ARH-ST-114-1
UC-4, UC-37

GAMMA,
X-RAY
DATA
REDUCTION
SYSTEM

VOLUME 1: GAMMA

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December 1974

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ABSTRACT

The Gamma, X-Ray, Data Reduction (GXDR) system performs automatic gamma energy analysis data reductions including the calculation of

- *Activity with or without time correction.*
- *Activation analysis.*
- *Precision.*
- *Limits of detection.*
- *Peak interference correction.*
- *Sorption correction.*
- *Random summing correction.*

Reports are assembled on magnetic tape. All of this is done quickly by the GXDR with 8K x 2¹⁶ computer core, 8K x 2²⁴ hard-wired core, and two cassette magnetic tape systems.

GAMMA, X-RAY DATA REDUCTION SYSTEM
VOLUME 1: GAMMA

INTRODUCTION

There is an ever-increasing number of samples to be analyzed, more and more corrections which can be applied to make the data more accurate, and less money and manpower to do the job.

The Gamma, X-Ray Data Reduction (GXDR) system (Figure 1) is an attempt to meet both the problems and the opportunities being imposed on the radioactive emission analysis facilities of Atlantic Richfield Hanford Company. While most of the detector systems are still in controlled counting rooms, many are being taken into the field or being installed in-line in effluent monitoring systems, production lines, and fissile scrap recovery facilities. The small dedicated computer is a great help in collecting and reducing these diverse data but the programming capability and money do not exist to equip every single pulse height analyzer with this capability. Even if this possibility existed, the informed manpower is not available to operate this computer. Should a better technique be developed, how is it to be implemented in 20 systems that are not linked in time, capacity, or capability?

CONCEPT

The basic concept of the GXDR system is to extend to all semiconductor detector users the accuracy, time, and labor-saving available through the use of modern automation techniques. Control of the detectors and their calibrations,

FIGURE 1

THE UNITS AT THE RIGHT AND AT THE LEFT ARE THE NS660 GAMMA DATA REDUCTION UNITS. THE NS880 X-RAY REDUCTION UNIT IS IN THE CENTER. THE TI733ASR TERMINALS ARE IN THE FOREGROUND. THE RIGHT TI733ASR SERVICES BOTH THE RIGHT NS660 AND THE NS880

control of the data acquisition equipment and the priority and timing of its use would be left in the hands of the user. After all, he and his management know best what has to be done, how quickly and how accurately it has to be done. Data reduction is performed on the GXDR system. The gamma data reduction units in GXDR are incapable of normal acquisition and are fully devoted to data reduction. In this way each unit can perform data reduction for up to 15 acquisition systems and neither type system need be purchased at the price of a stand-alone unit. The GXDR is purchased without detector amplifier, analog to digital convertor, timer, or multiplexer. The acquisition unit is purchased without computer, programming, printer, terminal and interface, point plotter, etc.

The satellite analyzer consists of a minimum-priced pulse height analyzer interfaced to a Tracor Northern NS-111 magnetic tape cassette deck. The gamma data reduction unit consists of a Tracor Northern NS-111A magnetic tape cassette deck to receive the spectral data, an NS-660 with 8K hard-wired memory for spectral data storage, and an 8K Nova 1200 computer for data reduction. The terminal is a Texas Instruments TI733ASR with dual cassettes, automatic search option, and remote device control option. The file of calibration tables and the output reports are stored on TI tapes. Calibration tables are searched for by name and entered into the computer by a simple command. Report segments are searched for by the customer's proper name, assembled, and automatically typed.

Since the gamma data reduction unit(s) is centrally located, only one all-inclusive program needs to be considered rather than a multiplicity in the case of independent analyzer systems. The program is not static. As

innovations are conceived and programmed they are implemented in the GXDR system. All programming has been performed by R. N. Erickson of Tracor Northern, Inc., to the author's specifications. The program is available from Tracor Northern under the name "NS660/Nova--ARIS II-AB"; and the version number, which at the time of this writing is "3D".

CAPABILITIES

Spectral data are received on cassette magnetic tape together with a log sheet (Figure 2). The log sheet contains the following information from the person who acquired the data.

- Tape number and detector system code.
- Customer name or code.
- Time of count (time of start of acquisition).
- Counting geometry; which includes the standard mount designation, the distance from the detector, and, if necessary, the coincidence status.
- Units in which the output is to be reported.
- Minimum (poorest) precision permitted for individual output analyses and whether or not the limits of detection are desired.
- Milliliters or grams of sample.
- Acquisition time in seconds.
- Time zero if the output is to be corrected for half-life.
- Magnetic tape cassette position.

Tape No.: 314

Time Count (days)	Geo.	*	Units	Limits	ml or g	Check Sum*	Acq. Time (seconds)	Time Zero (days)	GCF*
11026 341	700:1	15	mc/l	30X	1	0002Y701	3000	—	1.034
11049 0 ***	102-S-1 #47 100 ml Dresden								
11026 369	700:1	15	mc/l	30X	1	0002Y701	2000	—	1.034
11049 16 ***	RE-1 #53 100 ml Dresden								
11026 400	700:1	15	mc/l	30X	1	0002Y701	3000	—	1.034
11049 32 ***	ENDO IV #3 100 ml Dresden								
11027 414	700:1	15	mc/l	30X	1	0002Y701	2000	—	1.034
11049 48 ***	2301 RC-3 700 ml Thomas								
11034 360	700:1	15	mc/l	30X	1	0002Y701	3000	—	1.028
11049 64 ***	ENDO III #10 100 ml Dresden								
11034 423	700:1	15	mc/l	30X	1	0002Y701	3000	—	1.028
11049 80 ***	SS-1 #38 100 ml Dresden								
11034 540	700:1	15	mc/l	30X	1	0002Y701	3000	—	1.028
11049 96 ***	SS-1 #34 100 ml Dresden								
11035 455	700:1	15	mc/l	30X	1	0002Y701	3000	—	1.028
11049 112 ***	SS-1 #39 100 ml Dresden								

FIGURE 2

SAMPLE LOG SHEET

THE 11049 IN THE LEFT MARGIN IS THE HANFORD DATE THE DATA WERE REDUCED.
THE VALUE IN FRONT OF THE *** IS THE BEGINNING MAGNETIC TAPE POSITION.

- Sample identification.

The "time of count" and the detector system code will constitute the serial number for a particular analysis from acquisition through report. The detector system code appears in the instruction line as the letter in the CHECKSUM.

The GXDR system operator reads the spectral data from the cassette magnetic tape to the NS660, time 85 seconds for 4096 channels of data. The operator initiates a data reduction cycle, types in the customer's proper name, an unlimited amount of sample identification, and one typed line of instruction composed from the log sheet (Figure 2) in an average of 30 seconds if no change is made in calibration tables. Checks are automatically made during entry of the instruction line to assure that the appropriate calibration tables are in core and that the acquisition time matches that of the data spectrum. The computer reduces the data, types and tapes the report in an average of 30 seconds. The typed copy is the worksheet copy (Figure 3) kept on file for reference and calculation inquiries. It will contain all the file entry notations in addition to the report. The report is typed from magnetic tape, off line and automatically (Figure 4).

Because the 85 seconds required to enter a 4096 channel spectrum are largely unattended, one operator is able to perform data reductions on two gamma data reduction systems with little loss in time. No secretarial time is used or required.

Following is a list of the current data reduction capabilities of the gamma portion of the GXDR system. Each entry will be described in detail in the following pages.

RSSY701

```

RAM24101113 123 +.3009995E+03 +.1580080E+11 EU155 169 176 +.1444000E+03
1812000E+04 CD 57 240 248 +.4411998E+02 +.2697995E+03 CE144 263 270 +.
0000E+03 +.2848997E+03 U 235 367 375 +.9277797E+02 +.2590000E+12 CE141
287 294 +.8550997E+02 +.3245000E+02 CE139 328 336 +.5710698E+02 +.13720
+03 RA226 700 708 +.2748196E+03 +.5840000E+06 PU239 823 831 +.7580000E
+.8902000E+07 SB125 851 860 +.4055996E+03 +.1012000E+04 RU103 992 9
+.1553699E+03 +.3959997E+02 TH228 1161 1171 +.4867998E+03 +.6975996E+03
H106 1240 1248 +.2160500E+04 +.3710000E+03 CS137 1319 1325 +.2212800E+03 +
04100E+05 ZR 95 1510 1516 +.3987995E+03 +.6550000E+02 NB 95 1528 1536 +.22
99E+03 +.6550000E+02 ZR 95 1444 1455 +.4614800E+03 +.6550000E+02 EU154 2
6 2555 +.1000000E+04 +.5843996E+04 CS134 1589 1595 +.2639997E+03 +.7560000
3 CD 60 2661 2669 +.3900000E+03 +.1924080E+04 EU152 2809 2819 +.1681000E+0
+.4821000E+04 CD 60 2340 2349 +.3420000E+03 +.1924080E+04 CD 58 1615 1626
.2691997E+03 +.7129997E+02 K 40 2916 2927 +.4037000E+04 +.4671998E+

```

Y 4096 16

QTY

GCF=1.034 IX IL 5 20

RS=9

PEAK MODS--PK0BK0K0

0 0 0

0 0 0

0 0 0

INTEGRATION LIMITS 4050 4095

Y 0 16

DRESSEN

102-S-1 #47 100 ML

11026.341 15 30X 1 0002Y701 3000

<+.23E-02	UCI AM241/L	<+.12E-02	UCI EU155/L
<+.38E-03	UCI CD 57/L	<+.32E-02	UCI CE144/L
<+.77E-03	UCI U 235/L	<+.73E-03	UCI CE141/L
<+.44E-03	UCI CE139/L	<+.16E-02	UCI RA226/L
<+.42E+02	UCI PU239/L	<+.22E-02	UCI SB125/L
<+.74E-03	UCI RU103/L	<+.22E-02	UCI TH228/L
<+.95E-02	UCI RH106/L	+ .1131E-01	UCI CS137/L +.82E+01%
<+.15E-02	UCI ZR 95/L	<+.86E-03	UCI NB 95/L
<+.18E-02	UCI ZR 95/L	<+.38E-02	UCI EU154/L
<+.10E-02	UCI CS134/L	<+.15E-02	UCI CD 60/L
<+.65E-02	UCI EU152/L	<+.13E-02	UCI CD 60/L
D+.10E-02	UCI CD 58/L	<+.16E-01	UCI K 40/L

&NDFDTMRK

FIGURE 3

SAMPLE WORK SHEET

THE FIRST BLOCK, "RSSY701", IS THE SEARCH REQUEST FOR
 QI TABLE 701 FOLLOWED BY THE QHI ENTRY OF IT TO THE
 COMPUTER. "Y 4096 16" IS THE ENTRY OF A BACKGROUND
 SPECTRUM. "QTY" IS THE LEADING ENTRY FOR INPUT OF A
 QI TABLE NAMED Y. "Y 0 16" IS THE ENTRY OF A DATA SPECTRUM.
 THE NEXT BLOCK IS THE SAMPLE DATA REDUCTION.

