cesium contents.
Rn-Activity	Calculates the radon content of a given spectrum (radon in air).
Rn Mode	Automatic data acquisition and radon determination by using Gammadata charcoal canisters. After you have chosen this mode you are obliged to give the name of the background file, weight increase and time after finished exposure(in hours), average temperature during exposure before you can start the data acquisition. It stops the acquisition automatically when a predefined accuracy demand is fulfilled. The accuracy is set by the **Rn-parameters** in the 3.2 menue **settings**. The radon activity is determined and printed on the screen.

6.2.2 Determination of cesium content

When analysing samples containing cesium one often finds two different isotopes of cesium, [134]Cs and [137]Cs. This is due to the fact that these isotopes entered the atmosphere after the catastrophe in Chernobyl in April 1986. The WinDAS software has a routine to determine these two different activities in a quick and efficient way. The calibration sources that are delivered with the GDM 10/15/20 measurement systems, contain known activities of [134]Cs and [137]Cs. These calibration sources are used for automatic determination of cesium activity. The preparations needed and the use of the automatic routine for determination of cesium activity are described below.

A.   Collect a background spectrum overnight before the measurement.
     Save the background spectrum with the command **File Save**.

B.   Create a new spectrum with the command **File New.**

C.   Fetch an energy calibration using **caLibrate From file**. If the energy calibration
     is missing, a new calibration has to be done. See chapter 'Energy Calibration'
     in the manual.

D.   The test canister containing the known cesium activity is placed in the detector
     unit, and the data acquisition is started with the command **Acquire Start**.

E.   The data acquisition can be stopped with the command **Acquire Stop** after about 20 to
     30 minutes.

F.   The intensity calibration is now performed with the command **caLibrate Cs Intensity**.
     Enter the activity of each cesium isotope. The intensity calibration is now complete and is
     stored in the computer automatically. An example is shown below:

G. Store the spectrum with **File Save**. Create a new spectrum with the command **File New.** Move to Cs Mode in menu **Settings**.

H. Fetch an energy calibration using **caLibrate From file**.

I. When the intensity calibration is complete, the calibration data are stored in **Cs parameters**. This makes it possible to determine the cesium activity with the command **Acquire Start** without running **caLibrate Cs Intensity** again if the same geometry is used.

J. Define the desired statistical accuracy with the command **Cs-parameters** in menu **Settings**.

K. Determination of the cesium activity for an unknown sample can now be performed with the command **Acquire Start**. An example of the screen dialogue is given below.
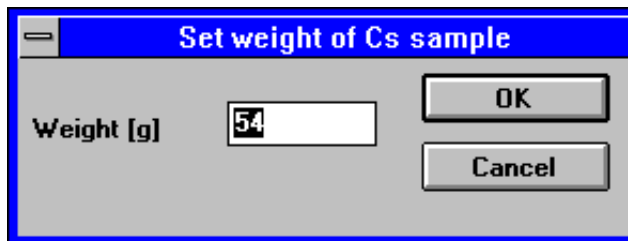
L. The cesium activity is printed out automatically when the desired statistical accuracy is obtained.

M. If you want to finish the acquisition before the desired statistical accuracy has been obtained, you can stop the data acquisition with the command **Acquire Stop**. After that the cesium content is determined with the command **Calculate Cs Activity**.

N. Store the analysed spectrum with the command **File Save**.

O. Set the spectrum area to zero with the command **File Clear** and start data acquisition again with the command **Acquire Start** if another measurement is to be performed.

Collect a new background spectrum the night before using the measurement system. The energy calibration should be redone in case of a change of the setting of the high- voltage supply. The energy calibration is easily checked by e.g. reading the channel number of the 0.344 MeV peak of europium 152.

It is important to use the same geometry when analysing unknown samples, as when the calibration was performed. If another geometry is being used, a new intensity calibration has to be performed.

6.2.3 Determination of radon content, Rn Mode

Since the nuclide radon-222 has a half-life of 3.8 days, one must take into account the decrease of activity from the end of data acquisition to the time of measurement. The software automatically compensates for this decrease, if the time(in hours) since the exposure was finished specifies when starting the measurement procedure. The ability of the charcoal to absorb radon gas depends on the relative humidity and temperature in the room where the canister was placed. The software compensates for that, given the mass increase of the canister and the mean temperature during exposure.

NOTE!
You should regenerate all charcoal canisters before mailing them out for renewed exposure. To do that, remove the plastic diffusion barrier from the canister and heat the canister at 140 degrees Celsius for about 12 hours (for GDM20 metallic canisters). Then reinsert the diffusion barrier and close the lid tightly. Determine the weight of the canister before sending it to the measurement site. It is important to use the proper calibration constant for the current type of carbon. This is done by running the command **Rn-parameters** in menu **Settings**.

Preparations and measurement procedure

Here follows a description of the preparations and the actual measurement procedure
for determining the radon concentration in houses by means of charcoal canisters.

A.   Collect a background during the night and save the file.

B.   Create a new spectrum with command **File New** and move to **Rn Mode** in menu **Settings**.
The program asks for the name of the background spectrum.
Place the charcoal canister in the detector unit.

C.   Fetch an energy calibration using **caLibrate From file**.

D.   Specify the desired statistical uncertainty by running the command
Rn-parameters in menu **Settings**.

E.   Start the activity measurement with **Acquire Start**. The program asks for the time (in hours) since the exposure was finished. You also give the weight increase of the charcoal canister and the mean temperature during exposure. The result is shown on the screen when the required accurecy has been reached.

Example of screen dialogue:

Specify sample

Weight increase [g]	2.2
Time [h]	2.
Temp [C]	20

OK

Cancel

F.   The maximum acquisition time can by running the command **Rn-parameters** in menu **Settings**. It is set to 600 seconds when the software is delivered. That means that the result is displayed after 600 seconds if the accurecy has not been obtained by then.

G.   The acquisition can be stopped at any time with **Acquire Stop**.
In that case, **Calculate Rn Activity** must be given to display the activity.

H.   Store the analysed spectrum using **File Save**.

I.   Use the **File Clear** command to zero spectrum.
Restart the data acquisition with **Acquire Start** if another measurement is to be performed.

Collect a new background spectrum the night before using the measurement system.
The energy calibration should be redone in case of a change of the setting of the high-voltage supply. The energy calibration is easily checked by e.g. reading the channel number of the 0.344 MeV peak of europium 152.

6.2.4 The Settings for Cs, Rn and Rn H$_2$ Mode

The automatic routines in WinDAS require the definition of certain parameters, such as energy windows, efficiency constants, etc. These parameters are defined by running the command **Settings Cs parameters** and **Rn parameters**.

NOTE: The parameters are properly defined when the system is delivered from Gammadata. However, if the system is altered in any way, you might have to review the parameters.

