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UNITED STATES ATOMIC ENERGY COMMISSION

**EQUATIONS USED FOR CALCULATION OF
DATA BY THE FEEDBACK METHOD**

By

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EQUATIONS USED FOR CALCULATION OF DATA BY THE FEEDBACK METHOD

Introduction

In order to acquaint the technical personnel with the fundamentals of the feedback method of assaying samples of TF_6 , a simple derivation of the equation is given. In using this method of assay, an unknown sample is determined by comparison with a standard sample of known isotopic ratio.

"Method of Calculation of Feedback Method of Analysis for C616 Composition," Col. Ser. No. 1F1-R557, A-2185, December 29, 1944, by M. G. Inghram, B. Y. Rustad and M. Fox, shows mathematically that the feedback method may be used to cover the entire range of isotopic ratios. In actual laboratory practice, this does not hold true, because the memory effect of the instrument invalidates the data when the unknown sample differs very widely from the standard. In this laboratory it is felt that a 50 percent difference in isotopic ratio between unknown and standard is the safe limit for a feedback assay which is to be reported as having a limit of error of 1 percent of the weight percent x reported. Therefore, the feedback method of assay is reserved for only those samples which differ from natural material by a small amount, and for which this small amount must be determined very accurately. It has been found practical to extend the useful range by using a secondary standard of approximately 1.0 weight percent x . This secondary standard has been very carefully assayed by many determinations, both by feedback comparison with natural material and by absolute determination by the slideback method.

Derivation

Figure 1 illustrates the conditions that exist for feedback operation. The receiver slit is opened so that 95 to 100 percent of the x beam (R) falls through and strikes the collector plate, while the y beam (Q) falls on the surface of the slit plate. The intensity of the x beam is measured by the FP-54 amplifier as a voltage across R_x , expressed in terms of deflection of the galvanometer. Since the FP-54 amplifier is linear over the range used, the galvanometer deflection is proportional to the x beam intensity.

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Chief, Declassification Branch <u>at</u>

1. $x = D \cdot N_x$
 where $x = x$ beam intensity
 $D =$ galvanometer deflection
 $N_x =$ proportionality constant for the amplifier.

The y beam intensity is measured by the total feedback amplifier which is sufficiently linear to insure that the feedback meter reading is proportional to the intensity of the y beam.

2. $y = I \cdot N_y$
 where $y =$ intensity of the y beam
 $I =$ intensity in units as measured by the feedback meter
 $N_y =$ proportionality constant for the amplifier.

The w component is neglected for the range of material determined by feedback in this laboratory.

The feedback voltage, which is equal to the voltage across R_y , is impressed across the precision potentiometer R_p . The bottom of resistor R_x is connected to the sliding contact of R_p so that it is possible to select a position that will provide the correct portion of the entire feedback voltage to buck out completely the voltage across R_x , except for a small remaining galvanometer deflection d . The portion of the feedback voltage used may be expressed as $(a/b) I$. Therefore, when the x is bucked out in feedback operation

3. $D \cdot N_x = (a/b) I \cdot N_y + dN_x$
 where $a/b =$ the fraction of I used to buck out the x .

It is desired to determine the percentage difference in the ratio of x/y between the standard and unknown with respect to the ratio of the standard, thus

4.
$$P = \frac{\frac{x_2}{y_2} - \frac{x_1}{y_1}}{\frac{x_1}{y_1}} (100)$$

where $\frac{x_1}{y_1} =$ mole ratio for the standard
 $\frac{x_2}{y_2} =$ mole ratio for the unknown.

This may be rewritten

5.
$$P = \left[\frac{\frac{x_2}{y_2}}{\frac{x_1}{y_1}} - \frac{\frac{x_1}{y_1}}{\frac{x_1}{y_1}} \right] 100$$

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Substituting from equations 1 and 2

$$6. \quad P = \left[\frac{\frac{D_2 \cdot N_x}{I_2 \cdot N_y}}{\frac{D_1 \cdot N_x}{I_1 \cdot N_y}} - \frac{\frac{D_1 \cdot N_x}{I_1 \cdot N_y}}{\frac{D_1 \cdot N_x}{I_1 \cdot N_y}} \right] 100$$

Dividing by $\frac{N_x}{N_y}$, 6 becomes

$$7. \quad P = \left[\frac{\frac{D_2}{I_2}}{\frac{D_1}{I_1}} - \frac{\frac{D_1}{I_1}}{\frac{D_1}{I_1}} \right] 100$$