TO: A.L.DRESSEN
FROM: V.W.HALL

DEC.26,1974

SS-1 #24 100ML

11025.404 15 30 1 0002Y701 3000

+ .3234E-01 UCI SB125/L $\pm .81E+01\%$

+ .1675E-01 UCI CS137/L $\pm .74E+01\%$

SS-1 #25 100ML

11025.455 15 30 1 0002Y701 3000

+ .3447E-01 UCI SB125/L $\pm .77E+01\%$

+ .1429E-01 UCI CS137/L $\pm .81E+01\%$

102-S-1 #47 100ML

11026.341 15 30X 1 0002Y701 3000

<+.23E-02 UCI AM241/L

<+.12E-02 UCI EU155/L

<+.38E-03 UCI CD 57/L

<+.32E-02 UCI CE144/L

<+.77E-03 UCI U 235/L

<+.73E-03 UCI CE141/L

<+.44E-03 UCI CE139/L

<+.16E-02 UCI RA226/L

<+.42E+02 UCI PU239/L

<+.22E-02 UCI SB125/L

<+.74E-03 UCI RU103/L

<+.22E-02 UCI TH228/L

<+.95E-02 UCI RH106/L

+ .1131E-01 UCI CS137/L $\pm .82E+01\%$

<+.15E-02 UCI ZR 95/L

<+.86E-03 UCI NB 95/L

<+.18E-02 UCI ZR 95/L

<+.38E-02 UCI EU154/L

<+.10E-02 UCI CS134/L

<+.15E-02 UCI CD 60/L

<+.65E-02 UCI EU152/L

<+.13E-02 UCI CD 60/L

<+.10E-02 UCI CD 58/L

<+.16E-01 UCI K 40/L

SE-1 #53 100ML

11026.369 15 30X 1 0002Y701 2000

<+.18E-01 UCI AM241/L

<+.91E-02 UCI EU155/L

<+.25E-02 UCI CD 57/L

<+.20E-01 UCI CE144/L

<+.41E-02 UCI U 235/L

<+.43E-02 UCI CE141/L

<+.26E-02 UCI CE139/L

<+.71E-02 UCI RA226/L

<+.19E+03 UCI PU239/L

+ .4316E-01 UCI SB125/L $\pm .11E+02\%$

<+.31E-02 UCI RU103/L

<+.65E-02 UCI TH228/L

<+.28E-01 UCI RH106/L

+ .3110E+00 UCI CS137/L $\pm .19E+01\%$

<+.27E-02 UCI ZR 95/L

<+.15E-02 UCI NB 95/L

<+.32E-02 UCI ZR 95/L

<+.58E-02 UCI EU154/L

<+.18E-02 UCI CS134/L

<+.22E-02 UCI CD 60/L

<+.97E-02 UCI EU152/L

<+.20E-02 UCI CD 60/L

<+.18E-02 UCI CD 58/L

<+.23E-01 UCI K 40/L

FIGURE 4

SAMPLE REPORT

NOTE THAT THE ENTRY LABELED "102-S-1 #47 100 ml" IS THE SAME DATA REDUCTION ILLUSTRATED IN FIGURE 3 AND IN MANY LOCATIONS THROUGHOUT THE PAPER.

This will be followed by a description of the entries provided for the system.

DETERMINATION OF NET PEAK AREA
SEARCH FOR PEAKS--QI
ACTIVITY WITHOUT TIME CORRECTION
ACTIVITY WITH TIME CORRECTION
ACTIVATION ANALYSIS RESULTS
PRECISION CALCULATION
THROWOUT LIMITS AND LIMITS OF DETECTION
BACKGROUND SUBTRACTION
RANDOM SUMMING CORRECTION--QT
 Total Count Integration Mode
 Pulser Mode
 Isotopic Mode
DETECTOR RECOVERY FACTOR--QT
PEAK INTERFERENCE CORRECTION--QT
SECOND-ORDER ACTIVATION ANALYSIS INTERFERENCE
 CORRECTION--QT
GEOMETRY FUNCTION--QG
EXTERNAL SORBER CORRECTION--QG
INTERNAL SORBER CORRECTION--QG
NEUTRON FLUX DENSITY--QG
UNITS MANIPULATION--QG
ERROR CHECKSUM AND ERROR TIME
QT CALIBRATION TABLE ENTRY
QG CALIBRATION TABLE SEARCH AND ENTRY
QI CALIBRATION TABLE SEARCH AND ENTRY
LINE EDITOR
ITEM EDITOR
REPORT FORMAT AND SEARCH
BREMSSTRAHLUNG ANALYSIS
CALIBRATION
MISCELLANEOUS PROGRAM COMMANDS

The GXDR system is a linear descendant of the Automatic Radioactive Inventory System^[1] to which it is hardware- and software-compatible (with an exchange of terminals). The basic method use to define a peak and to calculate its net area were described in 1971^[2] as performed interactively on the Nuclear Data 50/50. Some of the subsequent improvements in calculation and correction techniques and comparisons with other U. S. Atomic Energy Commission (now Energy Research and Development Administration) laboratories were

presented at the 1973 Winter Meeting of the American Nuclear Society.^[3] Since then numerous improvements have been made and are aired for the first time in this presentation under the specific headings of their application.

DETERMINATION OF NET PEAK AREA

Instructions

None.

Control Entry^[1,2]

(QT) Y

GCF = 1.001@ (IX IL 5@20@)

Calculation

Net area counts/second =

$$\frac{[\Sigma (IP-IX) \text{ through } (IP+IX) - (IL_1 + IL_2)] \times 0.5 \times (2IX+1)}{BD \times \text{time of acquisition}}$$

IP, the midpoint of a peak, is defined as the channel with the highest count content between two designated channel addresses from the isotope table (QI). It is also required to have channels with lower contents on both sides of it as a discouragement to the calculation of unresolved doublets and slopes as true peaks.

IX is the integer number of whole channels on either side of IP--the contents of which are to be summed for the gross count area of a peak. Normally this value is set at 5 or the whole number of channels equal to the Full Width at Half Maximum (FWHM) resolution of the reference peak, whichever is greater.

IL is defined as the limit of search for the noise continuum level on either side of IP and measured from IP. It is an integer number of channels equal to or greater than

IX. To determine the noise continuum level, a search is made between IP and the IL channels for the group of three consecutive channels with the lowest count content--the search to be conducted in increments of one channel. The average of these six channel contents times $2IX + 1$ equals the noise continuum contribution. Normally IL is set at four times IX.

BD--see Random Summing Correction.

NOTE: @ = SPACE CHARACTER.

With the employment of "normal" IX and IL values, the net peak area will always contain more than the peak area above the full width tenth maximum height. This means that the ratio of the net peak area determined to true net peak area will be a variable with energy, a constant at a particular energy, and always greater than 96%.^[1]

The highest channel content between designated Peak Search addresses will be identified as IP, whether or not there is a peak associated or if the actual peak maximum is located within those bounds. Non-peaks will be thrown out by the Precision Calculation or through the lack of channels with lower contents on both sides of IP.

Checks

QRC will list the channel address of the IP values and their associated net peak areas for the QI search addresses used in the most recent calculation of activity or PPM.

QRC lists the components of net peak area for the calculation of Bremsstrahlung and the resulting net area.

SEARCH FOR PEAKS--QIInstructions

11019.534@15@30X@1@0002 (Y701) @3000@@

Control Entries

QI

(Y701)

AM241	(113 123)	+.3009997E+03	+.1580080E+11
EU155	(169 176)	+.1444000E+C3	+.1812000E+04
CO 57	(240 248)	+.4411999E+02	+.2697998E+03

etc., for a maximum of 30 entries.

The "Y701" identifies the entry as an isotope (QI) table. Table names are assigned as one alpha character and three numeric characters for the QI Tables and all numeric characters for geometry (QG) tables.

The program searches the channel address limits, in the order listed, for the highest channel content. This value is designated as the midpoint of a peak, IP, from the Determination of Net Peak Area. Non-peaks will be thrown out by the Precision Calculation. Channel contents designated IP but not the true maximum for a peak will not be calculated; therefore it is essential that the search limits be wide enough to encompass the true peak center and that the energy calibration of the recording pulse height analyzer be consistent. Search limits which encompass two or more peaks will still choose the high channel content as IP. IP is also required to have channels with lower contents on both sides of it as a discouragement to the calculation of unresolved doublets and slopes as true peaks. Values that fail this requirement are not calculated for activity but are eligible for calculation as a Limit of Detection. Only

those areas chosen will be searched. Zero to 30 peaks may be chosen for any given isotopic emitter. The keyboard command, QRC, will read back the IP values assigned. This attribute can be useful with unusual spectra if a QI Table(s) is prepared in advance to "quarter" a spectrum.

The search for peaks is conducted immediately after the background strip, if any.

Checks

QRA will list the QI isotope table in core for a detailed tabulation of channel address limits.

QRC will list the channel address of the IP values and their associated net peak areas for the QI search address used in the most recent calculation of activity or PPM.

ACTIVITY WITHOUT TIME CORRECTION

Instructions

((CNTRL)X)

DRESSEN (CR) (LF)

Sample identification ((CNTRL)A)

(11026.341@15@30X@1@0002Y701@3000@@)

Control Entries

QT controls the GCF, "Geometry Correction Factor" or recovery factor
 the IX and IL factors used in determining Net Peak Area
 the mode and constants for Random Summing Correction
 and the correction for Peak Interference.

QG contains the GU Table, Geometry/ μ Sorption
 This table contains a sequence of 13 fixed channels, an energy scale.

corresponding to these entries are either geometry factors or sorption factors. Interpretation is based on the IP value for each peak of interest in the Determination of Net Peak Area. Interpolation is a linear function between the two bracketed energy points. Application is directed by the tens digit in the "Application Directive".

and the Geometry Table

The "Geometry" Table is called by the units digit in the "Application Directive" and it supplies the units of activity for the report; i.e. UCI /ML. It also supplies the "Unifying Factor", UF, which normalizes the disintegrations per second activity into whatever units are to be reported. See Units Manipulation for details.

QI contains the isotope name

the channel address limits

the BN factor, a variable numerator or multiplying factor equalling $\text{eff}^{-1}/\gamma/d$,
the half-life in days.

(CNTRL)X

initiates the calculation of activity and turns on whichever TI733 cassette is in "Record Mode".

(CNTRL)A

terminates the sample identification input.

11026.341

is the Time of Count in decimal digits which also serves as a serial number when combined with the detector identifying alpha character, "Y", in the CHECKSUM.

15

is the "Application Directive" for the Geometry (QG) Table, two decimal digits.

<u>Tens Digit</u>	<u>"GU" Table</u>	<u>"WV"</u>
1	Substitute .1 for contents	$\cdot (WV)^{-1}$
2	$\cdot GU$	$\cdot (WV)^{-1}$
3	μx in $\cdot e^{\mu x}$	$\cdot (WV)^{-1}$
4	μ in $\cdot \frac{\mu x}{1-e^{-\mu x}}$	x in same
5	g^{-1} from GU Table $\cdot (WV) =$	$\cdot (WV)^{-1}$
	μx in $\frac{\mu x}{1-e^{-\mu x}}$	

that is, the tens digit of one, as in the example (15), substitutes .1 for the contents of the "GU" table and applies the "WV" factor as a dividing factor in the calculation of activity. If the tens digit had been 4, the "GU" table would be interpreted as the factor, μ , and the "WV" as the factor, x , in the expression, $\frac{\mu x}{1-e^{-\mu x}}$. This factor(s) is applied as the multiplying factor, GEO, in the calculation of activity.

UNITS DIGIT The units digit supplies the units of activity for the report; i.e., UCI /ML. It also supplies the "Unifying Factor" UF, which normalizes the disintegrations per second activity into whatever units are to be reported; i.e., 37000 for UCI. See Units Manipulation for details.

30 is the Throwout Limit in units of 20 precision, an integer value. All net peak areas having precisions less than this value are calculated and reported. All net peak areas having precisions greater than this value are not calculated.

X is the control entry for the Calculation of Limits of Detection for net peaks having precisions greater than the Throwout Limit. Activity calculations are not affected.

1 is the "WV" factor whose application is directed by the "application directive", 15 in this example.

0002 is the name of the QG, geometry, Table to be used.

Y701 is the name of the QI, isotope, Table to be used.

Y is also the name of the detector and the QT Table.

0002Y701 Together, these entries form a Checksum which must match the table names in core or the program will interrupt with the message: ERROR CHECKSUM.

3000 is Acquisition Time in seconds. If this entry does not correspond to the contents of channel zero in the data spectrum, the program will interrupt with the message: ERROR TIME.

@ The last space aborts the Time Zero entry so that activity is calculated at the Time of Count.