Definition of Cs Parameters

The following parameters has to be given:

a)   Three values for the limits of the [134]Cs and ^{137}Cs peaks.
      Default values are:
      Left limit: 0.52 MeV
      Middle limit: 0.74 MeV
      Right limit: 0.87 MeV.

b)   The accuracy that should be obtained before the cesium acitivities are calculated can be chosen.Default value is:
      Accuracy(%):   10

c)   The efficiency calibration can be entered manually or calculated by
      caLibrate Cs-intensity

d)   The maximum allowed acquisition time for the Cs Mode.
      Default value is:
      Max Time(s):   600

Definition of Rn parameters

Rn Parameters	
Left [MeV]	0.26
Right [MeV]	0.39
Efficiency	1.2e-002
C0	1.8
C1	-1.47
C2	1.
C3	-0.237
C4	1.026
C5	-1.41e-002
Temp Coeff	2.e-002
DCorr	3.e-002
Weight Cross Point [g]	1.8
Accuracy [%]	10
Max Time [s]	600
H2O Cannister Weight [g]	175
H2O Efficiency Const	120

OK   Cancel

a) Two values for the energy window for radon measurements (the [214]Pb window).
   Default values are:
   Left limit: 0.26 MeV
   Right limit: 0.39 MeV

b) Efficiency constant for the calculation of the Rn-222 acitivity with GDM charcoal canister.
   Default value for system GDM 15/20 and GDM 20 metallic charcoal canister is:
   Efficiency const: 0.120

c) Efficiency constants for different Gammadata spectrometer systems:

_____

Metallic canisters delivered after Oct. 9, 1990:

Canister	Measuring system	Efficiency constant
GDM20, metallic	GDM 30	0.0171
GDM20, metallic	GDM 15/20	0.0120
GDM20, metallic	GDM 10-PLUS	0.00707

_____

d) A question about each of nine parameters for compensation for humidity and temperature effects on radon determination. Their default values are as follows (WCP = weight cross point in grams):

_____

Metallic canisters delivered after Oct. 9, 1990

_____

c_0	1.8
c_1	-1.47
c_2	1.00
c_3	-0.237
c_4	1.026
c5	-0.0141
Temp. coeff.	0.020
dkorr	0.03
WCP	1.8

_____

d) The accuracy that should be obtained before the cesium acitivities are calculated can be chosen. Default value is:
Accuracy(%):   10

e) Gammadata has calibrated one type of canister for measuring radon gas activity in water. Please contact Gammadata if you want to buy this type of canister. The parameters for Gammadata's RnH2O canister are:
H2O canister weight(g):   175   *maximum net weight of a full canister*
H2O efficiency const: 120   *efficiency constant for GDM15/20 system*

Rem: The changes in Rn-parameters will not take place before you have restarted the WinDAS software.When you exit WinDAS, the values are automatically stored in *WINDAS.INI*. Located in the WINDAS directory.

6.2.5 Acquiring data in pulse-height analysis mode: Single spectrum

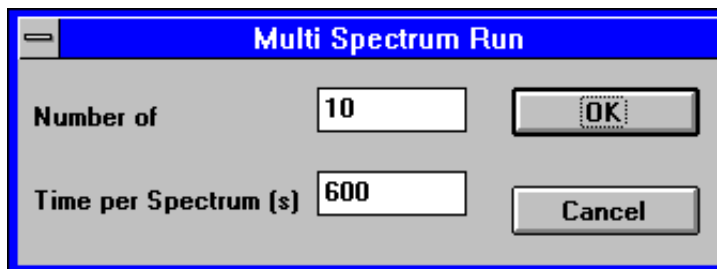The command

    Settings PHA Mode

move to the acquisition mode Pulse-Height Analysis mode. To start data acquisition in the active spectrum area by give the command

    Acquire Start

A rectangle with the text PHA in the upper right corner of the screen indicates the time since the start of the acquisition.

WinDAS allows you to analyse old data during data acquisition. Just display any desired spectrum by chosing one of the active spectrum that you can find in the menu **Window**, then perform any analysis you desire. The acquisition will continue in the spectrum where you started the acquisition during your analyse.

6.2.6 Acquiring data in pulse-height analysis mode: Spectrum series

The command

    Settings MSP Mode

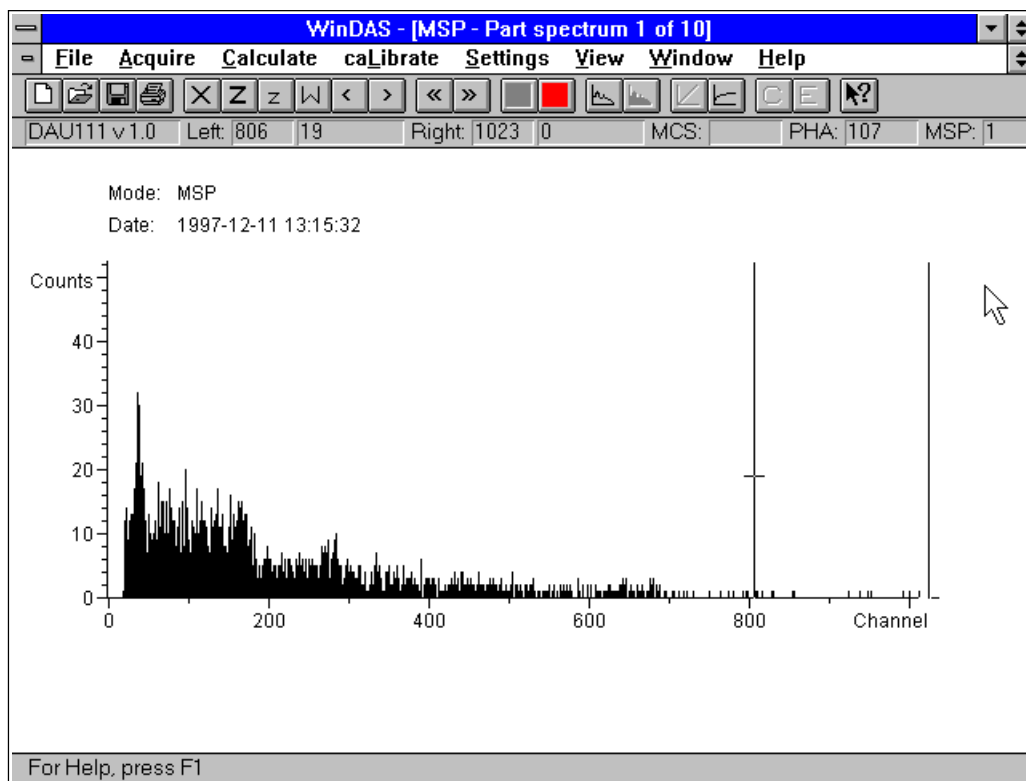move to the acquisition mode Multi Spectrum run mode. WinDAS asks for thereafter for:

Number of spectra   *Maximum 30 spectrum in one Multi Spectrum run*
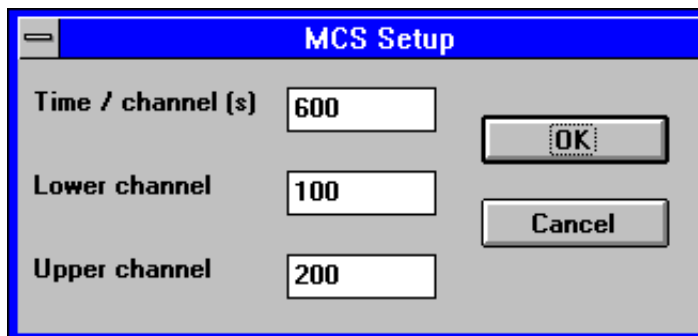Time per spectrum   *Acquisition time per each spectrum has to be defined.*

The command

Acquire Start

Starts a series experiment with pecified number of spectra.

