ABSOLUTE MEASUREMENT OF A TRITIUM STANDARD

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For the determination of a tritium absolute activity standard, a method of internal gas counting has been used. The procedure involves water reduction by uranium and zinc and measurement of the absolute disintegration rate of tritium per unit of the effective volume of the counter by a compensation method. A brief description of the measuring apparatus is given, as well as a critical discussion of the brass counter quality and the possibility of obtaining equal working conditions at the counter ends.

Introduction

Standard nuclear methods generally applied for the measurement of ionizing radiation can also be used for $^3$H detection. However, the choice of method is restricted already in the case of standard source thicknesses (0.1 mg/cm$^2$) due to high absorption losses of $^3$H beta radiation. The absorption value can be calculated approximately.$^{1,2}$ The accuracy of experimental determination is low and depends on the kind of layer used. Due to these restrictions, $^3$H is detected by special methods, such as scintillation and internal gas counting, which do not cause deformation of the $^3$H beta spectrum.$^{1-3}$ The natural $^3$H content of water is measured, relatively, by the liquid scintillation or internal gas counting methods. Therefore, a $^3$H standard is required for calibration of the detector, with an activity known to within 2%.$^{1,3-5}$ An absolute measurement of the $^3$H standard activity by the method of internal gas counting is presented in this paper.

Experimental

Quantitative relationships

Water activity is obtained by establishing a quantitative relationship between the mass and activity of hydrogen in the liquid and the gas phase.
Hydrogen activity in these phases is directly proportional to the product of hydrogen mass and \(^3\text{H}\) concentration:

\[
A = \frac{N_a}{M_T} \cdot \lambda_T \cdot m_{\text{H}_2} \cdot c_T
\]

\[
A' = \frac{N_a}{M_T} \cdot \lambda_T \cdot m_{\text{H}_2} \cdot c_T'
\]

where
- \(N_a\) – the Avogadro number,
- \(M_T\) – the molecular weight of tritium,
- \(\lambda_T\) – the radioactive decay constant,
- \(m_{\text{H}_2}\), \(m_{\text{H}_2}'\) – the hydrogen masses in the liquid and the gas phases, respectively,
- \(c_T, c_T'\) – the corresponding tritium concentrations per g of hydrogen.

By definition, the \(m_{\text{H}_2}/m_{\text{H}_2}'\) ratio is the yield, \(K\), in the chemical reaction of hydrogen transfer from the liquid into the gas phase and \(c_T/c_T'\) is the coefficient, \(K_1\), characterizing tritium distribution during this transfer. With the exception of quantitative reactions, this distribution is not equal due to the difference in the reaction rates of hydrogen and tritium molecules.\(^5,8\) Therefore the specific activity of HTO on the basis of Eqs (1) and (2) is:

\[
A_{sk} (\text{dps/g}) = \frac{1}{K_1} \cdot K \cdot m \cdot \frac{V}{V_c} \cdot A_c
\]

where
- \(A_c\) – the absolute disintegration rate in the effective volume of the counter,
- \(V, V_c\) – the gas volume and working volume of the counter, respectively,
- \(m\) – the mass of the HTO sample.

The mass of water can be measured in two ways: directly, gravimetrically; and indirectly, by determining gas parameters, pressure (\(p\)), volume (\(V\)) and temperature (\(T\)) from the equation of state for an ideal gas.

A second independent equation for HTO specific activity has been developed on this basis:

\[
A_{sp} (\text{dps/g}) = \frac{1}{M_{\text{H}_2} \cdot \rho} \cdot K_1 \cdot \frac{RT}{\rho g} \cdot \frac{[r - l] + \Delta}{A_c/V_c}
\]