Calculation

$$\text{Activity} = \frac{\text{Net Area} \cdot \text{BN} \cdot \text{GEO}}{\text{UF}}$$

where

Net Area = net area in counts/second from Determination of Net Area.

BN = $\text{Eff}^{-1}/\gamma/d$, the multiplier factor from the QI Table.

GEO = the multiplier factor from the tens digit of the "application directive" - QG Table.

UF = the dividing factor from the units digit of the "applications directive" - QG Table.

As many activities will be calculated as there are peaks called for in the QI, isotope, Table and which have a precision less than the Throwout Limit.

Checks

QRA will list the QI Table in core and its name (see Figures 5 and 6).

QRC will list the channel address of the IP values and their associated net peak areas for the QI search addresses used in the most recent calculation of activity or PPM.

QRD will list the most recently calculated precisions or confidence levels for all IP values.

QRE will list the Geometry Table from the QG Table.

QRF will list the factor entries of the "GU" Table from the QG Table and the name of the QG Table (see Figure 7).

ERROR CHECKSUM will be the automatic output during entry of the instruction line if the names of the QG, QI, and QT Tables in computer core do not match the CHECKSUM entry.

ERROR TIME will be the automatic output during entry of the instruction line if the Acquisition Time entry does not correspond to the contents of channel zero in the data spectrum.

O@R@O@ will list the present contents of channel zero in the data spectrum.

ACTIVITY WITH TIME CORRECTION

Instructions

((CNTRL)X)

JONES (CR) (LF)

Sample identification ((CNTRL)A)

11020.611@46@10@7.050@0000R500@1000@10000@

QRA ISOTOPE TABLE

Y701

AM241	113	123	+.3009992E+03	+.1580030E+11
EU155	169	176	+.1444000E+03	+.1312000E+04
CO 57	240	248	+.4411998E+02	+.2697993E+03
CE144	263	270	+.3700000E+03	+.2848997E+03
U 235	367	375	+.9277795E+02	+.2590000E+12
CE141	287	294	+.3550996E+02	+.3245000E+02
CE139	328	336	+.5710698E+02	+.1372000E+03
RA226	700	708	+.2748196E+03	+.5340000E+06
PU239	823	831	+.7580000E+07	+.3902000E+07
SB125	851	860	+.4055994E+03	+.1012000E+04
RJ103	992	996	+.1553699E+03	+.3959996E+02
TH228	1161	1171	+.4867998E+03	+.6975994E+03
RH106	1240	1248	+.2160500E+04	+.3710000E+03
CS137	1319	1325	+.2212800E+03	+.1104100E+05
ZR 95	1510	1516	+.3987993E+03	+.6350000E+02
NB 95	1528	1536	+.2226999E+03	+.6350000E+02
ZR 95	1444	1455	+.4614800E+03	+.6350000E+02
EU154	2546	2555	+.1000000E+04	+.5843992E+04
CS134	1589	1595	+.2639995E+03	+.7560000E+03
CO 60	2661	2669	+.3900000E+03	+.1924030E+04
EU152	2809	2819	+.1681000E+04	+.4821000E+04
CO 60	2340	2349	+.3420000E+03	+.1924080E+04
CO 58	1615	1626	+.2691994E+03	+.7129995E+02
K 40	2916	2927	+.4037000E+04	+.4671998E+12

FIGURE 5

QI TABLE Y701

AS READ BACK FROM THE COMPUTER USING ROUTINE QRA.

DATA ARE ENTERED ON EACH LINE IN THE SEQUENCE:

ISOTOPE NAME, LIMITS OF SEARCH IN CHANNELS,

BN MULTIPLIER, AND HALF-LIFE IN DAYS.

QRA ISOTOPE TABLE

R500

AM241	114	123	+.6400000E+02	+.1591120E+06
EU155	169	176	+.3403400E+02	+.1812000E+04
CO 57	240	243	+.1463699E+02	+.2697993E+03
CE144	263	270	+.1122699E+03	+.2843997E+03
U 235	367	375	+.3304799E+02	+.2599999E+12
CE141	287	294	+.2801999E+02	+.3245000E+02
CE139	328	336	+.1970399E+02	+.1372000E+03
RA226	700	708	+.9921997E+02	+.5840000E+06
PU239	823	831	+.2766000E+07	+.8902000E+07
SB125	851	860	+.1417199E+03	+.1012000E+04
RU103	992	996	+.5333899E+02	+.3959996E+02
TH228	1161	1171	+.2277600E+03	+.6975994E+03
RH106	1240	1248	+.7478999E+03	+.3710000E+03
CS137	1319	1325	+.9554999E+02	+.1104100E+05
ZR 95	1510	1516	+.1621700E+03	+.8550000E+02
CS134	1589	1595	+.1090500E+03	+.7550000E+03
NB 95	1528	1536	+.8412700E+02	+.3514996E+02
EU154	2546	2555	+.4121694E+03	+.5843992E+04
CO 60	2661	2669	+.1646600E+03	+.1924030E+04
EU152	2809	2829	+.6990398E+03	+.4321000E+04
K 40	2915	2927	+.1639000E+04	+.4670000E+12
TC 99	+.3318600E+00		+.7352659E+03	
SR 90	+.8921399E+03		+.1040900E+05	

FIGURE 6

QI TABLE R500

THE LAST TWO LINES OF ENTRY ARE THE
BREMSSTRAHLUNG TABLE

QRF GU TABLE
0002

117 +.2804500E+00
150 +.2613700E+00
200 +.2476700E+00
300 +.2217600E+00
400 +.2028800E+00
500 +.1762400E+00
600 +.1581400E+00
1000 +.1442300E+00
1200 +.1332000E+00
1500 +.1172000E+00
2000 +.1052500E+00
3000 +.8770000E-01
4000 +.7296001E-01
CF = +.1100000E+05
E = +.9350000E+10

QRE GEOMETRY TABLE

15 +.2405000E+04
15 +.2200000E+04
15 +.1490000E+04
15 +.2590000E+05
15 +.1480000E+05
15 +.3700000E+04
00 +.1489973E+05

FIGURE 7

QG TABLE 0002

AS READ BACK FROM THE COMPUTER USING
ROUTINES QRF AND QRE. THE QRF OR GU TABLES
REPRESENT THE μ FACTORS USED FOR A
WATER MATRIX ATTENUATION CORRECTION.

Control Entries

Same as "ACTIVITY WITHOUT TIME CORRECTION", plus

10000 is Time Zero in decimal digits to which the activities are to be corrected.

Calculation

$$\text{Activity} = \frac{\text{Net Area} \cdot \text{BN} \cdot \text{GEO} \cdot e^{\lambda T}}{\text{UF}}$$

where

Net Area = net area in counts/second from Determination of Net Area.

BN = $\text{Eff}^{-1}/\gamma/d$, the multiplier factor from the QI Table.

GEO = the multiplier factor from the tens digit of the "application directive" - QG Table.

UF = the dividing factor from the units digit of the "application directive" - QG Table.

λ = $\ln 2 \div \text{half-life}$ (QI Table).

T = time difference in days between Time of Count and Time Zero. The time difference will be negative for time corrections forward in time (decreased activity).

The following test is performed:

$$\text{RX} = \frac{\text{Acquisition Time in seconds}}{T_{1/2}(\text{QI Table}) \times 86400}$$

if $\text{RX} \geq 0.01$ calculate

$$\text{DT} = \frac{-T_{1/2} \cdot \ln[(1 - e^{-\text{RX} \cdot \ln 2}) / \text{RX} \cdot \ln 2]}{\ln 2}$$

$$\text{Time of Count (above)} = (\text{Time of Count}) + \text{DT} \cdot \frac{\text{RX}}{1 - \text{RX}}$$

This test compensates Time of Count and the subsequent

adjustment of activity to Time Zero for those cases in which the period of acquisition is significant compared with the half-life of the analyzed isotope.

Checks

Same as ACTIVITY WITHOUT TIME CORRECTION.

ACTIVATION ANALYSIS RESULTS

Instructions

((CNTRL)Z)

BROWN (CR).(LF)

Sample identification ((CNTRL)A)

11234.485@50@10@15.012@0003E900@100@131@30@110@

Control Entries

Same as ACTIVITY WITHOUT TIME CORRECTION, plus*

*(CNTRL)Z initiates the calculation of activation analysis results and turns on which ever TI733 cassette is in "Record Mode".

QI contains the element name

the channel address search limits

*the BN factor, a variable numerator or multiplier factor

$$BN = \frac{\text{eff}^{-1} \cdot k}{\gamma/d \cdot \sigma}$$

where:

$$k = \frac{\text{atomic weight} \cdot 10^{24}}{\text{Avogadro's No.} \cdot \text{isotopic abundance}}$$

σ = cross-section in barns

*the half-life in seconds

QG contains the GU Table

the Geometry Table

*CF@, the neutron source Time Zero for decay correction, the 14th line of the GU Table

*F@, the neutron flux density, the 15th line of the GU Table

(CNTRL)A terminates the sample identification input.

11234.485 is Time of Count in decimal digits which also serves as a serial number when combined with the detector identifying alpha character "E" in the CHECKSUM.

50 is the "application directive" for the QG Table, two decimal digits.

10 is the Throwout Limit in units of 2 σ precision, an integer value. All net peak areas having precisions less than this value are calculated and reported. All net peak areas having precisions greater than this value are not calculated.

15.012 is the "WV" factor whose application is directed by the "application directive"--50 in this example.

0003 is the name of the QG, geometry, Table to be used.

E900 is the name of the QI, isotope, Table to be used.

E is also the detector name and the name of the QT Table.

0003E900 together, these entries form a CHECKSUM which must match the table names in core or the program will interrupt with the message: ERROR CHECKSUM.

100 is live Acquisition Time in seconds. If this entry does not correspond to the contents of channel zero in the data spectrum, the program will interrupt with the message: ERROR TIME.

*131 is acquisition Clock Time.

*30 Time Out of Reactor, TOR, in seconds.

*110 is Time of Irradiation, TR, in seconds.

Calculation

$$\text{PPM} = \frac{\text{activity} \cdot e^{\lambda \cdot \text{TOR}} \cdot e^{\lambda \cdot \text{TC}}}{(1 - e^{-\lambda \cdot \text{TR}}) \cdot F}$$

where activity = the same value as in Activity Without Time Correction

$$\lambda \cdot \text{TC} = \frac{\ln 2}{966.425} \cdot \text{time difference in days between Time of Count and CF from QG Table}$$

$$\lambda \cdot \text{TR} = \frac{\ln 2 \cdot \text{TR (Time of Irradiation)}}{T_{1/2} \text{ from QI Table}}$$

$$F = \text{neutron flux density from QG Table}$$

$$\lambda \cdot \text{TOR} = \frac{\ln 2 \cdot \text{TOR (Time Out of Reactor)}}{T_{1/2} \text{ from QI Table}}$$

The following test is performed:

$$\text{RZ} = \frac{\text{Clock Time in seconds}}{T_{1/2} \text{ from QI Table}}$$

if $\text{RZ} \geq 0.01$, calculate

$$\text{DT} = \frac{-T_{1/2} \cdot \ln[(1 - e^{-\text{RZ} \cdot \ln 2}) / \text{RZ} \cdot \ln 2]}{\ln 2}$$

$$\text{TOR (above)} = \text{TOR} + \text{DT} \cdot \frac{\text{RZ}}{T_{1/2}}$$

See the Second-Order Activation Analysis Interference Correction.

Checks

Same as ACTIVITY WITHOUT TIME CORRECTION.

PRECISION CALCULATIONInstructions

None.

Control Entries

None. Every Net Peak Area is automatically subjected to a calculation of precision. The output value is compared with the absolute value of the Throwout Limit entered in the instruction line for the calculation of Activity or Activation Analysis Results. If the precision value is less than the Throwout Limit the calculation for that peak value proceeds and the precision is ultimately reported with the activity or PPM output to two significant figures; *i.e.*, $\pm .82E+01\%$ (Figure 4). The precision value is calculated as a percentage of the activity or PPM at the 95% confidence level (2 σ). If the precision value is greater than the Throwout Limit the calculation for that peak value is terminated.