To keep you informed on the progress of the experiment, WinDAS updates the spectrum number in the rectangle.

6.2.7 Acquiring data in multi-channel scaling mode, MCS mode

The command

Settings MCS Mode

move to the acquisition mode Mult channel scaling. WinDAS asks for thereafter for:

Time/channel(s):   t   *Time/channel in seconds for the multichannel window*
Lower channel: x1   *Lower limit for the multichannel window*
Upper channel: x2   *Upper limit for the multichannel window*

The command

Acquire Start

starts a multi-channel scaling experiment.

This defines a pulse-height window covering channels #x1 through x2 in the ADC. Pulses within the window are counted in subsequent time intervals of t seconds each. The results are put in subsequent channels in the WinDAS spectrum. Hereby WinDAS provides a powerful method to study effects varying in time.

A rectangle with the text MCS in the upper right corner of the screen indicates the time since the start of the acquisition.

7 Energy Calibration

To determine the energy of the detected gamma radiation, the spectrum must first be energy calibrated.

For the NaI detector the amplitude of the signal from the PM tube is proportional to the energy of the detected gamma radiation (the deviation is at the most 1-2 %). Thus in principle there is a direct proportionality between the channel number and the gamma energy. To determine the linear calibration function, two photo peaks are required. Their energies shall preferably be situated at the beginning and the end of the energy interval of interest.

The calibration can be done with one spectrum, which contains at least two photo peaks. It is important to emphasize that an energy calibration is only useful as long as nothing is changed during or between the measurements, which affects the amplification. Therefore, the gain must be exactly the same in the unknown spectrum as in the calibration spectrum.

The calibration can be stored together with the calibrated spectrum, and later be called from other spectra, which are to be calibrated and which have the same amplifier setting.

Before the programme can determine the constants of the calibration function, the positions of the two calibration peaks must be determined and their energies entered. As a measure of a peak position one can use for example the number of the channel, which contains the most pulses. A more accurate measure is obtained, if one instead uses the centre-of-mass of the peak. The computer code of GDM 10 uses this latter method.

The peaks are analysed one by one, and the routine for the calibration is the following:

1. Place the cross at the left edge of the peak. Then click on the left mouse button to define the lower marker. The upper marker is similarly placed at the right edge of the same peak by clicking on the right mouse button.

2. The command **`Calculate Centroid`**, which gives the channel position of the centre-of-mass of the peak (for a calibrated spectrum also the energy is obtained). The standard deviation is also given, as well as the FWHM(Full Width Half Maximum).
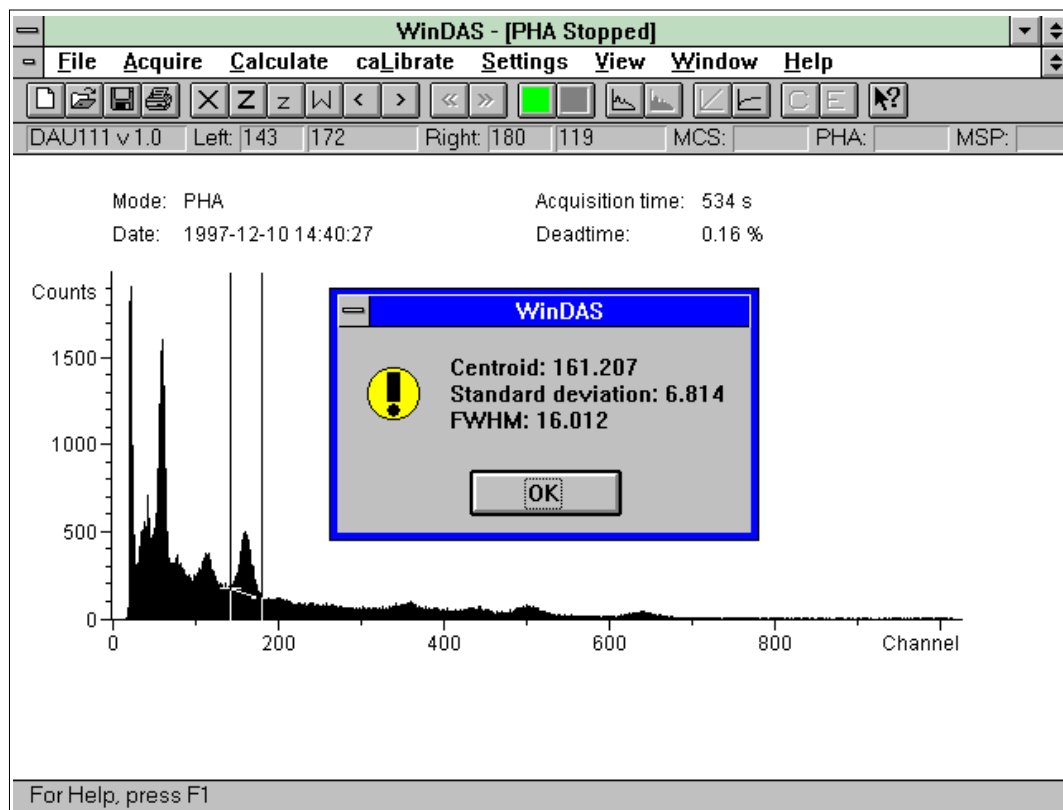
3. The peak's centre-of-mass is kept if you directly give the command **caLibrate Energy** after you have calculated the centroid. The peak is given its energy value (e.g. 0.662 MeV) by entering 0.662 after you have given the command **caLibrate Energy**. If you already now the peak's centre-of-mass you can give the command **caLibrate Energy** without calculate the centroid in advance. The default energy values should be given in MeV.

4. Repeat points 1, 2 and 3 above for the other calibration peak. When this is done, the spectrum is calibrated and the channel axis is automatically transformed to an energy axis.

5. If one is satisfied with the calibration, it can be stored together with the spectrum with the command **File Save** (if the spectrum was loaded from another storage unit than the floppy disc, don't forget to specify the desired destination unit). The command **File Save** saves the parameters of the calibration function together with the calibrated spectrum.

6. If one is not satisfied with the calibration (for example a mistake was done in the centroid determination), the commands **CEN** and **caLibrate Energy** can be repeated.

If a calibration has been done, and the constants have been saved together with a spectrum, one can assign the calibration constants to an uncalibrated spectrum using the command **caLibrate From file**.

