Two-channel Gamma Counting of Cr$^{51}$ and I$^{131}$

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Red blood cells are easily labelled with Cr$^{51}$ and blood plasma is readily tagged with I$^{131}$. However, the proximity of the principal gamma energies of these two isotopes complicates the use of differential pulse height analysis techniques for the measurement of doubly labelled blood. Instrumentation for accomplishing this procedure includes a 3 in. well-type scintillation counter operated with two single-channel differential pulse height analyzers. A method is presented for setting up two channels with the analyzers to obtain adequate separation of Cr$^{51}$ and I$^{131}$. A simple correction for the cross-channel activities is shown. The accuracy of the method is evaluated by the assay of mixed Cr$^{51} + I^{131}$ sources prepared gravimetrically.

COMPTANT À DEUX CANASEURS DES RAYONNEMENTS GAMMAS
DU Cr$^{51}$ ET DE I$^{131}$

Les globules rouges sont facilement marqués par Cr$^{51}$, et le plasma par I$^{131}$. Néanmoins, la proximité des énergies gamma principales de ces deux isotopes complique l’usage de l’analyseur d’impulsion différentiel pour mesurer du sang doublement marqué. Parmi les instruments qui accomplissent ce procédé il y a un crystal de 3 in. avec un puits qui a le diamètre d’une éprouvette accouplé dans deux analyseurs d’impulsions simultanés. On présente une méthode qui accomplit une séparation suffisante de Cr$^{51}$ et de I$^{131}$ à l’aide de deux canaux individuels accouplés avec un seul crystal à puits. La précision de cette méthode est évaluée par l’examen des sources de Cr$^{51}$ et I$^{131}$ mêlés qui ont été préparés d’une manière gravimétrique.

ДВУХКАНАЛЬНАЯ РЕГИСТРАЦИЯ ГАММА-ИЗЛУЧЕНИЯ Cr$^{51}$ И I$^{131}$.

Эритроциты легко метятся с помощью Cr$^{51}$, а плазма крови — с помощью I$^{131}$. Однако измерение активности крови с двойной меткой малы в энергиях основного гамма-излучения этих двух изотопов затрудняют их различение по методу обычной амплитудной дискриминации. Аппаратура для осуществления такой раздельной регистрации включает два одноканальных амплитудных анализатора импульсов с одним коллимированным триевымом сцинтилляционным счетчиком. Предлагается схема включения двух каналов, обеспечивающая раздельную регистрацию Cr$^{51}$ и I$^{131}$. Вводится простая неправка для учета взаимовлияния каналов. Точность метода определена экспериментально путем промера препаратов Cr$^{51} + I^{131}$ изготовленных в виде смесей с заданным соотношением компонент.

GAMMA-MESSUNG VON Cr$^{51}$ UND I$^{131}$ MIT ZWEI KANÄLEN

Rote Blutkörperchen kann man leicht mit Cr$^{51}$ und Blutplasma mit I$^{131}$ markieren. Jedoch die Nähe der prinzipalen Gamma-Energien dieser beiden Isotope erschwert die Anwendung der Differential-Puls-höhenanalysetechnik zur Messung doppelt markierten Blutes. Unter den Instrumenten zur Durchführung dieses Verfahrens befindet sich ein 3 in. schachhaltlicher Scintillationsdetektor mit dem zwei separate Kanal-Differential-Puls höhen-Analysatoren, ein jeder mit einem einzigen Kanal, verbunden sind. Es wird eine Methode gezeigt, bei der zwei Kanäle mit den Analysatoren eine ausreichende Trennung von Cr$^{51}$ und I$^{131}$ erlangen. Es wird eine einfache Korrektur für Kanalüberkreuzungsaktivität gezeigt. Die Genauigkeit der Methode wird durch die Bestimmung gemischter Cr$^{51} + I^{131}$ Quellen, die gravimetrisch vorbereitet sind, geprüft.
The authors wished to measure the relative flow rates of red cells and plasma in the dog with a well-type scintillation counter and with continuous sampling of blood doubly labelled with Cr\(^{51}\) and I\(^{131}\).

The principal photopeaks of Cr\(^{51}\) and I\(^{131}\) at 0.32 MeV and 0.364 MeV are too close together for convenient separation (Figs. 1 and 2). The 5.5 keV characteristic vanadium X-radiation from Cr\(^{51}\) K capture is below the detectable energy range of the well counter. Other investigators have used the 0.64–0.72 MeV photopeaks of I\(^{131}\) for two-channel counting,\(^{(1)}\) but the statistical accuracy of this method is limited because only about 12 per cent of the I\(^{131}\) decays through these energies.