Calculation

If Net Area is negative $\pm .99\%$ is reported

$$\% @ 95\% CL = \frac{196 \sqrt{\text{Net Area} \cdot \text{Time} \cdot \text{BD} + 2 \cdot \text{Noise Continuum}}}{\text{Net Area} \cdot \text{Time} \cdot \text{BD}}$$

where

Net Area · Time · BD = net total counts in the spectral peak before corrections for time, recovery, random summing, etc.

Time = Acquisition time from the instruction line and the contents of channel zero of the spectral data.

BD (see Random Summing Correction)

Noise Continuum = $(IL_1 + IL_h) \cdot 0.5 \cdot (2IX + 1)$, from the Determination of Net Peak Area. This is an absolute value.

Checks

QRD will list the most recently calculated precisions or confidence levels for all IP values.

THROWOUT LIMITS AND LIMITS OF DETECTIONThrowout LimitsInstructions

11026.341@15@ (30) X@1@0002Y701@3000@@

Control Entries

None. Every Net Peak Area is automatically subjected to a calculation of precision. The output value is compared with the absolute value of the Throwout Limit entered in the instruction line for the calculation of Activity or Analysis Results. If the precision value is less than the Throwout Limit the calculation proceeds. If the precision value is greater than the Throwout Limit the calculation for that peak is terminated. If the net area is negative, + 99% is reported--a value which will normally exceed the Throwout Limit.

Checks

QRD will list the most recently calculated precisions or confidence levels for all IP values.

Limits of DetectionInstructions

11026.341@15@30 (X) @1@0002Y701@3000@@

Control Entries

None. Whenever the precision exceeds the absolute

value of the Throwout Limit for a particular peak, "X" in the position indicated will cause the Limits of Detection for that peak to be calculated.

Calculations

Detection Limit^[4] (Activity) =

$$\frac{SD \cdot BN \cdot GEO \cdot e^{\lambda \cdot T}}{UF \cdot \text{time of acquisition}} \left(((IL_1 + IL_h) \cdot 0.5 \cdot (2IX + 1) + \frac{SD^2}{4})^{1/2} + \frac{SD}{2} \right)$$

where

SD = standard deviation = $\frac{196}{\text{Throwout Limit}}$

BN = $\text{eff}^{-1} / \gamma / d$, the multiplier factor from the QI Table

GEO = the multiplier factor from the tens digit of the "application directive" - QG Table.

λ = $\ln 2 \div \text{half-life}$ (QI Table)

T = time difference in days between Time of Count and Time Zero

UF = the dividing factor from the units digit of the applications directive - QG Table

$(IL_1 + IL_h) \cdot 0.5$ = average noise continuum (see Determination of Net Peak Area)

$(2IX + 1)$ = the number of channels summed to determine gross peak area (see Determination of Net Peak Area).

Detection Limit (Activation Analysis Results) =

$$\frac{SD \cdot BN \cdot GEO \cdot e^{\lambda \cdot \text{TOR}} \cdot e^{\lambda \cdot \text{TC}}}{UF \cdot \text{time of acquisition} \cdot (1 - e^{\lambda \cdot \text{TR}}) \cdot F} \left(((IL_1 + IL_h) \cdot 0.5 \cdot (2IX + 1) + \frac{SD^2}{4})^{1/2} + \frac{SD}{2} \right)$$

where

BN = $\frac{\text{eff}^{-1} \cdot k}{\gamma / d \cdot \sigma}$, the multiplier factor from the QI table

For all others see Activation Analysis Results.

Limits of Detection are a function of the detector efficiency for the peaks of interest, of the noise continuum per unit time in the areas of the peaks of interest, and of the precision required. A detector system does not have a limit of detection for a particular isotope or element unless these parameters are satisfied and the Limit of Detection will vary depending on the continuum interference due to other emitters in any given spectrum. Peaked background and its associated continuum are stripped from the sample spectrum prior to calculation of the Limits of Detection (see Background Subtraction).

Checks

QRD will list the most recently calculated precisions or confidence levels for all IP values.

Calculation of Activity or PPM with lower precision requirements (higher values) will result in the activity or PPM calculated to be present.

BACKGROUND SUBTRACTION

Instruction

(Y@4096@16)

Control Entry

None.

Calculations

If the second 4096 channel of hardware memory (NS636) contains zeros, there will be no background subtracted. Any other contents of these channels will cause a background

subtraction. The instruction above causes a spectrum to be read from cassette magnetic tape to the 4096 channels of memory starting at address 4096. A file of current, long acquisition time backgrounds is kept for the detector systems in service.

The acquisition time in seconds for the background spectrum is contained in channel 4096 and for the sample spectrum in channel zero. A normalizing factor is constructed from the ratio of sample-to-background acquisition times, the background spectrum multiplied by it, and the product subtracted from the sample spectrum, channel by channel, from channels 1 to 4095. The background subtraction is destructive to the sample spectrum; that is, the background can remain resident in analyzer memory and be reused; but the sample spectrum has been permanently altered in core. If multiple determinations of activity are performed on a spectrum, that sample spectrum must be reentered from cassette magnetic tape if a background subtraction has been performed.

Checks

CHECKSUM

P@G@(Starting Address)@(Stop Address)@ before and after Determination of Activity

O@R@(Address)@ will read the contents of a single address, as for checking the acquisition time for a sample (Address 0) or a background (Address 4096).

RANDOM SUMMING CORRECTION--QT

Instruction

None.

Random summing correction is available in three modes:

- Total count integration mode.
- Pulser mode.
- Isotopic mode.

Random summing is the phenomenon of loss in net peak area due to the random addition of the energies of two or more photons resulting in the recording of an event at their combined energies and not in the full energy peak(s) of the emitter(s). Only the total count integration mode requires precalibration. All modes are applied before Background Subtraction.

Total Count Integration Mode

Control Entry

QTC

GCF = 1.001@IX IL 5@20@

RS= (71000@)

PEAK MODS--PK@BK@K@

0@0@0@

0@0@0@

0@0@0@

INTEGRATION LIMITS ((CNTRL D))

Calculation

$$BD = GCF \left[1 - \frac{\sum 1}{RS \cdot \text{Acquisition Time}} \right]$$

where

BD = a dividing factor in the Determination of Net Peak Area

GCF = Geometry Correction Factor, a normalizing factor (see Detector Recovery Factor)

In the Total Count Integration Mode of random summing correction the total integrated spectral count rate is related to the loss in net peak areas by means of a prior calibration. A very low count rate emitter [<100 counts per second (c/s) total integrated count] with a high energy peak and a long half-life [such as ^{60}Co , ^{40}K or ^{22}Na] is analyzed on a given acquisition system. The net peak area is established as the 1.00 fractional yield. Without moving the first source, introduce a second emitting source of high activity and low energy such as ^{51}Cr , ^{113}Sn , or ^{137}Cs . The random, full energy, sum peak at twice the energy of the primary emission must be lower in energy than the peak(s) used for determination of fractional yield. Plot fractional yield versus total integrated count rate (minus the integrated count rate of the high-energy emitter). The slope of the resulting straight line with zero intercept will be the value "RS".

$$\text{Fractional yield} = \left[1 - \frac{\sum_{1}^{4095}}{\text{RS} \cdot \text{Acquisition Time}} \right]$$

QT automatically sets the integration limits from channel 1 to 4095 and this random summing mode unless the "INTEGRATION LIMITS" entry is countered with anything but (CNTRL D). In order to be valid this random summing mode must have available for integration all the counts that are received by the primary detector. It is not valid for Compton suppression systems or bias amplified systems.

Pulser Mode

Control Entry

QTY

GCF = 1.034@IX IL 5@20@

RS= (9@)

PEAK MODS--PK@BK@K@

0@0@0@

0@0@0@

0@0@0@

INTEGRATION LIMITS (4050@4095@)

Calculation

$$BD = GCF \cdot \left[\frac{\sum_{4050}^{4095}}{RS \cdot \text{acquisition time}} \right]$$

where

BD = a dividing factor in the Determination of Net Peak Area

GCF = Geometry Correction Factor, a normalizing factor.

The Pulser Mode of random summing correction is self-calibrating. It presumes that anything that happens to a pulse from the detector will happen to a pulser pulse introduced at the input to the analog to digital convertor (ADC). The amplitude of the pulser pulse is adjusted to fall in the last 90 channels of sample spectrum. Our pulser is set at 9 c/s by scaling down the analyzer timing oscillator pulse. The contents of the 10 channels lower in energy than the lower energy INTEGRATION LIMIT are averaged and subtracted from the channels to be integrated. This removes the continuum caused by high-energy emitters, Bremsstrahlung and random summing.

This mode of random summing is used for all Compton suppression acquisition systems and for all satellite acquisition systems not in our control. It has the advantage over the isotopic mode of random summing correction in not having to have the RS value time-corrected and in not contributing to the spectrum in the energy range used.

The use of INTEGRATION LIMITS in the QT Table entry automatically causes the calculation for the pulse/isotopic mode to be used. This is true even when the limits 1 and 4095 are used.

Isotopic Mode

Control Entry

Same as Pulser Mode.

Calculation

Same as Pulser Mode.

The RS value is the net peak area (γ/s) of the isotopic peak to be used. The RS value must be time-corrected for decay and the isotope used must not be present in the sample or background spectra. Determination of Activity for the isotope used for random summing correction will result in an erroneous activity. The isotopic source must be mounted on or in the proximity of the detector in such a manner that the geometry is fixed and that the radiation of the source is not attenuated by the sample or *vice versa*.

Checks

Determine Activity with and without Random Summing Correction. The Random Summing Correction is voided by using the Total Count Integration Mode and entering IE75 for RS.

CHECKSUM automatically verifies the QT Table entry by name.

DETECTOR RECOVERY FACTOR--QTInstruction

None.

Control Entry

QTY

GCF = (1.034) @IX IL 5@20@

Calculation

$BD = GCF \cdot (\text{Random Summing Correction})$

The Detector Recovery Factor and BD are dividing factors used in the Determination of Net Peak Area. The Detector Recovery Factor is locally known as the Geometry Correction Factor, GCF, since one of the primary functions of this factor is to monitor the relative position between the detector and detached geometry positions.

Every detector system in use which provides data to the GXDR system for reduction is monitored daily for recovery against a long-lived standard mount. Spectra are taken which are representative of geometries attached to and detached from the detector. The spectra are analyzed on the GXDR system using a $GCF = 1$, a Geometry Table "UF" equal to the standard activity value at the Time Zero of record, and the Time Zero of record. The output is the GCF or Detector Recovery Factor for the detector day.

Variations from day to day of greater than 0.5% must be verified and, if necessary, corrected. Day to day records are kept, summarized and plotted quarterly to document (internally only) long-term recovery trends. The precision of this analysis $(2\sigma)_R^{[1]}$ is not allowed to exceed $\pm 1\%$ at the 95% confidence level; however it does contribute to the

uncertainty of the accuracy by that amount.

The GCF factor has been in use since the mid-1960's to compensate for detector vagaries. Documentation was started in June 1968.^[5] The concept has proven most helpful in maintaining calibrations through detector movement, repair, redrift, and removal (in multiple detector systems).

Checks

CHECKSUM automatically verifies the QT Table entry by name.

PEAK INTERFERENCE CORRECTION--QT

Instruction

None.

Control Entry

(QT) Y

GCF = 0.998@IX IL 5@20@

RS = 9

PEAK MODS--PK@BK@K@

(1@8@3.0834@)

Calculation

The first entry in PEAK MODS, PK, is the location in the QI Table of the recipient peak. The BK entry is the location in the QI Table of the donor peak. The K entry is the constant to be multiplied by the Net Peak Area of the donor and subtracted from the Net Peak Area of the recipient.