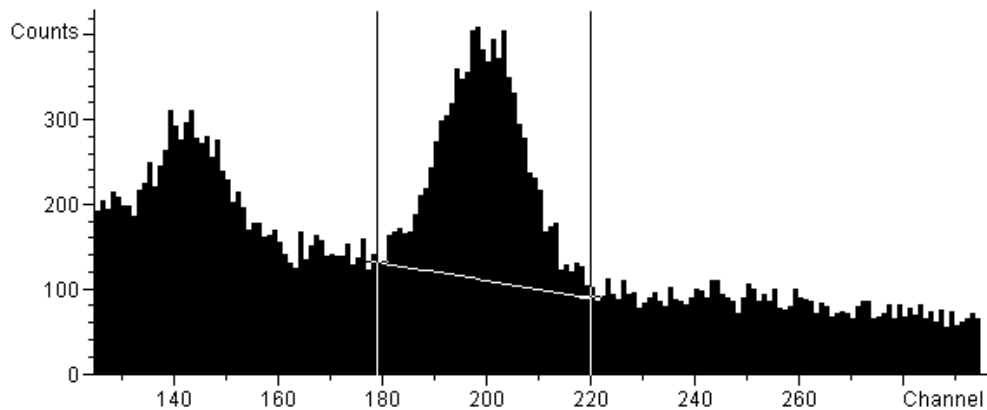Figure 5 shows an example of a photo peak on top of background radiation.

Figure 5.

If two spectra with one photo peak each are to be used for the energy calibration, one can first add the spectra with the command **File Add**, and then calibrate the summed spectrum, and finally store the calibration constants together with the summed spectrum under a new file name.

To make it easier to place the markers it may be necessary to amplify the spectrum, i.e. to change the scale of the y-axis. This is done with the command **View Fixed scale**. To return to automatic scaling, type **View Autoscale**.

7.1 Summary: Energy Calibration

Left Mouse button	Places the lower marker at the cross which is moved with the mouse.
Right Mouse button	Places the upper marker at the cross which is moved with the mouse.
Calculate Centroid	Determines the centroid position and the area above the background of a peak. In a calibrated spectrum one also obtains the energy. The peak is defined by placing markers to the left and to the right of the peak before the command **Calculate Centroid** is written.
caLibrate Energy	With the command **caLibrate Energy**, one assigns the peak position, determined by **Calculate Centroid**, to an energy value in MeV.
File Save	Saves the spectrum. If the spectrum is calibrated the spectrum is saved including energy calibration constants.
caLibrate From file	Calibration of a spectrum with the aid of an earlier calibration.
File Add	This command is used for adding two spectra.
View eXpand	Expands the region between the markers.
View Fixed scale	Gives a new scale on the intensity axis (y-axis).
View Autoscale	Gives an automatic scaling of the intensity axis (y-axis).

8 Efficiency Calibration

If the activity of an unknown sample is to be determined, one must be able to relate the measured count rate **P** to the gamma activity **A** of the sample. The ratio **P/A** is the efficiency of the detector. It depends on the energy of the gamma radiation. By measuring the count rate for samples with known activities containing several different gamma energies one can determine an efficiency curve for the detector. It is in general not a straight line and therefore several points are required for an accurate determination. Since the efficiency is dependent on the solid angle with which the detector sees the sample, it is important that the calibration source and the unknown samples are measured with the same geometry!

For example, a solution of ^{152}Eu has a 'gamma activity' of **A** Bq (becquerel) for the 0.244 MeV transition, i.e. the solution emits **A** gamma quanta per second with the energy 0.244 MeV. The solution is measured for the time t and the area of the corresponding photo peak is determined to be **Y** pulses. Then the efficiency of the detector (k_{eff}) at the energy 0.244 MeV becomes:

$$k_{eff} = \frac{Y}{A\,t}$$

The efficiencies for the other energies within the interesting region are determined similarly. The values of the efficiencies are drawn in a calibration diagram. An example of a calibration diagram based on a selection of gamma transitions in the decay of ^{152}Eu is shown in figure 6.
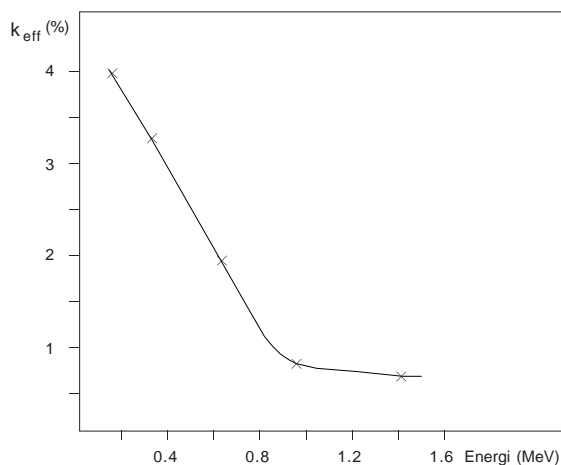

Figure 6.

The activity of an unknown sample can now be determined with the aid of this diagram, provided that the measurement is made with the same geometry. If the geometry is changed an error is introduced, the size of which depends on how different the geometry became. If the shape of the calibration source and the sample is different this will also effect the error.

If the area of a photo peak in an unknown sample is determined to be **C** pulses, and the measuring time was T seconds, the 'gamma activity' (**B**) for the corresponding gamma transition is:

$$B = \frac{C}{T\,k_{eff}}$$

where k_{eff} is the efficiency for the corresponding gamma energy, which can be read from the diagram.

The quantity 'gamma activity' used here is obtained from the activity, i.e. the number of decays per second, of the radioactive sample by multiplying the latter with a factor that gives the number of gamma-rays emitted per decay.

9 Small Vocabulary of Nuclear Physics

Radioactive decay and ionising radiation

Some nuclei (nuclides) spontaneously transform (decay) into new nuclei by emitting particles. The particle radiation can be alpha radiation (helium nuclei) or beta radiation (electrons). The decay can also occur by electron capture, where the K-electron of the mother nucleus together with a proton are transformed to a neutron. In radioactive decay the product nuclei often also emit electromagnetic radiation of very high frequency, gamma radiation.

Alpha radiation

In alpha decay, alpha particles are emitted, which are helium nuclei (2 protons and 2 neutrons). The daughter nucleus always gets two units of atomic number and 4 units of mass number less than the mother nucleus. Example:

$$ {}^{224}_{88}\text{Ra} \rightarrow {}^{220}_{86}\text{Rn} + {}^{4}_{2}\text{He} $$
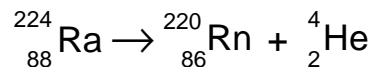
Beta radiation

Nuclei which have too many neutrons relative to the number of protons disintegrate by beta decay, i.e they emit beta particles. These β-particles are ordinary electrons. A neutron in the nucleus is transformed into a proton, and subsequently a β^--particle and an anti-neutrino are emitted.

Nuclei which have too many protons relative to the number of neutrons also disintegrate by beta decay, the corresponding particles however being positively charged electrons (β^+-particles, positrons). A proton in the nucleus is then transformed into a neutron and subsequently a β^+-particle and a neutrino are emitted.