For these reasons the authors have employed two single-channel precision differential pulse height analyzers, designed by FRANCIS\(^{(2)}\), to provide reasonably good separation of the principal Cr\(^{51}\) and I\(^{131}\) photopeaks as obtained from a 3 in. well-type scintillation counter. The no. 1 channel, for Cr\(^{51}\) (Fig. 3), is centered slightly towards the low-energy side of the 0.32 MeV photopeak. The no. 2 channel, for I\(^{131}\) (Fig. 4), is shifted toward the high-energy portion of the 0.364 MeV photopeak. With a pure Cr\(^{51}\) source

**Fig. 1.** Spectra of Cr\(^{51}\) and I\(^{131}\) obtained from 3 in. NaI well crystal.

**Fig. 2.** Channel positions for the simultaneous counting of Cr\(^{51}\) and I\(^{131}\).

**Fig. 3.** Relative response of the channels to a Cr\(^{51}\) source.
the counting rate on channel no. 1 is proportional to the area $R_1$ of Fig. 3. Some $\text{Cr}^{51}$ activity, proportional to the area $K_2R_1$, also appears on channel no. 2. With a pure $\text{I}^{131}$ source the counting rate on channel no. 2 is proportional to the area $R_2$ of Fig. 4. A small amount of $\text{I}^{131}$ activity also appears on channel no. 1, proportional to the area $K_1R_2$. With a mixed $\text{Cr}^{51} + \text{I}^{131}$ source the counting rate on channel no. 1 is proportional to the area $R_1$ from $\text{Cr}^{51}$ plus the superimposed area $K_1R_2$ from $\text{I}^{131}$. The counting rate on channel no. 2 is proportional to the area $R_2$ from $\text{I}^{131}$ plus the superimposed area $K_2R_1$ from $\text{Cr}^{51}$. These relationships are shown algebraically:

$$A_1 = R_1 + K_1R_2 = \text{total activity counted on channel no. 1},$$

and

$$A_2 = R_2 + K_2R_1 = \text{total activity counted on channel no. 2}.$$

It may be shown that

$$R_1 = \frac{A_1 - K_1A_2}{1 - K_1K_2} = \text{Cr}^{51} \text{ activity appearing on channel no. 1},$$

and similarly

$$R_2 = \frac{A_2 - K_2A_1}{1 - K_1K_2} = \text{I}^{131} \text{ activity appearing on channel no. 2}.$$

$K_2$ is easily obtained by dividing the counting rate on channel no. 2 by that of channel no. 1 when a pure $\text{Cr}^{51}$ source is placed in the well. Similarly, $K_1$ is measured by dividing the rate on channel no. 1 by that of no. 2 when counting a pure $\text{I}^{131}$ source. With proper channel adjustments, the $K$ values can be kept within 0.06-0.08. Since the product $K_1K_2$ is less than 0.01, the denominator of the above equations may be considered unity.

Therefore

$$R_1 \approx A_1 - K_1A_2$$

and

$$R_2 \approx A_2 - K_2A_1.$$

The degree of channel separation obtainable is limited by the width of the photo-peaks. With the instrumentation employed by the authors, the half-width at 0.32 MeV is about 11 per cent and decreasing to 8.3 per cent at 0.64 MeV. In our experience a conventional well crystal of $\frac{1}{4}$ in. diameter is unsatisfactory, giving half-widths of the order of 30 per cent.
### Table 1. Two-channel counting of mixed $\text{Cr}^{51}$ and $\text{I}^{131}$ sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Channel no. 1</th>
<th>Channel no. 2</th>
<th>$K$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$E = 30.8 \text{ V}$</td>
<td>$E = 33.2 \text{ V}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\Delta E = 2 \text{ V}$</td>
<td>$\Delta E = 5 \text{ V}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Background = 0.3</td>
<td>Background = 0.5</td>
<td></td>
</tr>
<tr>
<td>Counts (sec)</td>
<td>Time (sec)</td>
<td>$A_1$ (counts/see)</td>
<td>$A_2$ (counts/see)</td>
</tr>
<tr>
<td>Counts (sec)</td>
<td>Time (sec)</td>
<td>$A_1$ (counts/see)</td>
<td>$A_2$ (counts/see)</td>
</tr>
<tr>
<td>$\text{Cr}^{51}$ std.</td>
<td>12800</td>
<td>21.7</td>
<td>590</td>
</tr>
<tr>
<td>$\text{I}^{131}$ std.</td>
<td>1280</td>
<td>36.6</td>
<td>35.0</td>
</tr>
<tr>
<td>No. 1</td>
<td>3200</td>
<td>49.3</td>
<td>650</td>
</tr>
<tr>
<td>No. 2</td>
<td>6400</td>
<td>20.1</td>
<td>317</td>
</tr>
<tr>
<td>No. 3</td>
<td>12800</td>
<td>21.0</td>
<td>610</td>
</tr>
<tr>
<td>No. 4</td>
<td>25600</td>
<td>21.2</td>
<td>1210</td>
</tr>
<tr>
<td>No. 5</td>
<td>25600</td>
<td>21.5</td>
<td>1190</td>
</tr>
<tr>
<td>$\text{Cr}^{51}$ std.</td>
<td>12800</td>
<td>22.3</td>
<td>573</td>
</tr>
<tr>
<td>$\text{I}^{131}$ std.</td>
<td>1280</td>
<td>36.1</td>
<td>35.4</td>
</tr>
</tbody>
</table>

