CHARACTERISTICS OF PLASTIC SCINTILLATOR GRANULES

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Methods are described for measuring the absorption coefficient of the material, the absorption coefficient of a layer of granules, and the scintillation performance. The theory of light diffusion in a scattering medium is used and is compared with experiment.

Granulated plastic scintillator is used for internal counting of radioactive liquids, especially aqueous solutions of β-emitters [1, 2], the solution being poured into a flat-bottomed vessel containing a layer with p g/cm² of granules. The vessel is placed on a photomultiplier, with the scalar operated with a simple discriminator. The most important characteristics are the efficiency E (count/disintegration) and the counting volume v (ml/cm²), i.e., the volume that can be used with a specified counting efficiency.

Tests have shown that standard equipment used with a FEU-19 photomultiplier and granules with r ≈ 170 µm will give an efficiency for C¹⁴ of about 35% even in amounts as small as 0.1 µM [3].

The scintillation light is absorbed by the layer, so the effective absorption may be characterized by a factor x, which tends to a limit as the thickness increases; E at the same time decreases.

Table 1

<table>
<thead>
<tr>
<th>Medium</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = n₀/n₁</td>
<td>1</td>
<td>1.33</td>
<td>1.50</td>
</tr>
<tr>
<td>I' (µA · cm² · g⁻¹)</td>
<td>0.48</td>
<td>0.70</td>
<td>0.90</td>
</tr>
<tr>
<td>I₀ (µA)</td>
<td>0.085</td>
<td>1.135</td>
<td>0.23</td>
</tr>
<tr>
<td>x (cm² · g⁻¹)</td>
<td>6.2</td>
<td>5.8</td>
<td>3.9</td>
</tr>
</tbody>
</table>

The v for a given β emitter and discriminator setting increases with the scintillation efficiency η of the granules and the technical light yield τη, while it is inversely related to x.

E should increase as r is reduced (due to reduction in self-absorption in the liquid), as is found with thin layers (with little light absorption); the fall in E as p increases is the more rapid the greater or (as will be shown below) the smaller r.

The theory of such detectors has been discussed [4], and it has been shown that E is governed by r, x, and η for a given radiation source and given discriminator threshold. Granule testing must therefore include measurement of η and x for the r appropriate to the problem. The arguments given here are for this case, the directly measured quantity being the photocurrent I, which is proportional to the light flux F at the cathode.

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Theory. The transmission of light through the layer to the cathode is a diffusion process, each particle being a center characterized by scattering and absorption cross sections \( \sigma_s \) and \( \sigma_a \). The corresponding quantities of 1 g of granules and \( \Sigma_s \) and \( \Sigma_a \).

The transmission coefficient \( \tau \) for light falling from outside onto the layer of granules is given by theory [4] as

\[
\tau = \frac{F}{F_0} = \frac{I}{I_0} = \frac{1}{\chi \rho + \gamma \sh \rho},
\]

\[
\chi = \sqrt{3\Sigma_s \Sigma_a (1 - \mu)},
\]

\[
\gamma = \frac{(1 - r_1) (1 - r_2)}{2a (1 - r_1r_2)},
\]

\[
\alpha = \sqrt{\frac{4\sigma_a}{3\sigma_s (1 - \mu)}}.
\]

Here \( \mu \) is the mean cosine of the scattering angle produced by a particle, \( r_1 \) and \( r_2 \) are the reflection coefficients at the upper and lower boundaries of the layer, \( F \) and \( I \) are the light flux and current for a layer \( \rho \), and \( F_0 \) and \( I_0 \) are the same for \( \rho = 0 \).

It can be shown that for spherical particles with \( n = 1.5 \) and diameter \( d \)

\[
\chi = 1.67d^{-1/2}k^{1/2},
\]

in which \( k \) is the absorption coefficient of the material. If \( kp \gg 1 \),

\[
\ln \tau \approx \ln \frac{1 + \gamma}{2} - \chi \rho.
\]

To deduce the \( F \) due to a scintillation at a distance \( x \) from the photocathode we have to include the following factors,

\[
F = \eta t \frac{\beta}{\chi} \frac{\sh \chi \rho}{\chi \sh \chi \rho + \beta \ch \chi \rho},
\]

in which

\[
\beta = \frac{3}{2} \Sigma_s (1 - \mu).
\]

As \( F' \) is proportional to \( t \), the results for \( F' \) may be compared with Fig. 1 by bringing the points for \( n = 1.07 \) into coincidence (points in Fig. 1). Also, \( \eta \) was deduced as follows. The layer of granules was replaced by a plate of \( p \) g/cm\(^2\) of PS of the same composition, in the same vessel; the photocurrent \( I_s \) was measured. Then

\[
\eta = \frac{\eta_s}{\eta_s} = \frac{I' (0)}{I_0 \tau_s}.
\]