Gamma radiation

After the emission of an α particle or a β particle the product nucleus may be left in an excited state. Excited nuclei decay to their ground state by emitting gamma radiation, which is electromagnetic radiation of extremely short wave length and thus high frequency.

Activity

With the activity of a radioactive source is meant the number of decays per unit time. The SI unit for activity is 1 Bq (1 becquerel). 1 becquerel = one decay per second. An older unit for activity is 1 Ci (1 curie). 1 Ci = 3.7 • 1010 Bq. Normally one means the activity of the source, i.e. the number of disintegrating nuclei per second, but for studies of gamma intensities one may also use the concept of 'gamma activity' to indicate that only a fraction of all disintegrations result in the decay of a certain gamma transition in the daughter nucleus (see figure 11).

Decay scheme

A decay scheme is an energy diagram of the decay. It normally includes notations of the **mother nucleus** (decaying nucleus), the **daughter nucleus** (resulting nucleus), type of decay, decay paths and their respective percentage distribution, **half life** and **energy levels** of the daughter nucleus, (see figure 11).
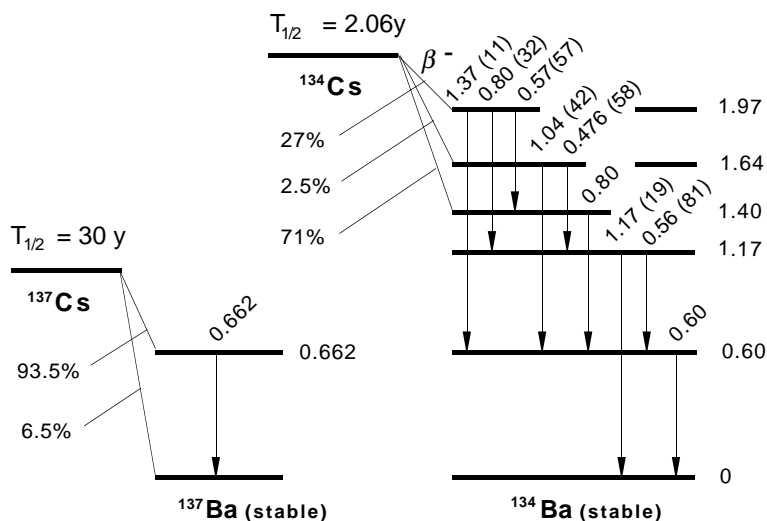

Figure 11.

Compton scattering

The collision between a gamma quantum and an electron is called Compton scattering. The scattering may be treated similarly to the collision between two bodies, for example billiard balls, which gives a relation between the energy and angle of the scattered gamma quantum (see figure 12 and the included equation).

$$E_{out} = \frac{E_{in}}{1 + \dfrac{E_{in}}{mc^2}\,(\,1 - \cos\Phi\,)}$$

Scattered gamma
quantum E_{out}

Φ

Incoming gamma quantum
with energy E_{in}

Recoiling
electron
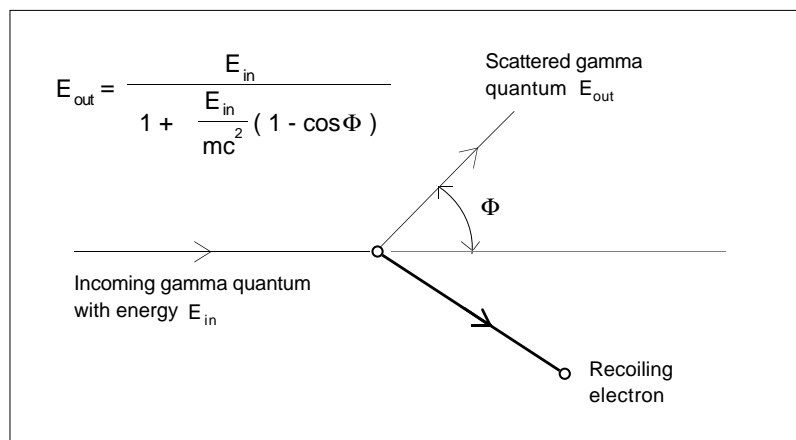
Figure 12.

According to the expression above it is realised that the gamma quantum loses maximum energy in the NaI crystal if it is scattered by 180°. The corresponding energy transferred to the crystal corresponds to the Compton edge in the gamma spectrum.

Excited level

In radioactive decay the nucleus may be left in another energy level than the ground state. These energy levels correspond to excited ('more energetic rich') levels of the daughter nucleus (see figure 11). Normally one or several gamma quanta are emitted to bring the daughter nucleus to its ground state. There is always a certain probability for emission of one of the electrons of the atom (conversion electron) instead of a gamma quantum. For excitation energies larger than 1.02 MeV a process where an electron-positron pair is formed is also possible (pair formation). The last two processes thus affect to what extent the decaying nuclei decay by gamma radiation, i.e. the gamma activity.

Internal conversion

Internal conversion resembles the photo-electric effect, since the nucleus gives off all of its excitation energy to an electron (conversion electron), which is emitted with the kinetic energy K_e, given by

$$K_e = E_g - I_b$$

where

I_b = the binding energy of the electron
E_g = the gamma-ray energy

Electron capture

Electron capture is a form of β-decay and implies that a proton in the nucleus is transformed into a neutron. In the process, primarily the K-electrons (those closest to the nucleus) are captured.The vacancy in the shell is filled by electrons from the outer electron shells, which results in characteristic X-rays of the daughter nucleus.

Half life

The half life is the time after which half the number of nuclei have decayed.

10 Collection of Some Typical Spectra with Associated Decay Schemes

Cesium-137 and Potassium-40

Figure 13 shows a spectrum with only ^{137}Cs, while figure 14 shows a source containing both ^{137}Cs and [40]K.
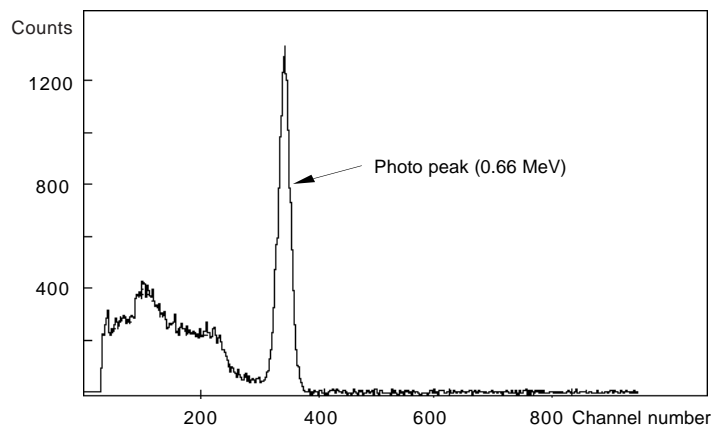
Figure 13. Spectrum from the cesium-137 decay.
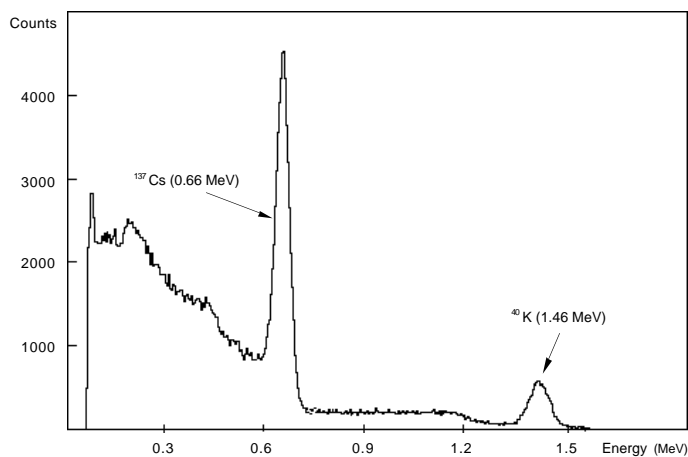
Figure 14. Gamma spectrum from a sample containing cesium-137 and potassium-40.