Corrected Net Peak Area (Recipient) =

Net Peak Area (Recipient) - Net Peak Area (Donor) $\cdot \frac{GU_D}{GU_R} \cdot K$

GUD/GUR = the GU Table directives to apply the geometry function or sorption corrections as a function of energy.

BN--see QI Table, Activity or Activation Analysis Results

In the example used, the following partial QI Table is called for on the Instruction Line:

C331

(AM241)	113	123	(+.2959500E+03)	+ .1580080E+11
EU155	169	176		
CO 57	240	248		
CE144	263	270		
U 235	367	375		
CE141	287	294		
CE139	328	336		
(U 237)	412	420	(+.8948000E+03)	+ .6750000E+01

The spectrum of ^{237}U contributes to the ^{241}Am peak at 59.6 keV. Therefore the ^{237}U peak at 208 keV is the donor peak, BK, and it is the 8th entry in the QI Table. The recipient peak, PK, is the ^{241}Am peak which is located in line 1 of the QI Table.

$$K = \frac{\text{BN of donor peak}}{\text{BN of donor at recipient peak energy}} = \frac{894.8}{290.2} = 3.0834$$

The Peak Interference Correction is performed after the Background Subtraction, if any, and before the Determination of Net Peak Areas.

The Peak Interference Correction is negated by entering zeros for PK, BK, and K. Up to three entry lines may be made and the entries are interchangeable with the Second Order Activation Analysis Interference Corrections.

Checks

CHECKSUM automatically verifies the QT and QI Table entries by name.

SECOND-ORDER ACTIVATION ANALYSIS INTERFERENCE CORRECTION--QTInstruction

None.

Control Entry

(QT) E

GCF = 1.001@ IX IL 5@20@

RS = 9

PEAK MODS--PK@BK@K@

(8@8@1.923E14@)

The only difference in entry format between Second-Order Activation Analysis Interference Correction and Peak Interference Correction is that in this mode of correction the values of "PK" and "BK" must be the same and not equal to zero.

Calculation

Second-Order activation analysis interference is the production of isotopes through second-order nuclear reactions which interfere with the measurement of the primary trace element. For instance, activation analysis of zinc and nickel in a copper matrix can be made by measuring ^{65}Zn and ^{65}Ni . However, neutron interaction with the copper can produce the following second-order reactions:

The decay products of ^{64}Cu are the same as the isotopes being used to measure the trace content of zinc and nickel. This contribution must be corrected.

The 1st and 2nd entries in PEAK MODS, PK and BK are the location in the QI Table of the peak to be corrected--eight in the example. The K entry is a constant in the expression:

$$\frac{K \cdot WV}{BN}$$

which is to be subtracted from the gross peak area designated by PK and BK. The Second-Order Activation Analysis Interference Correction is performed after the Background Subtraction, if any, and before the Determination of Net Peak Area.

The K entry is the micrograms of second order interference isotope formed at a given flux density (F_c), irradiation time and thermal to resonance neutron flux ratio (ϕ_{th}/ϕ_r), divided into the flux density (F_c).

$$K = F_c / \mu g$$

The flux density (F_c) need not be the same as the flux density (F) used for Activation Analysis.

The "WV" value is in units of grams and is entered in the instruction line; therefore caution must be used in making the entry, particularly with a 4 in the tens digit of the Applications Directive (see Internal Sorber Corrections). The BN factor is the variable numerator or multiplier factor stored in the QI Table as the 3rd entry on the peak line designated by PK and BK (see QI Table, Activity or Activation Analysis Results).

The Second-Order Activation Analysis Interference Correction is negated by entering zeros for PK, BK, and K. Up to three entry lines may be made and the entries are interchangeable with the Peak Interference Correction.

Checks

CHECKSUM automatically verifies the QT and QI Table entries by name.

GEOMETRY FUNCTION--QG

Instruction

11011.540@ (2) 1@10@.10011@ (0403) C102@1000@@

Control Entry

QG Table

0403

117	+.3298000E+01
160	+.3319000E+01
200	+.3329000E+01
300	+.3298000E+01
400	+.3201000E+01
600	+.3061000E+01
800	+.3061000E+01
1000	+.3061000E+01
1200	+.3061000E+01
1600	+.3061000E+01
2000	+.3061000E+01
3000	+.3061000E+01
4000	+.3061000E+01

The ratio between geometry positions is a composite of the least square law, air attenuation, elastic scattering, and detector thickness distribution. The latter three constituents are energy-dependent; therefore geometry will be an energy-dependent function. This function is plotted from ratios of net peak areas of the same mount between adjacent

geometry positions. From this plot the geometry factors as a function of energies are entered in the GU table. Interpretation is based on the IP value for each peak of interest in the Determination of Net Peak Area. Interpolation is a linear function between the two bracketed energy points.

Application of a Geometry Function is specifically directed by a "2" in the tens digit of the application directive--21 in the example.

<u>Tens Digit</u>	<u>"GU" Table</u>	<u>"WV"</u>
1	Substitute .1 for contents	$\cdot (WV)^{-1}$
2	$\cdot GU$	$\cdot (WV)^{-1}$
3	$x\mu$ in $\cdot e^{\mu x}$	$(WV)^{-1}$
4	μ in $\frac{\mu x}{1-e^{-\mu x}}$	x in same
5	g^{-1} from GU Table $\cdot (WV) =$ μx in $\cdot \frac{\mu x}{1-e^{-\mu x}}$	$\cdot (WV)^{-1}$

The GU Table is directed to be used as a multiplying function and the WV entry in the instruction line (.10011 in the example) as a dividing factor in the calculation of Activity or Activation Analysis Results.

The purpose of the "2" in the tens digit of the application directive is to apply a geometry function from a geometry position that has been calibrated to one that has not. Obviously it will be unnecessary to apply a geometry function to a geometry position that is independently calibrated. If, in addition, no sorption corrections are to be applied via the application directive, the GU Table is set equal to 1 with a "1" in the tens digit of the application directive.

Calculation

The output of the GU Table is the GEO factor in the calculation of Activity and Activation Analysis Results.

Checks

QRF will list the name of the QG Table and the factor entries of the "GU" Table from the QG Table (see Figure 7).

CHECKSUM will automatically verify the QG Table entry by name.

EXTERNAL SORBER CORRECTION--QG

Instruction

11011.486@ (3) 1@10@.04999@ (0005) c102@1000@@

Control Entry

QG Table

0005

117	+.2874909E+01
160	+.1331179E+01
200	+.7303400E+00
300	+.2667500E+00
400	+.1455500E+00
600	+.7484900E-01
800	+.5412700E-01
1000	+.4428700E-01
1200	+.3858900E-01
1600	+.3211400E-01
2000	+.2796999E-01
3000	+.2253199E-01
4000	+.1991660E-01

External Sorption Correction is calculated by multiplying Net Peak Area by the factor $e^{\mu x}$, which is energy-dependent. The GU Table contains the combined " μx " factor. Interpretation is based on the IP values for each peak of interest in the Determination of Net Peak Area.

Interpolation is a linear function between the two bracketed energy points. Energy is a fixed function in the GU Table and is in units of channels.

A word of caution: Due to elastic scatter, an external sorber must cover all exposed surfaces of the detector or the correction will not be adequate.

Application of an External Sorber Correction is specifically directed by a "3" in the tens digit of the application directive--31 in the example.

<u>Tens Digit</u>	<u>"GU" Table</u>	<u>"WV"</u>
1	Substitute .1 for contents	$\cdot (WV)^{-1}$
2	$\cdot GU$	$\cdot (WV)^{-1}$
3	μx in $\cdot e^{\mu x}$	$\cdot (WV)^{-1}$
4	μ in $\frac{\mu x}{1 - e^{-\mu x}}$	x in same
5	g^{-1} from GU Table $\cdot (WV) =$ x in $\cdot \frac{\mu x}{1 - e^{-\mu x}}$	$\cdot (WV)^{-1}$

The GU Table is directed to be used as an exponential and the exponential as a multiplying factor in the calculation of Activity or Activation Analysis Results. The WV entry in the instruction line (.04999 in the example) is directed to be used as a dividing factor in these calculations.

If a Geometry Function or an Internal Sorber Correction must be applied simultaneously with an external sorber correction, the latter is easily combined with the other factors in the QI Table BN factor. External sorption factors for specific isotopic peaks with 22 mil cadmium are maintained with calibration data to facilitate construction of QI Tables with this combination in mind. As with all of

the tens digits application directives, the GU Table can be negated by setting the tens digit to "1".

Calculations

$e^{\mu x}$ = GEO factor in the calculation of Activity or Activation Analysis Results

where

$$\mu = \text{cm}^2/\text{g}^{[6]}$$

$$x = \frac{g}{\text{cm}^2} = \frac{g}{\text{cm}^3} (\text{specific gravity}) \cdot \text{cm} (\text{thickness})$$

Checks

QRF will list the name of the QG Table and the factor entries of the "GU" Table from the QG Table (see Figure 7).

CHECKSUM will automatically verify the QG Table entry by name.

INTERNAL SORBER CORRECTION--QG

Instructions

11020.611@ (4) 6@10@7.050@ (0000) R500@1000@10000@

Control Entry

QG Table

0000

117	+.2804500E+00
160	+.2613700E+00
200	+.2476700E+00
300	+.2217600E+00
400	+.2028800E+00
600	+.1762400E+00
800	+.1581400E+00
1000	+.1442300E+00
1200	+.1332000E+00
1600	+.1172000E+00
2000	+.1052500E+00
3000	+.8770000E-01
4000	+.7296001E-01

Internal Sorber Correction is calculated by multiplying Net Peak Area by the factor $\frac{\mu x}{1-e^{-\mu x}}$, which is energy-dependent. The GU Table contains the " μ " factor.^[6] Interpretation is based on the IP values for each peak of interest in the Determination of Net Peak Area. Interpolation is a linear function between the two bracketed energy points. Energy is a fixed function in the GU Table and is in units of channels.

If a Geometry Function or an External Sorber Correction must be applied simultaneously with an internal sorber correction, either or both of the former may be combined with the other factors which make up the QI Table BN factor. As with all of the tens digits application directive, the GU Table can be negated by setting the tens digit to "1".

Calculations

Application of an Internal Sorber Correction is specifically directed by a "4" or a "5" in the tens digit of the application directive--46 in this example.

<u>Tens Digit</u>	<u>"GU" Table</u>	<u>"WV"</u>
1	Substitute .1 for contents	• (WV)
2	• GU	• (WV)
3	μx in $\cdot e^{\mu x}$	• (WV)
4	μ in $\frac{\mu x}{1-e^{-\mu x}}$	x in same
5	g^{-1} from GU Table • (WV) =	• (WV)
	x in $\cdot \frac{\mu x}{1-e^{-\mu x}}$	

The GU Table is directed to be used in an exponential function and that function as a multiplying factor, GEO, in the calculation of Activity or Activation Analysis Results.

The difference between 4X and 5X application directives is the treatment of the WV entry. In the 4X mode WV is the x value of the μx in the sorption exponential function. In the 5X mode it is the same x value but restricted to units of weight and the same value is also directed to be used as a dividing factor in the calculation of Activity or Activation Analysis Results.

There are three modes of determining the "x" value in the factor μx :

- Direct measurement of specific gravity and thickness.
- Determination from the effect of sorption on an internal, multipeaked isotope.
- Determination from the effect of sorption on an external isotopic source.

All three modes presume photon cross-sections can be assigned^[6] through knowledge of the elemental composition of the source media, as with metal foils and simple compounds, or through assignment of a model, such as the use of aluminum photon cross-sections to represent sandy soils.

Case 1, the example GU Table from QG Table 0000, contains the photon cross-sections used for water. The WV value, 7.050, is the known sample container path length, 7.00 centimeters, times the density of the sample.

