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CONVENTIONS IN EXPRESSING ISOTOPIC COMPOSITION OF URANIUM SAMPLES, AVERAGE ATOMIC WEIGHTS

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The following discussion is written for the convenience of those handling Y-12 product; it presents some of the conventions used in expressing isotopic composition and suggests an atomic weight scale for use in connection with mixtures of varying isotopic constitution.

In describing these mixtures it is necessary to specify the relative amounts of 24, 25, and 28. At least four different methods of description are in current use. The percentages of the various constituents may be expressed on either an atomic or a mass basis; alternatively two ratios between the amounts of the three different components may be given on either an atomic or mass basis.

(1) R and S - These quantities have been used to express the results of assays by neutron methods at Berkeley and at Site Y.

Definition: $R = \frac{\text{mass of 28}}{\text{mass of 25}}$ in a given sample

$S = \frac{\text{mass of 25}}{\text{mass of 24}}$ in a given sample

(2) r and s - Mass spectrometer determinations are often expressed in terms of atomic ratios. The symbols r and s are proposed for the ratios in question.

Definition: $r = \frac{\text{No. of atoms of 28}}{\text{No. of atoms of 25}}$ in a given sample

Definition: $s = \frac{\text{No. of atoms of 25}}{\text{No. of atoms of 24}}$ in a given sample

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(3) Mass percent -

Definition: $100\, a_i = 100\, (m_i / \sum_i m_i)$ = mass percent of i^{th} component (i = 24, 25, 28) where m_i is the mass of the i^{th} component in a given sample.

(4) Atomic percent -

Definition: $100\, x_i = 100\, (n_i / \sum_i n_i)$ = atomic percent of i^{th} component, where n_i is the number of atoms of the i^{th} component (i = 24, 25, 28) in a given sample.

RELATIONS BETWEEN THE ABOVE QUANTITIES

$$R = \underline{r}\, \frac{238.08}{235.07} = \underline{r} \times 1.0128$$

$$S = \underline{s}\, \frac{235.07}{234.06} = \underline{s} \times 1.0043$$

$$\text{mass fraction } 24 = a_{24} = \frac{1/S}{1 + R + 1/S}$$

$$\text{mass fraction } 25 = a_{25} = \frac{1}{1 + R + 1/S}$$

$$\text{mass fraction } 28 = a_{28} = \frac{R}{1 + R + 1/S}$$

$$\text{atomic fraction } 24 = x_{24} = \frac{1/\underline{s}}{1 + \underline{r} + 1/\underline{s}}$$

$$\text{atomic fraction } 25 = x_{25} = \frac{1}{1 + \underline{r} + 1/\underline{s}}$$

$$\text{atomic fraction } 28 = x_{28} = \frac{\underline{r}}{1 + \underline{r} + 1/\underline{s}}$$

let M_i = atomic weight of i^{th} constituent

$\bar{M}$ = average atomic weight of sample

$$\bar{M} = \sum_i x_i M_i$$

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$$a_i = x_i(M_i/\overline{M}) = x_i(M_i/\sum_i x_i M_i)$$

$$x_i = a_i \frac{1}{M_i\left(\sum_i(a_i/M_i)\right)}$$

In mass spectrometer data, the amount of 24 is often not given. In this case a reasonable assumption for present racetrack material is that s is constant and equal to 122. Then,

$$\overline{M} = x_{28} M_{28} + x_{25} M_{25} + (x_{25}/122) M_{24}$$

$$= x_{28} M_{28} + x_{25} (M_{25} + M_{24}/122)$$

CHEMICAL ATOMIC WEIGHTS OF 24, 25, 28 AND THEIR MIXTURES

The following packing fractions are given by Hahn, Flügge, and Mattauch[1]:

Isotope	(M - A)/A	Calculated Atomic Weight: Physical Scale (O^{16} = 16,000....)	Calculated Atomic Weight: Chemical Scale (Normal Oxygen = 16,000....)
24	5.51×10^{-4}	234.12_9	234.06
25	5.70×10^{-4}	235.13_4	235.07
28	6.08×10^{-4}	238.14_5	238.08

The fourth column is obtained from the third by dividing by 1.000275.

From Nier's mass spectrometer assays of normal material (r = 139, s = 17000), we obtain

$x_{24} = 0.00005_{85}$ for normal uranium

$x_{25} = 0.0071_{42}$ for normal uranium

1) Physik. Z., 41, 1-14 (1940)

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$x_{28} = 0.992_{799}$ for normal uranium

Using these values and the above atomic weights, the calculated chemical atomic weight of normal uranium is 238.06 (cf. 238.07, Int. Chem. At. Wt.).

It is fully realized that the above numbers contain a greater number of figures than our experimental knowledge justifies. It seems worthwhile, however, purely for the sake of consistency, to adopt a given set of values for the atomic weights of the uranium isotopes and for the composition of normal uranium, especially when stoichiometric calculations are made for large samples. The above numbers are proposed for this purpose.

The above numbers and relations have been kindly checked by Dudley Williams and Gerhart Friedlander.

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