Figure 15 shows the corresponding decay scheme for ^{137}Cs and [40]K.
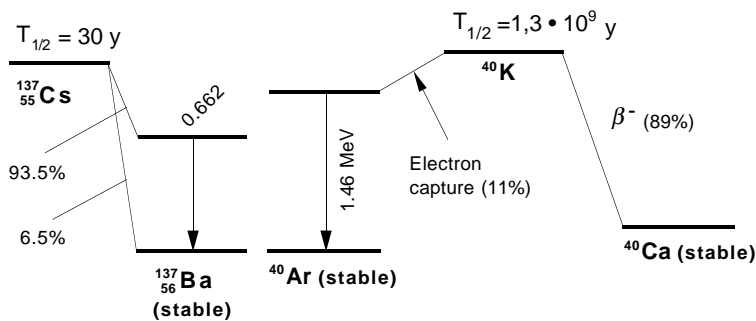
Figure 15.

Cesium-134 and Cesium-137

Samples containing the remains from the radioactive fallout from the Chernobyl accident give a typical gamma spectrum as illustrated in figure 16.
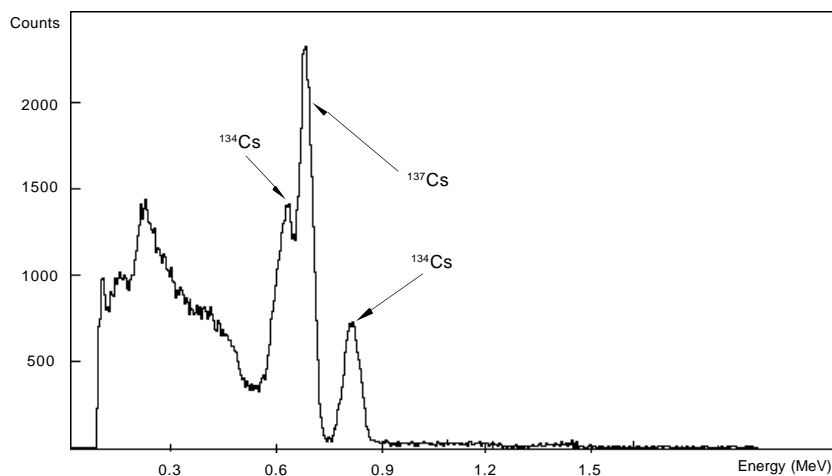
Figure 16. Gamma spectrum from a sample of meat. The spectrum was obtained in 1987.

For interpretation of the part of the gamma spectrum originating from the decay of ^{134}Cs, its decay scheme is given in figure 17. As can be seen from the spectrum the 0.60 and 0.80 MeV transitions dominate.
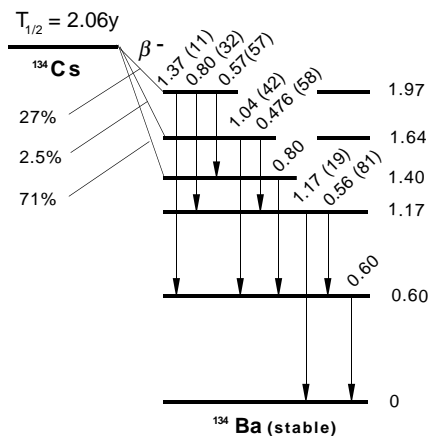
Figure 17.

The Uranium-238 decay series

If one collects radon daughters on a wire at voltage or takes an older wrist watch with luminous clock face, one obtains two gamma spectra which resemble each other as figures 18 and 19 show.
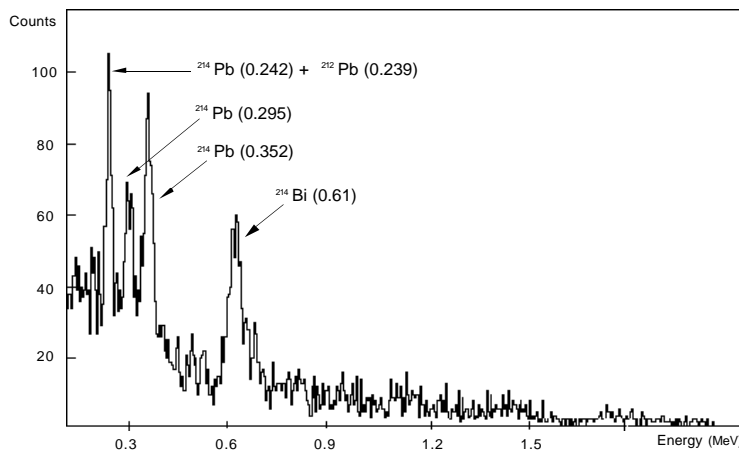
Figure 18. Gamma spectrum from collected radon daughters.
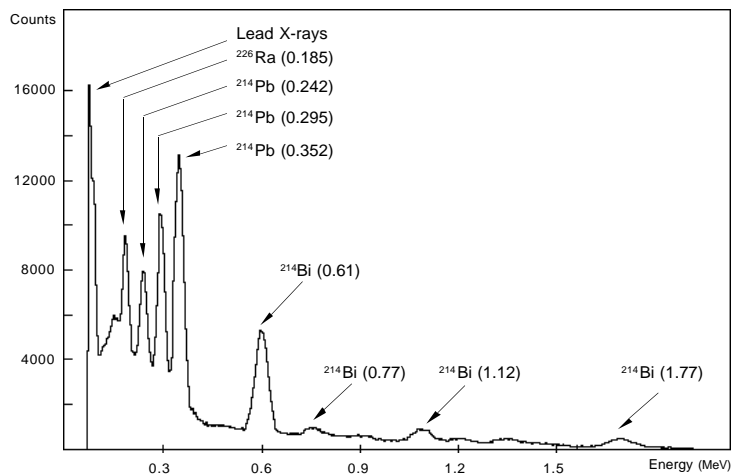
Figure 19. Gamma spectrum from wrist watch with luminous clock face.