The Units of "x" (WV) Will Be	When "μ" (GU Table) are
g/cm^2 or $\frac{\text{g} \cdot \text{cm}}{\text{cm}^3}$	$\frac{\text{cm}^2}{\text{g}}$: photon cross-section.
g/cm^3	$\frac{\text{cm}^2}{\text{g}} \cdot \text{cm}$: photon cross-section times thickness or path length.
g	$\frac{\text{cm}^2}{\text{g}} \cdot \text{cm} \cdot \frac{1}{\text{cm}^3}$: photon cross-section times thickness divided by sample volume (tens digit 5 in application directive).
cm	$\frac{\text{cm}^2}{\text{g}} \cdot \frac{\text{g}}{\text{cm}^3}$: photon cross-section times specific gravity.

Case 2, determination of "x" from the effect of sorption on an internal, multi peaked isotope such as ^{239}Pu .
Using ^{239}Pu for the model, let

I_1 = the peak area at 129.28 keV

I_2 = peak area at 413.6 keV

then

$$x = \frac{\ln \left[\frac{(I_1/I_2)_{\text{emitted}}}{(I_1/I_2)_{\text{observed}}} \right]}{\mu_1 - \mu_2} \quad (1)$$

and

$$(I_1/I_2)_{\text{emitted}} = \frac{e^{x(\mu_1 - \mu_2)}}{(I_1/I_2)_{\text{observed}}} \quad (2)$$

Since it is virtually impossible to prepare a sorption-free mount of plutonium-239, a water-mount is prepared in a known thickness container. The latter equation is used to calculate the emitted ratio of peak areas as a part of detector calibration and the derived value is used in all subsequent calculations of the value of "x" by this mode.

Separate values of the emitted peak area ratio are maintained for each detector, with and without the 22-mil cadmium sorber used to reduce the proportion of counts

received from americium-241. If such an absorber is used it is essential to have all surfaces of the detector covered-- not just the surface between the source and the detector. Elastic scatter, particularly in a lead shield, can cause a significant percentage of the source emission to be received at full energy by the detector but around a single plane sorber.

Case 3, determination of "x" from the effect of sorption on an external isotopic source. The sorption the emission from an external source experiences in passing through a sample, which is acting as an external absorber, is expressed by the following function:

$$I_{\text{emitted}} = I_{\text{observed}} e^{\mu x}$$

$$x = \frac{\ln(I_e/I_o)}{\mu}$$

The ratio of Net Peak Areas for any given peak through the air path to that through the sample is compared with the photon cross-section^[6] (cm²/g). The "x" obtained can be entered directly as the WV value where the tens digit of the application directive has been set to 4.

Care must be exercised not to use an isotope for the measurement of "x" that could be present in the sample and not to analyze for that peak(s) in the data reduction. It is useful but not necessary for the isotope chosen to have a long half-life and an emission close to and lower than the energy of the principal emission to be characterized. For instance, the 356.0 keV emission of ¹³³Ba has been useful in measuring the "x" value for the passive analysis of ²³⁹Pu utilizing the 413.7 keV.

All three cases calculate internal sorption correction according to the expression

$$\frac{\mu x}{1 - e^{-\mu x}} = \text{GEO factor in the calculation of Activity or Activation Analysis Results}$$

Checks

QRF will list the name of the QG Table and the factor entries of the "GU" Table from the QG Table (see Figure 7).

CHECKSUM will automatically verify the QG Table entry by name.

NEUTRON FLUX DENSITY--QG

Instruction

(CNTRL Z)

Control Entry

QG Table

(CF = 11000)

(F = .9543000E+10)

Calculations

Starting neutron flux density (F) is entered in the QG Table (line 15 of the GU Table) together with the time zero (CF) (line 14 of the GU Table) for the flux density measurement. Flux is presumed to be directly proportional to the 966.425 day half-life of ^{252}Cf .

$$\text{Activation Analysis Results PPM} = \frac{\text{Activity } e^{\lambda \text{TOR}} \cdot (e^{\lambda \text{TC}})}{(1 - e^{-\lambda \text{TR}}) \cdot (F)}$$

where

$$\lambda \text{TC} = \frac{\ln 2}{966.425} \cdot \text{Time difference in days between Time of Count from the CNTRL Z instruction line and CF from the QG Table.}$$

F = Neutron Flux Density from the QG Table.

Any perturbations to neutron flux density other than those caused by radioactive decay should be included in the Detector Recovery Factor (GCF) in the QT Table.

Checks

QRF will list the name of the QG Table and the CF and F entries in the QG Table as the 14th and 15th lines (see Figure 7).

CHECKSUM will automatically verify the QG Table entry by name.

UNITS MANIPULATION--QG

Instruction

11026.341@1 (5) @30x@1@ (0002) Y701@3000@@

Control Entry

QG Table

GEOMETRY TABLE

0	16	+.2405000E+04
1	16	+.2200000E+04
2	16	+.1480000E+04
3	16	+.2590000E+05
4	16	+.1480000E+05
5	16	+.3700000E+04
6	00	+.1489973E+05

The units in which results will be reported are directed by the units digit of the application directive--15 in this example. The "5" signals the use of line five in the GEOMETRY TABLE of the QG Table. Each line in the GEOMETRY TABLE contains the line name (or number), the two-digit directive to the Units Table, and the unifying factor, UF.

The Units Table is a fixed program entry as follows:

UCI	1
DPS	2
PCI	3
MG@ [@ = space]	4
/ML	5
/L@	6
/MG	7
/MM	8
/KG	9
@@@	0
PPM	:

The Units Table entries are called for use from the Geometry Table of the QG Tables. Two entries are called together. The first entry, "1" in the example (line 5), calls for "UCI" which follows the Activity or Activation Analysis Results readout, preceded and followed by a single space. This is followed by the five-digit alpha-numeric identity from the QI Table and then the units "/L@", which were called for by the second entry, "6" (Figures 3 and 4). A line of output called for by the units digit of the application directive, 5, and GU Table, 0002, would appear as follows:

```
<+.95E-02  UCI RH106/L      +.1131E-01 UCI CS137/L  ±.82E+01%
```

A brief inspection of the Units Table will show the broad spectrum of readout units available. The unifying factor, UF, which is the last entry on each line of the Geometry Table is intended to contain whatever factor is necessary to convert disintegrations per second to the units required. UF is a dividing factor in the calculation of Activity or Activation Analysis Results. In the example QG Table, 0002, lines 0 through 5 are intended to read out in units of "UCI/L", 16. The UF values contain the dividing

factor 37000 d/s/ μ Ci times the sample volume in liters--
.065, .060, .040, .700, .400, and .100, respectively.

Line 6 calls for no units, 00, and the UF divider contains the standard activity value at Time Zero for the standard used in the calculation of the Detector Recovery Factor, GCF. An entry of 1 for the UF factor will cause disintegrations per second to be read out. If the BN value in the QI Table is also set to "1", counts per second in the Net Peak Area can be read out.

Calculations

$$\text{Activity} = \frac{\text{Net Area} \cdot \text{BN} \cdot \text{GEO}}{(\text{UF})}$$

Checks

QRE will list the Geometry Table from the QG Table (see Figure 7).

CHECKSUM will automatically verify the QG Table entry by name (QRF).

ERROR CHECKSUM AND ERROR TIME

Instruction

11026.341@15@30x@1@ (0002Y701) @ (3000) @@

Control Entries

QG Table 0002

QI Table Y701

QT Table Y

3000 in channel zero of the data spectrum. Acquisition Time in seconds.

Error Checksum

Error Checksum verifies that the QG, QI, and QT Tables called for in the instruction line are indeed in computer core ready to be used in the data reduction. Use of these tables is nondestructive--that is, they need not be reentered in successive data reductions until a different table is required. When a change is needed only the table involved needs to be changed.

Error Time

Error Time verifies that the Acquisition Time entered in the instruction line matches the time of acquisition contained in channel zero of the data spectrum. This checks that the analyzer clock is functioning properly and it warns the operator if he has the wrong cassette containing data spectra or the incorrect position on that tape.

If an error is detected in either the CHECKSUM or TIME, the record function of the TI733 terminal is immediately shut off by the program. The instruction line with the error message will not be recorded on cassette tape if the following sequence is followed:

1. Switch TI733 Record from "Line" to "Local" and back to "OFF".
2. Type (CNTRL X) or (CNTRL Z).
3. Switch TI733 Record from "OFF" to "LINE".
4. Manually turn Record Control "ON".
5. Type (CNTRL A).
6. Reenter instruction line.

If it is necessary to change the contents of channel zero in the data spectrum, acquisition time in seconds, type

O@W@O@ (new contents).

Calculations

None.

Checks

QRF will list the name of the QG Table.

QRA will list the name of the QI Table.

By elimination, if neither the QG or QI caused an ERROR CHECKSUM, then it must be the QT entry.

O@R@O@ will list the present contents of channel zero in the data spectrum.

QT CALIBRATION TABLE ENTRY

Instruction

(QT) Y

The only mode of QT Table entry is the fully manual entry mode. It cannot be stored on tape and it cannot be edited.

Control Entries

The "Y" in the example above is

- a. The name of the QT Table.
- b. The mechanism for opening the QT routine for instruction entries.
- c. The first control entry.

The value entered must be a single alpha character--the same character as the alpha character to be used in the QI Table name so that both tables may be verified by CHECKSUM.

The next entry, "GCF=" is the decimal or floating point number representing the Detector Recovery Factor, terminated by a space (@). This is followed on the same line by "IX IL". These values must be integers within the range 1 to 30. Each is terminated by a space (@). The values are described in Determination of Net Peak Area.

The next line echos "RS=" and requires the integer Random Summing Correction constant, terminated by a space. The following line echos "PEAK MODS--PK@BK@K@". The entries described in Peak Interference Correction or Second-Order Activation Analysis Interference Corrections are to be entered. "PK" is the location in the QI Table of the recipient peak, an integer line number terminated with a space (@). "BK" is the location in the QI Table of the donor peak, an integer line number terminated with a space (@). The "K" entry is a multiplying constant, a decimal or floating point number terminated by a space (@). If no use is to be made of the Peak Inteference Correction, enter:

```
0(space)0(space)0(space)
0@0@0@
0@0@0@
```

The next line echos "INTEGRATION LIMITS". Entry of a "(CNTRL) D" will cause implementation of the total count integration mode of Random Summing Correction. Entry of integer channel "(Start)@((STOP)@" will cause implementation of either the pulser or isotopic modes of Random Summing Correction. In either event the entries to the QT Table will have been terminated.

Calculations

None.

Checks

CHECKSUM will automatically verify the QT Table entry by name.

QG CALIBRATION TABLE SEARCH AND ENTRYFrom TI733 Cassette Tape to ComputerInstructions

(RS) \$ (\$0002(CNTRL Q))

(QHG@)

Control Entries

The TI733 cassette containing the required QG Table must be mounted, rewound, ready, and in playback mode. All TI733 controls are in "LINE" (see Miscellaneous Program Commands).

RS is the keyboard command that initiates the remote search capability of the TI733. When it has been accepted by the program, the "\$" will be echoed but not included in the search "title".

\$0002 is an example of a search title for a QG Table for which a request for search is being made. The dollar sign is used to make the name unique from numerical sequences which might be in the tables.

(CNTRL Q) terminates the search title and initiates the search. When the title has been found, a carriage return-line feed will be executed.

QHG enters a QG Table from cassette tape to the computer.

Initiating a QG TableInstructions

(QGG) or an existing QG Table in core may be edited and its name changed.

Control Entries (Figure 7)

The first item to be entered is the code identification or name. This name must consist of a four-digit integer terminated by a space (@). Next the routine will identify the "IP" sequence for which a "GU" entry is required, terminated by a space (@). The "IP's" are predetermined. All 13 entries must be made as requested--one for each designated "IP". The 14th line will echo "CF=", enter the Time Zero for calculating activity of the californium-252 neutron source, and hence time zero for the decay of the neutron flux in the Californium Multiplier. The 15th line will echo "F=", enter flux density in neutrons/cm·sec at Time zero.

