BALANCED IONIZATION CHAMBER FOR DIFFERENTIAL MEASUREMENTS OF GAMMA RAYS

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Balanced Ionization Chamber for Differential Measurements of Gamma Rays

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The purpose of the work was to develop a method of measuring very small differences in the half lives of gamma ray emitting radioactive substances. The apparatus was then used to try to detect a difference in the half lives of Be\textsuperscript{7} metal and BeO. The results of the measurements on the two different chemical forms of beryllium will be given.

The method of balanced ionization chambers can also be used to measure in a short time the half lives of long life substances. Results on the measurement of the half lives of 106 day yttrium and Be\textsuperscript{7} will also be reported.

The statistical fluctuations in the net activity of two nearly equal samples in the balanced arrangement will be discussed to show that the fluctuations observed are those to be expected from the random nature of the ionization events.

The schematic arrangement of the apparatus is shown in Figure 1. It consists of two argon filled ionization chambers made as nearly equal as possible. The collecting electrodes of the two chambers are connected together and to the input of a conventional electrometer circuit using a General Electric type FP-54 pliotron. The collecting potential for the chambers is taken from a dry cell battery pack delivering potentials of +400 volts and -400 volts. The polarities of the collection voltages are chosen so that the ionization current in one chamber opposes the ionization current in the other chamber. Thus, equal samples placed in the chambers will cause no deflection of the galvanometer of the electrometer circuit. With this differential arrangement very small differences in the activities of two large samples can be measured.
In order to determine the performance of the system, a sample of Be\textsuperscript{7} was adjusted to nearly the same strength as a sample of radium in equilibrium with its radioactive products and these two samples were compared in the balanced ionization chambers. The strength of the radium sample remains constant whereas the Be\textsuperscript{7} diminishes in activity. A graph of the decrease in activity of the Be\textsuperscript{7} versus time is shown in Figure 2. From this graph the half life of Be\textsuperscript{7} is determined from the slope of the activity line to be 52 days.

The importance of the half life measurement part of the experiment lies in the discovery that the half life of the substance under investigation can be determined to a fair degree of accuracy in a time of observation extending over only a few percent of the entire half life of the sample.

The decay period of 106 day yttrium was also checked by this method.

Discussion of statistical fluctuations:

Observations of the rate of drift of the galvanometer when two nearly equal sources of Be\textsuperscript{7} were placed in the balanced ionization chambers were taken over many 600 second intervals. The error in the results of a series of observations was determined by the usual mean squares method.

The following definitions will be used:

\[ A = 300 \text{ mm/sec} = \text{rate of drift when only one of the sources is in either chamber.} \]
\[ \langle \overline{v} \rangle = 50 \times 10^{-4} \text{ mm/sec} = \text{average of the sum of the squares of the residuals for a series of observations.} \]
\[ N = \text{the number of steps required to arrive at a certain deflection.} \]
\[ d = \text{the average length of each step.} \]

The total deflection for one observation is given by \( A \times T = 1.8 \times 10^5 \text{ mm}. \)

The average residual is the square root of \( \langle \overline{v} \rangle \); which is \( \pm 7 \times 10^{-2} \text{ mm/sec}. \)

Observed for 600 secs. the average \( v = \pm 42 \text{ mm}. \) Also we know that \( N \times d = 1.8 \times 10^5 \text{ for one observation.} \)
The error in $N$ is proportional to the square root of $N$, while $N$ is, in turn, proportional to the number of ionization events. We know that the average error is $\pm 42$ mm and therefore we may write $d\sqrt{2N} = \pm 42$. The factor 2 reflects the fact that 2 sources contribute to $N$ in the balanced arrangement.

From the two equations for $N$ and $d$, we find $d = 0.005$ mm. To check this value, we assume a loss of energy of 400 Kev for each gamma ray emitted by Be$^7$. From a knowledge of the electrical capacitance of the system and the ionization potential of argon we calculate that one gamma ray can cause a deflection of 0.015 mm. This is the same order of magnitude as the $d$ found above but is somewhat higher because the average energy loss for Be$^7$ gamma rays in the chambers would not be as high as 400 Kev.

The results of the observations on Be$^7$ metal and BeO are shown by the graph of Figure 3. The data is plotted in such a way that if there is an observable difference in the half lives of the two Be$^7$ sources, it will be indicated by the slope of a straight line passed through the triangular points. The mean squares analysis of the data gives the difference in half lives:

$$\frac{\Delta \lambda}{\lambda} = -1.57 \times 10^{-4} \pm 2.27 \times 10^{-4}.$$

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Fig. 1
SCHEMATIC DIAGRAM OF
BALANCED IONIZATION CHAMBERS

- SOURCE HOLDER -

Lucite
3/4" Aluminum
BeO Ceramic or Crushed Be metal covered with wax

FP54 Electrometer Circuit

Galv.
Fig. 3 Observed Activities of Be$^7$ Sources in Balanced Chambers $\delta e^{\lambda t}$ vs Time

- No. 1 BeO-Be Metal
- No. 2 BeO-Be Metal
- Average of BeO-Be Metal

$\delta e^{\lambda t} = M_0 + M \frac{\Delta A}{\lambda} + t$

$M = 0$ - Initial activity of sources (270 mm sec$^{-1}$)

Solid line is best fit. Dotted line corresponds to $\frac{\Delta A}{\lambda} = 10^{-3}$
Fig. 3: Observed activities of Be\textsuperscript{7} sources in balanced chambers; \( e^{\lambda t} \) vs. time

- ○ Na.1 BeO-Be Metal
- ○ Na.2 BeO-Be Metal
- △ Average of BeO-Be Metal

\[ e^{\lambda t} = M_0 + M \frac{\Delta A}{\lambda} t \]

\( M = 0 \) = Initial activity of sources (270 mm sec\(^{-1}\))

Solid line is best fit. Dotted line corresponds to \( \frac{\Delta A}{\lambda} \times 10^{-3} \)