As the wrist watch contains much higher activity one can discover many more details in its spectrum, which the partial magnification of figure 20 shows. A partial magnification can be obtained by choosing a different Y-scale. The most pronounced photo peaks are relatively easy to identify. It is more difficult with the weakest peaks, particularly if one suspects doublets or triplets, i.e. two or three gamma energies which overlap partially or completely in the spectrum. In the identification it can be of great help to compare the intensities of the peaks.
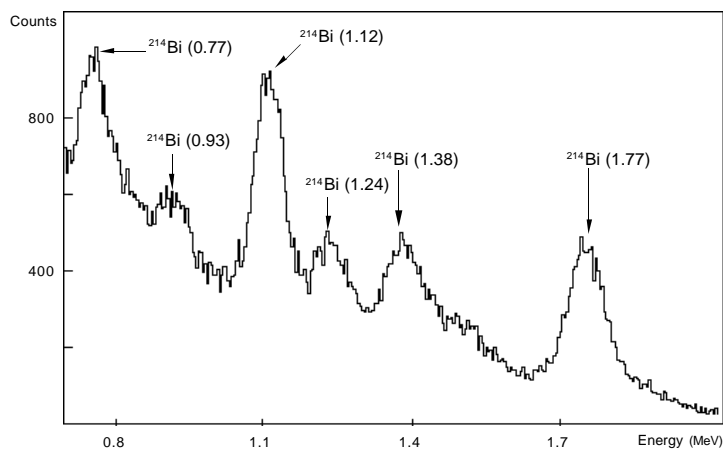
Figure 20. Partial magnification of the gamma spectrum from a wrist watch.

The spectra in figures 18 to 20 are explained with the help of the decay chain of ^{238}U, which is shown in figure 21 starting from ^{234}U.

Figure 21.

The Thorium-232 decay series

An example from the decay chain of ^{232}Th is given in figure 22, which shows a gamma spectrum from the gas mantle of a kerosene lamp.
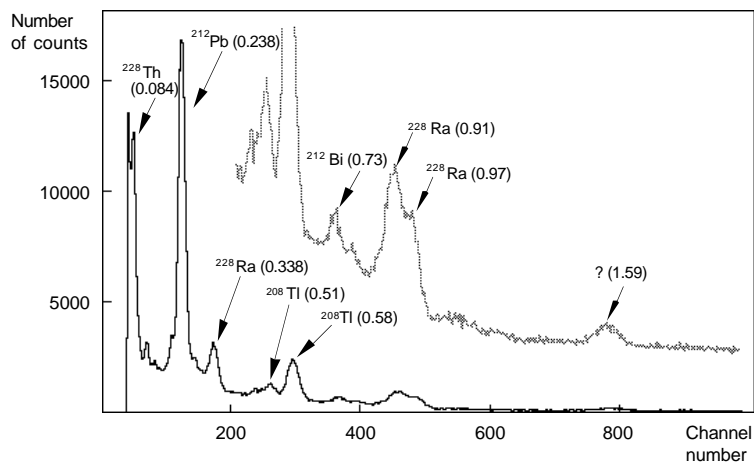

Figure 22. Gamma spectrum from the gas mantle of a kerosene lamp.

The spectrum in figure 22 can be identified with the help of the decay chain of ²³²Th shown in figure 23.
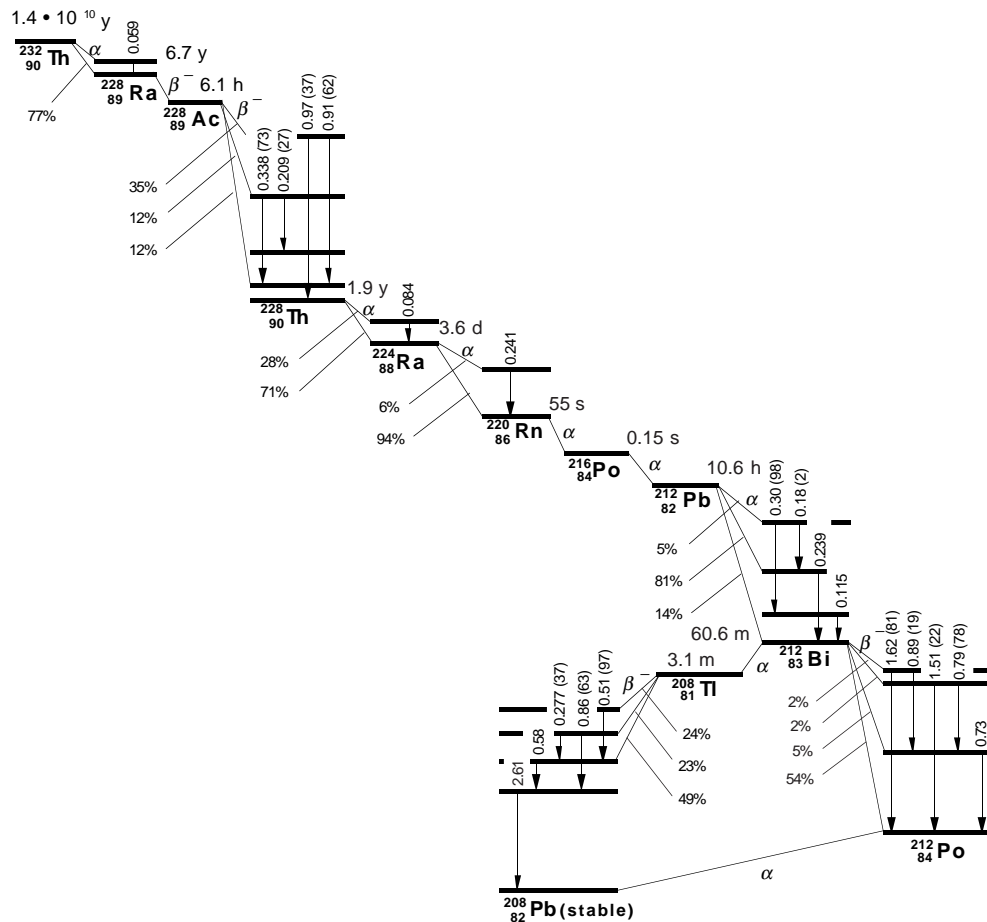
Figure 23.