A "CNTRL D" may be used at this point to exit the routine with the previous remaining contents of the QG Table intact. Up to 10 entries to the GEOMETRY Table may be set. The computer will type each geometry number and await input of the two-digit units code and the desired unification factor (UF) terminated by a space (@). When all Geometry Table entries desired have been entered, type "CNTRL D" to exit. Unless otherwise limited, all constants are positive and will be stored to 7 significant figures. They may be entered as integers, decimal numbers, or floating point numbers.

From Computer to TI733 Cassette Tape

Instructions

(QJG@)

Control Entries

The TI733 cassette containing calibrated tables

must be mounted, rewound, ready, and in playback mode.

1. All of the TI733 cassette control switches (bottom row) are in the "LINE" position.
2. Type "RS", the computer will echo will a dollar sign (\$) which is not part of the search code entry. Type "&& (CR) (CNTRL)Q".
3. When the terminal responds with a Carriage Return (CR)-Line Feed (LF), the end of recorded tables on the cassette will have been found. Type "RV" to reverse one block, hence to write over the && entry.
4. Place the cassette in use to record mode by placing the opposite cassette to playback mode, RC1 or RC2.
5. Type "QJG@". The computer will type
"\$ (QG Table name) (CR) (LF)
(QG Table name) (CR)
(QG Table contents)".
The first line is the search title and the second the table name.
6. Repeat Step 5 for as many QG or QI (QJI) entries as are to be stored on TI733 cassette tape (see Initiating a QG Table).
7. All of the TI733 cassette control switches (bottom row) are to be set to "LOCAL".
8. Enable Record Control by pressing the "ON" rocker switch.
9. Type "&&(CR)".
10. Return all TI733 cassette control switches

(bottom row) to "LINE".

Calculation

None.

Checks

QRF will list the QG Table name in computer core and the factor entries of the "GU" Table from the QG Table, the CF entry, and the F entry (see Figure 7).

QRE will list the Geometry Table from the QG Table.

QI CALIBRATION TABLE SEARCH AND ENTRY

From TI733 Cassette Tape to Computer

Instructions

(RS) \$ (SY701(CNTRL Q))

(QHI@)

Control Entries

Same as QG Table entries except substitute "I" for "G". Names for QI Tables consist of an alpha character followed by three integers--Y701 in the example. A prior dollar sign is entered for consistency with the QG Table.

QHI enters a QI Table from cassette tape to the computer.

Initiating a QI Table

Instructions

(QI) or an existing QI Table in core may be edited and its name changed.

Control Entries (Figure 5)

The first item to be entered is the code identification or name. This name must consist of an alpha character followed by three integers terminated by a space (@). Next the routine will initiate a line of entries which contain:

1. Five alpha-numeric characters which identify the isotope or element represented by this line of entries. Pad with spaces (@) if less than five characters are wanted.
2. The limits of search in channel numbers for a spectral peak, (Start)@(Stop)@. Two entries of up to four integer digits each, terminated by a space (@) in each case, are allowed. The first integer must be less than the second entry. Search areas may duplicate or overlap other search areas. They need not be in any given order.
3. The "BN" multiplier entry may contain up to 7 significant figures and may be entered as an integer, a decimal, or a floating point number. Entry is terminated by a space (@).
4. The "TI" entry or half-life entry has the same limitations as the "BN" entry. The units are days for the calculation of Activity, (CNTRL X) and seconds for the calculation of Activation Analysis Results (CNTRL Z).

Up to 30 lines of entry may be made. If less than 30 lines are desired, the Isotope Table may be exited and the Bremsstrahlung Table entered by typing a space (@)

instead of an isotope name. The QI Table may be exited by typing a (CNTRL) D.

The Bremsstrahlung Table consists of a maximum of two lines of entry, identical to the lines of the Isotope Table except that there are no search limits entered. If two entries are made the lower energy beta emitter will be the first entry. If no entries or one entry are to be made, terminate by typing (CNTRL) D (see Bremsstrahlung Analysis).

From Computer to TI733 Cassette Tape

Instruction

(QJI@)

Control Entries

Same as QG Table entries except substitute "I" for "G". Name for QI Tables consist of an alpha character followed by three integers--Y701 in the example.

QJI Enters a QI Table from the computer to TI733 cassette tape.

Calculations

None.

Checks

QRA will list the name and contents of the QI Table, including the Bremsstrahlung Table, as the last 1 or 2 lines (see Figures 5 and 6).

LINE EDITORInstructions(QMB)

Entry to the Bremsstrahlung Table. Asking for line zero will cause an immediate exit to the executive. Asking for a line higher than 2 will also cause a prompt exit. If there are no entries ask for Line 1, and a carriage return/line feed sequence will ensue. Typing a plus (+) will allow generation of a new line.

(QMG)

Entry to the Geometry Table. Line zero is the numerical identification for this table. The I.D. can be read and changed, but request for deletion (-) or insertion (+) will cause an error printout. Advance to the next line by typing an up arrow (shift,N). Editor line numbers are 1 higher than the Geometry Table call numbers, units digit of the application directive (see Units Manipulation).

(QMI)

Entry to the Isotope Table. Line zero is the alpha-numerical identification for this table. The I.D. can be read and changed but not deleted.

(QMU)

Entry to the GU Table. Here there is a fixed number of entries, so nothing can be added or deleted, but the entries can be changed by means of the underline (shift,O) command. Line 14 is the CF entry. Line 15 is the F entry.

Control Entries

"_" (shift, O) = change this line. Enter the new line as desired in the proper format for that table.

"^" (shift, "N") = go to the next line of this table and type it.

"+" (plus) = insert a line at this point. Current line and all lines above it are shifted upward (in numerical value).

"-" (minus) = delete this line and type the next line.

The series of commands which start with the letters "QM" are entry points to the editor routine which allows one to manipulate the Bremsstrahlung, geometry, isotope, and "GU" Tables. Four commands are common to all of the edit functions. The four commands and their effects on any given table are noted above.

Note four points in using the edit functions:

1. If a line is added (inserted) in a table, all entries in the table at and above the current line will be shifted upward in line number in order to make room for the line to be inserted.
2. To add to the end of a table, step beyond the last entry and then insert.
3. Initial entry to each routine must be followed by the desired line number of the table terminated by a space character (@). Subsequent commands are via the Control Entry key functions.
4. Exit from any routine is always accomplished by typing CNTRL D.

Calculations

None.

Checks

The commands QRA, QRE, and QRF will read the present table contents in computer core.

ITEM EDITOR

The Item Editor is intended to change replicate items entered on the TI733 magnetic tape cassette--QG or QI

Calibration Tables. For instance, the QI Tables contain a half-life of $+.3959999E+02$ for RU103 and it is desired to change it to $+.3935000E+02$ in all of the tables.

Instructions

None.

Control Entries

1. Set all of the TI733 control switches to "LINE" (lower row or rocker switches on cassette control panel).
2. Insert the cassette to be edited into CASSETTE 1 transport and a spare cassette into CASSETTE 2 transport.
3. Type the following commands: "RWI" and "RW2" if the cassette tapes are not already rewound. Type "RL1," "RL2", and "RC1".
4. Set all of the TI733 control switches to "LOCAL" (lower row of switches).
5. Type (ESC)\$. The keyboard will respond with a carriage return-line feed. Type the search characters, the data to be replaced--" $+.3959999E+02$ " in the sample case.
6. Press PLAYBACK CONTROL-CONT START.
7. When the tape stops, press PLAYBACK CONTROL-BLOCK REV.
8. Press CHAR FWD to print out one character at a time.
9. When the characters to be changed are printed (and verified), press (TAPE) and "strike over" the new

characters--"35000" in the example.

NOTE: If a typographical error is made at this point, backspace with (TAPE) until the print head moves back just over the character in error, then type in the correct character. Use (TAPE) to advance to the end of the character string typed and continue typing. DO NOT USE THE SPACE BAR TO ADVANCE!

This editor mode is to be used only to edit characters which have had space allocated to them on tape. No more and no less characters may be used.

10. Press BLOCK FWD to print out the remainder of the block.
11. Set RECORD CONTROL to OFF.
12. Press BLOCK REV.
13. Set CASSETTE 1 to RECORD.
14. Press BLOCK REV.
15. Set RECORD CONTROL to ON.
16. Press BLOCK FWD.
17. Set RECORD CONTROL TO OFF.
18. Set CASSETTE 1 to PLAYBACK.
19. Type (ESC)\$.
20. Repeat Steps 6 through 19 until all entries have been edited.

Calculations

None.

Checks

The commands QRA, QRE, and QRF will verify the edited items after the individual tables have been read into the

computer via the QHG or QHI routines

or

search for and print the desired information from cassette magnetic tape in "LOCAL" mode.

REPORT FORMAT AND SEARCH

Routinely, when calculating Activity or Activation Analysis Results, the cassette transport in PLAYBACK contains the Q Table cassette in use and the other transport contains the customer report cassette.

Report Format

Instructions

CNTRL X (or Z).

Control Entries

The given name of the customer, the charge code, or whatever identification is desired, followed by a carriage return (CR)-line feed (LF). The entry must be less than 16 characters in length including the (CR). This line of entry will be the search code by which the report segments are located on the report cassette tape (DRESSEN is the search code used in Figure 3 as an example). This line will not print in the report (Figure 4).

Complete the identification of the sample and terminate with a CNTRL A. This information will print in the report (Figure 4).

Calculations:

None

Checks

LOCAL printout.

Report SearchInstructions

None (Figure 4).

Control Entries

1. Set all of the TI733 control switches to "LINE" (lower row of rocker switches on cassette control panel).
2. The report cassette is presumed to be mounted in CASSETTE 2 transport.
3. Type the following commands: "RW2", "RL2", and "RC2".
4. Set all of the TI733 control switches except RECORD to LOCAL (lower row of switches).
5. Type (ESC)\$. The keyboard will respond with a carriage return-line feed. Type the search code (see Report Format above) including (CR) only--DRESSEN (CR) in the example (Figure 3).
6. Press PLAYBACK CONTROL-CONT START.
7. When the tape stops, press PAPER ADV to clear the terminal for the finished report. [A spare cassette may be mounted in CASSETTE 1 transport, RECORD, set to LOCAL, and RECORD CONTROL set to ON if a tape is to be prepared of this report only, to be duplicated later.]
8. Type the report heading.

9. Press PLAYBACK CONTROL-CONT START.
10. At the completion of each report block, type (ESC)\$ and press PLAYBACK-CONT START.
11. When the tape stops, press PLAYBACK-CONT START.
12. If pages are to be broken between blocks of reports, type the page number and any other page identification before Step 11.
13. If pages are to be broken within the block of a report, press PLAYBACK CONTROL-STOP during last line desired on the page. Press BLOCK FWD to complete the line. Type the page number and any other page identification, then press PLAYBACK CONTROL-CONT START.
14. Repeat Steps 10 through 13 until all report blocks coded to the desired customer code (DRESSEN) have been dumped from tape. It is advisable to mark the samples reported on the "Log Sheet" (Figure 2) as they are dumped from tape to be assured none are lost. It is also a convenient point at which charges or billing can be assembled.

Calculations

None.

Checks

Finished report.

BREMSSTRAHLUNG ANALYSIS

Instruction

CNTRL X (or Z).

Control Entry

Bremsstrahlung analysis will not be performed unless there is an entry in the Bremsstrahlung Table. This table is entered after the Isotope Table in the QI Table by typing a space (@) instead of an isotope name or through the editor routine by typing "QMB@" and the line number. The maximum number of entries is 2 (Figure 6).

The program stores the average net noise continuum channel content (see Determination of Net Peak Area) of the first 7 peaks (14 values) and of the 16th peak (2 values) of the entries in the QI Table (Figure 6). Net values are obtained for the first 14 entries by averaging the last 2 values and subtracting that value from the individual gross average values. The most recently stored continuum values may be accessed by typing "QRG".