The value for the ratio of $\frac{D_1}{I_1}$ is determined by running the standard sample in the instrument and noting the intensity reading for the y and the galvanometer deflection for the x, without bucking out the x peak. Thus we may establish

$$8. \quad K = \frac{D_1}{I_1}$$

Multiplying numerators and denominators of 7 by K

$$9. \quad P = \left[\frac{\frac{D_2}{K \cdot I_2}}{\frac{D_1}{K \cdot I_1}} - \frac{\frac{D_1}{K \cdot I_1}}{\frac{D_1}{K \cdot I_1}} \right] 100$$

Since $K \cdot I_1 = D_1$, from equation 8, the denominators of 9 become unity and

$$10. \quad P = \left[\frac{D_2}{K \cdot I_2} - \frac{D_1}{K \cdot I_1} \right] 100$$

Substituting from equation 3

$$11. \quad P = \left[\frac{\left[\frac{(a/b)_2 \cdot I_2 \cdot N_y}{K I_2 N_x} + \frac{d_2}{K \cdot I_2} \right]}{\left[\frac{(a/b)_1 \cdot I_1 \cdot N_y}{K I_1 N_x} + \frac{d_1}{K \cdot I_1} \right]} - \frac{\left[\frac{(a/b)_1 \cdot I_1 \cdot N_y}{K I_1 N_x} + \frac{d_1}{K \cdot I_1} \right]}{\left[\frac{(a/b)_1 \cdot I_1 \cdot N_y}{K I_1 N_x} + \frac{d_1}{K \cdot I_1} \right]} \right] 100$$

which becomes

$$12. \quad P = \left[\frac{\frac{(a/b)_2 \cdot N_y}{K \cdot N_x} + \frac{d_2}{K I_2}}{\frac{(a/b)_1 \cdot N_y}{K \cdot N_x} + \frac{d_1}{K I_1}} - \frac{\frac{(a/b)_1 \cdot N_y}{K \cdot N_x} + \frac{d_1}{K I_1}}{\frac{(a/b)_1 \cdot N_y}{K \cdot N_x} + \frac{d_1}{K I_1}} \right] 100$$

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Since the potentiometer setting is the same for the standard and for the unknown and the difference is noted only by galvanometer deflection, $(a/b)_1 = (a/b)_2$ and 12 become

$$13. P = \frac{d_2}{KI_2} (100) - \frac{d_1}{KI_1} (100)$$

Figure 2 graphically illustrates the values used, showing the unknown superimposed on the standard. The y peaks are given in units of Intensity, I_1 and I_2 . The x peaks are given in terms of Galvanometer Deflection, D_1 and D_2 . D_1 for instance is the sum of $(a/b) I_1 + d_1$.

Since $(a/b) I_1$ and $(a/b) I_2$ drop out of the final equation because they are equal proportions of y_1 and y_2 respectively, there remain only the parts d_1 and d_2 to consider.

In equation 13, the value of KI_1 gives the value of the x peak for the standard, while KI_2 represents the value that the x peak would be for a standard whose y peak is equal to I_2 .

Therefore, a correction has been made to compensate for the difference in intensity between the standard and the unknown, and equation 13 represents the difference in heights of the x peaks of the standard, divided by the height of the x peak of the standard, giving percentage difference of x content with respect to the standard.

Equation 13 is used for the routine calculation of the percentage increase or decrease in x content of a sample as compared with the standard.

Calculation of Wt. % X

The calculation of the x content expressed in terms of weight percent of x, "Calculation of X Content from Data Obtained by AT Feedback Determinations," March 7, 1946, CD-336-191, by A. E. Cameron and G. P. Happ, is given as

$$14. \frac{\text{Wt. } x_2 (100)}{\text{Wt. } x_2 + \text{Wt. } y_2} = \frac{N (100)}{N + 140.8}$$

The enhancement N is defined as

$$15. N = 1 + \frac{P}{100}$$

Therefore, substituting 15 in equation 14

$$16. \text{Wt. \% } x = \frac{100 + P}{1 + \frac{P}{100} + 140.8}$$

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The routine of instrument operation and the routine of calculating operations are given in the Standard Procedures Manual.

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figure 1.

figure 2.

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