Rock samples

Many schools have samples of rocks containing different radioactive isotopes. These rocks can contain relatively high concentrations of radioactive isotopes, which make possible short measuring times. Usually longer measuring times are needed in order to obtain good statistics. Figures 24 and 25 show two spectra from two pieces of rock, whose isotopes can be identified with the two given decay chains.
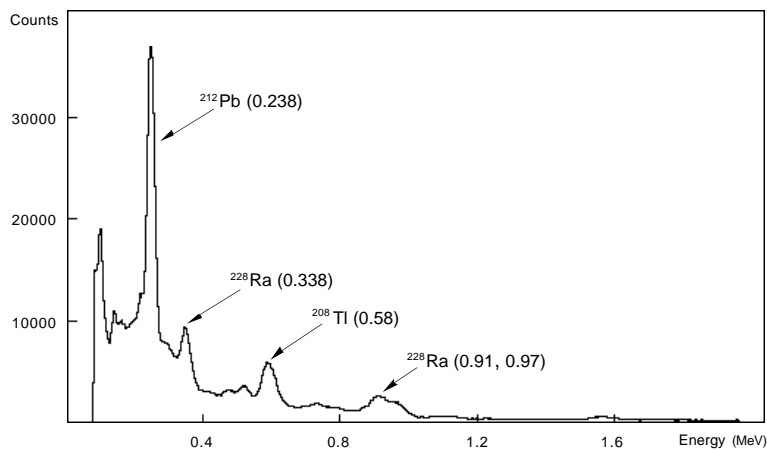
Figure 24. Gamma spectrum from rock sample (Allanite).
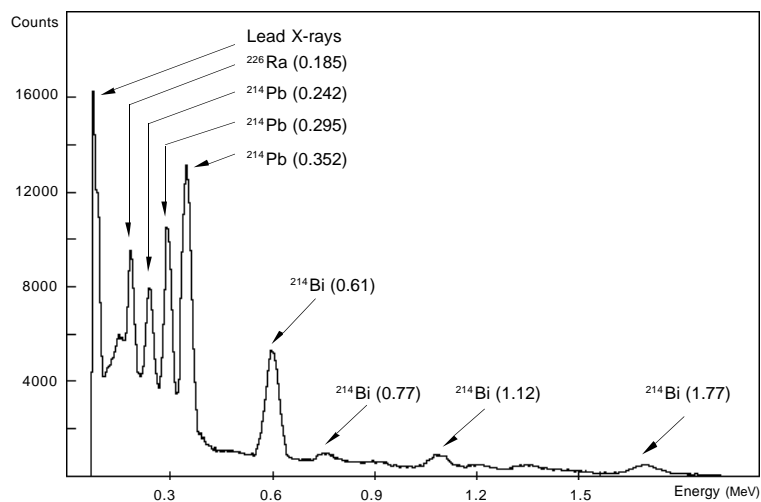
Figure 25. Gamma spectrum from a rock sample (Metatorbenite).

Europium-152

^{152}Eu is a frequently used calibration source, and its gamma spectrum is shown in figure 26. The decay scheme of ^{152}Eu is rather complicated, but the parts that are of interest for the interpretation of the spectrum are shown in figure 27. Those who wish to study the decay scheme in more detail are advised to use the 'Table of Isotopes'.
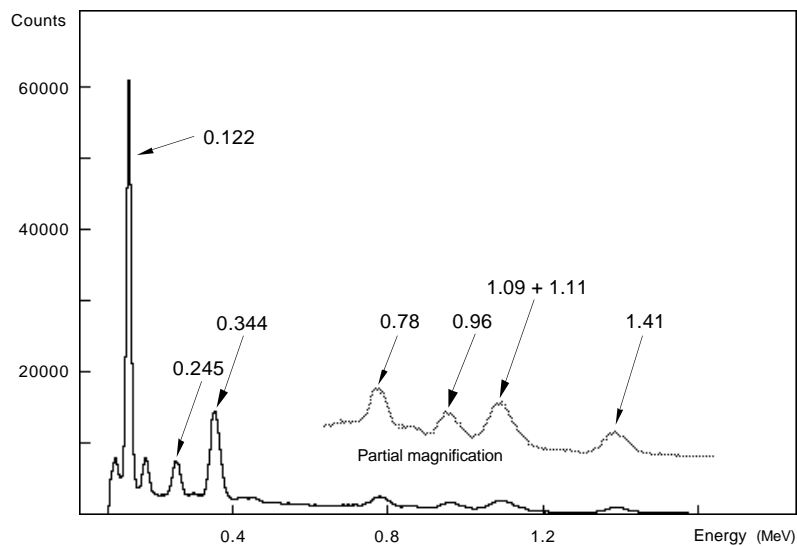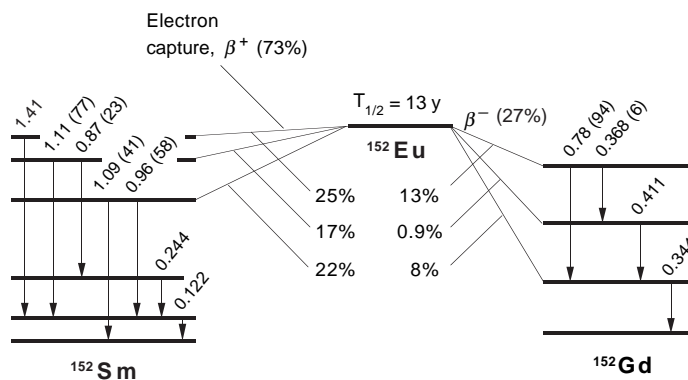

Figure 26. 152Eu spectrum.

Figure 27.

Cobolt-60

A common source for energy calibration is ^{60}Co. Figure 28 shows a spectrum of ^{60}Co and figure 29 shows selected parts of its decay scheme.

Figure 28. 60Co spectrum.
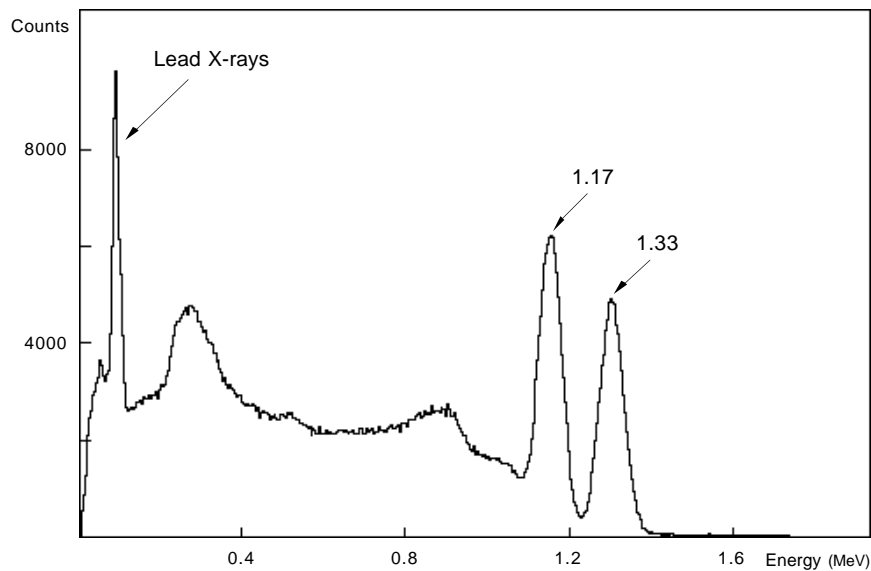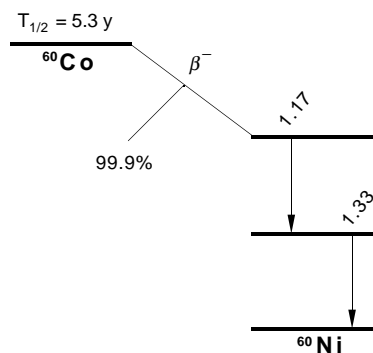
Figure 29.