A test is performed using the 5th through the 10th continuum values. Values 5 and 6 are averaged and assigned the "IP" code (see Determination of Net Peak Area) value associated with the 3rd isotope in the QI Table, CO 57 in R500 (Figure 6). The 7th and 8th values are averaged and assigned the IP value for CE144. The 9th and 10th values are averaged and assigned the IP value for U 235. The best least square fit through these three points is derived and the energy intercept in channels determined.

If there is no entry in the Bremsstrahlung Table or if the intercept determined above is outside Channels 200 to 1000, the calculation of Bremsstrahlung is terminated.

Calculation

If the intercept is between Channels 200 and 1000, the first 14 net values listed by the QRG command are summed and divided by the acquisition time and the "BD" value (see Random Summing Correction). The resultant value is a Net Peak Area to be treated like any other Net Peak Area. Its value is listed as the 17th value printed in response to the QRG command. It is assigned an IP value equal to the intercept divided by three for any calculation involving attenuation correction. Net Peak Areas having an intercept between 200 and 450 are assigned the isotope name in the first line of the Bremsstrahlung Table. Intercept values between 451 and 1000 are assigned the isotope name in the second line of the Bremsstrahlung Table. Obviously the search areas and order of isotopes in the QI Table will radically affect the BN values and the intercept values in the Bremsstrahlung calculation. We have standardized on the principal peaks of AM241, EU155, CO 57, CE144, U 235, CE141, CE139, and CS134 for the first 7 and 16th isotopes, respectively. [We are primarily interested in TC 99 or PM147 and SR 90 and these search locations work.] Different pure beta emitters might require a different search pattern or different intercept values.

Checks

The command QRG will read out the current 14 net continuum values, the two gross continuum values used as continuum values in the calculation of Net Area and the Net Peak Area used in the calculation of Bremsstrahlung Activity, in that order.

CALIBRATION

Calibration is not a separate mode of operation or a separate program routine. It involves the reevaluation of units in any of the existing routines.

Instruction

CNTRL X (or Z).

Control Entry

QI Table. Entry to the BN factor of the QI Table has been the easiest entry point to secure calibration data.

Calculation

In the calculation of Activity With or Without Time Correction

$$\text{Activity} = \frac{\text{Net Area} \cdot \text{BN} \cdot \text{GEO} \cdot e^{\lambda T}}{\text{UF}}$$

where

$\text{BN} = \text{Eff}^{-1}/\gamma/d$, the multiplier from the QI Table.

$$\text{If Eff} = \frac{\text{Net Area} \cdot \text{GEO} \cdot e^{\lambda T}}{\text{UF}} \cdot \frac{1}{d/s/ml@T_0 \cdot \gamma/d}$$

$$\text{then BN} = \frac{1}{d/s/ml@T_0 \cdot \gamma/d}$$

where $d/s/ml@T$ = the activity per milliliter of the calibration standard solution at time zero

and

UF = the standard aliquot size in milliliters.

This mode of application requires limits of search to be in the QI Table for each peak to be processed. Multiple

isotopic sources may be used because the time correction, GCF, random summing correction, half-lives, WV and GEO, are natural values.

In another mode:

$$\frac{1}{BN} = \text{Eff} \cdot \gamma / d = \frac{\text{Net Area} \cdot \text{GEO}}{\text{Activity@T}}$$

In this mode wide search areas can be set to automatically locate the highest channel content within the range. QRC can then be utilized after the calculation to read back the IP values for the peaks calculated. To use this mode of calibration:

- Activity must be entered as d/s at the Time of Count utilizing either WV or UF as entry vehicles.
- The calculation is valid for only one isotope at a time in the range of search.
- Half-life values in the QI Table are ignored and no half-life correction is called for.
- All QG and QT Table entries operate normally.

This mode is useful in the calibration of Bremsstrahlung emitters when the QI Table is set in the standard form for Bremsstrahlung Analysis.

Additional manipulation of units can result in entries for the GU Table of the QG Table, either sorption or geometry function values.

Figure 8 illustrates the calibration data filed for each acquisition system and each peak. The theory behind these cards is that any given value should have to be calculated only once. The first line contains the energy of the peak in keV, the isotope name, the QI Table search range

661.638 keV		¹³⁷ Cs	1319-1326	T _{1/2} = 11041	days
0.8458		y/d	Eff-1 = 1012.65		
Y = 0.941	Z = 0.8988		.022"Cd = 0.964067		
1:1	70.810	1	0.328		
1:2	466.715		0.086		
1:3	1197.3				
25	742.5				
65					
500					
700					
T1					
T2	577.51				
2:1					
1/4:1	59.188	Y	0.423		
1/4:2	390.11		0.152		

FIGURE 8

SAMPLE CALIBRATION CARD

1319-1326 ARE THE SEARCH LIMITS FOR THE PEAK IN CHANNELS.

Y = BRANCHING RATIO Z = INTERNAL CONVERSION RATIO

$$y/d = \frac{y \cdot z}{d}$$

.022"Cd IS THE EXTERNAL SORPTION FACTOR FOR THAT AMOUNT OF CADMIUM, A DIVIDING FACTOR.

THE FIRST COLUMN CONTAINS "BN" VALUES, THE SECOND "R/S" VALUES, AND THE THIRD, FRACTION OF SPHERE VALUES

and half-life in days, and the letter(s) code of the detector system. The second line contains the gamma per disintegration value and the inverted efficiency for the primary calibration geometry for the acquisition system, 1:3 or 1" diameter flat mount at Position 3 (for "C" detector). The third line contains the branching ratio (Y) and the internal conversion (Z) as a ratio such that the γ in γ/d equals $Y \cdot Z$ and finally the sorption factor for a 22-mil cadmium external sorber as a dividing factor. The latter value is utilized when internal and external sorption corrections must be applied in the same data reduction.

The three columns of data corresponding to source size and distance notations are the QI Table "BN" values, R/S values, and the fraction of sphere (F) values or the BN/BN ratio used in "Peak Interference Correction" calculations. The R/S value is the ratio of net peak areas of a noncoincident peak to the coincident peak at the same energy. The fraction of sphere (F) value in a point source-single detector geometry is the solid angle between them expressed as a fraction of a sphere. It becomes more complex with multiple detectors and bulk samples. The values Y, Z, R/S, and F are used in the program COICOR^[7] to correct for true coincidence. This correction is applied in all geometries within two detector diameters or to bulk sample geometries that vary the fraction of sphere (F) value. The R/S value is a multiple factor and can be determined either through direct calibration (the preferred method) or through COICOR^[7] if the sources are not available. The point is that it need not be recalibrated every time a branching ratio value is changed or an efficiency curve is reassessed.

To facilitate updating, all entries on the calibration cards are made in pencil. The reverse side of the

calibration cards contain a listing of the other peaks emitted by the subject isotopes and their γ/d values. Cross-section data will be integrated into these cards as necessary.

A master file of isotopic emitters is maintained with the accepted values of peak energy, branching ratio (Y), internal conversion factor (Z), half-life, and gamma-gamma coincidence. The master file is kept updated at all times. The calibration data cards are updated as the QI Tables are updated.

Checks

QRC will list the IP values of the peaks most recently calculated, together with their associated Net Peak Areas. These values may be used for manual calculations if desired; QRF will list the counting precisions (2σ) for the peaks most recently calibrated.

MISCELLANEOUS PROGRAM COMMANDS

(CNTRL)D	will terminate any operation and return control to the program. Where the computer cannot accept control, the program may have to be reinitiated at starting address 38.
(Rubout)	will delete any <u>incompletely</u> entered alphanumeric code. Retype corrected code from the beginning. Completed codes cannot be deleted except by typing (CNTRL)D and restarting the entire command chain.
C@B@	Entry to the calibrate table. The present table (if any) will be printed followed by three asterisks. If the present table is satisfactory, type the letter "K" meaning 'keep'; but if a new table is desired, type the letter "N". The computer will then ask for channel number and the corresponding energy.

NOTE: The channel numbers must be in ascending order. Up to 10 channels and energies may be entered.

E@PA@ Gives the energy of the intensified peaks in memory as calculated from the above table.

IK@ Removes all computer set intensification.

J@ Display expansion routine.
Commands and effects are as follows:

- "A" Start of expanded region given by TTY.
- "B" Print boundaries of intensification within region.
- "C" Crossover of intensification within region to computer intensification.
- "D" Move start of region down by amount designated.
- "I" Start region at first intensified region shown when in normal CRT scan.
- "K" Kill computer intensification from presently intensified region.
- "L" Width of region to be entered from TTY.
- "P" Print centroid of intensified peak in region.
- "R" Return to previous normal expansion.
- "S" Scan continuously to start of expanded region.
- "U" Move start of region up by amount designated.
- "V" Place memory in visual (CRT) scan mode.
- "X" Print limits of entire expanded region.
- "(" Move start of region down by amount designated by previous "D" command.
- ")" Move region up by amount designated by last "U".

K@ Kills the data in all channels. Does not affect intensification.

O@R@(ADDRESS)@ Gives the contents of the address in decimal.

O@W@(ADDRESS)@(NUMBER)@ Places the given integer

number at the address.

P@A@ Prints the addresses of the boundaries of the intensified regions.

P@G@(START)@(STOP)@ Prints the contents of the addresses.

P@I@ Prints the contents of the intensified regions.

RB Set cassette (on TI terminal) currently in the "READ" mode in motion to read one block from tape.

RC1 Set #1 (left-hand) cassette to read mode.

RC2 Set #2 cassette to read mode.

RL1 Advance #1 cassette to load point.

NOTE: Use the commands to advance to load point only if the tape is currently on clear leader at the beginning of tape.

RL2 Advance #2 cassette to load point.

RP Set read cassette to the continuous playback mode. Printing will continue until the "X-OFF" character is encountered.

RS(CODE)↑Q Search for the designated "CODE" (up to 16 characters). Terminate the "CODE" entry by typing a "↑Q" (CTRL,Q).

RV Reverse read cassette one block.

RW1 Rewind cassette #1.

RW2 Rewind cassette #2.

V@ Places the memory in visual (CRT) display mode.

Y@(START ADDRESS)@(NUMBER OF BLOCKS)@ Input data from the NS-111A and place the number of blocks (256 channels/block) desired in NS-636 core starting at the location specified.

Z@(START)@(STOP)@ Zeros (erases) the contents of addresses from START to STOP.

Instructions for Using the Texas Instruments ASR733 as A
Program Source in the NS-660 System

Generating a loader in boot format on tape:

- A1. Load the paper tapes marked "Boot Format Punch" and "Absolute Loader-ASR733" into the Nova using the Nova Binary Loader.
- A2. Reattach the ASR733 to the Nova.
- A3. Follow the directions on the program writeup for the "Boot Format Punch" to dump the "Absolute Loader-ASR733" to tape.

The loader has now been generated. A number of loaders can be generated at this time by following Step A3.

Loading the "Absolute Loader-ARS733":

- B1. Toggle the ASR733 bootstrap routine into core. Note that this replaces the paper tape bootstrap routine.
- B2. Place a cassette generated by Step A3 into the ASR733 and set that drive to the read mode.
- B3. Disable the Remove Device Control (RDC). Start the bootstrap loader at address 17766.
- B4. The tape will be read. Since the RDC is disabled the tape must be stopped manually after the computer halts.
- B5. Enable the RDC.

The "Absolute Loader--ASR733" is now in core and can be used to both read and write programs using the ASR733.

Note: An alternate starting address for the input routine of the "Absolute Loader--ASR733" is location 17777.

ACKNOWLEDMENTS

The author wishes to recognize the contributions of Robert N. Erickson of Northern Scientific, Inc., for his

patience, cooperation, and programming; of Vernon W. Hall for assistance in testing and applying the GXDR concept; and to Eleanore Earhart for outstanding editorial and manuscript assistance in the preparation of this document.

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