**Average**

- $K_2 = 0.078$
- $K_1 = 0.073$

### Table 2. Determining source strengths in $\text{Cr}^{51}$ and $\text{I}^{131}$ mixtures

#### $\text{Cr}^{51}$ strengths

<table>
<thead>
<tr>
<th>Mixed Source</th>
<th>$A_1 - K_1 A_2 = R_1$ (counts/sec)</th>
<th>Calculated (g)</th>
<th>Gravimetric (g)</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>64.7 - 4.1 = 60.6</td>
<td>0.1036</td>
<td>0.1009</td>
<td>+2.7</td>
</tr>
<tr>
<td>No. 2</td>
<td>317 - 19 = 298</td>
<td>0.510</td>
<td>0.5000</td>
<td>+2.0</td>
</tr>
<tr>
<td>No. 3</td>
<td>610 - 39 = 571</td>
<td>0.978</td>
<td>0.9957</td>
<td>-1.8</td>
</tr>
<tr>
<td>No. 4</td>
<td>1210 - 77 = 1133</td>
<td>1.938</td>
<td>2.0097</td>
<td>-3.6</td>
</tr>
<tr>
<td>No. 5</td>
<td>1190 - 44 = 1146</td>
<td>1.962</td>
<td>2.0213</td>
<td>-2.9</td>
</tr>
</tbody>
</table>

#### $\text{I}^{131}$ strengths

<table>
<thead>
<tr>
<th>Mixed Source</th>
<th>$A_2 - K_2 A_1 = R_2$ (counts/sec)</th>
<th>Calculated (g)</th>
<th>Gravimetric (g)</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>55.5 - 5.0 = 50.5</td>
<td>0.1020</td>
<td>0.1008</td>
<td>+1.2</td>
</tr>
<tr>
<td>No. 2</td>
<td>264 - 25 = 239</td>
<td>0.481</td>
<td>0.4940</td>
<td>-2.6</td>
</tr>
<tr>
<td>No. 3</td>
<td>532 - 48 = 484</td>
<td>0.977</td>
<td>0.9885</td>
<td>-1.2</td>
</tr>
<tr>
<td>No. 4</td>
<td>1060 - 94 = 966</td>
<td>1.950</td>
<td>1.9911</td>
<td>-2.1</td>
</tr>
<tr>
<td>No. 5</td>
<td>600 - 93 = 507</td>
<td>1.921</td>
<td>1.6052</td>
<td>+1.6</td>
</tr>
</tbody>
</table>
Table 3. Twenty consecutive determinations of 10 mixed Cr$^{51}$ + I$^{131}$ sources

<table>
<thead>
<tr>
<th>Mixed Source</th>
<th>Mass Cr$^{51}$ solution</th>
<th>Mass I$^{131}$ solution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calculated (g)</td>
<td>Gravimetric (g)</td>
</tr>
<tr>
<td>No. 1</td>
<td>0.1021</td>
<td>0.1009</td>
</tr>
<tr>
<td>No. 2</td>
<td>0.507</td>
<td>0.5000</td>
</tr>
<tr>
<td>No. 3</td>
<td>0.980</td>
<td>0.9957</td>
</tr>
<tr>
<td>No. 4</td>
<td>1.88</td>
<td>2.0097</td>
</tr>
<tr>
<td>No. 5</td>
<td>1.93</td>
<td>2.0213</td>
</tr>
<tr>
<td>No. 6</td>
<td>0.993</td>
<td>1.0002</td>
</tr>
<tr>
<td>No. 7</td>
<td>0.980</td>
<td>1.0018</td>
</tr>
<tr>
<td>No. 8</td>
<td>0.198</td>
<td>0.1970</td>
</tr>
<tr>
<td>No. 9</td>
<td>0.191</td>
<td>0.1935</td>
</tr>
<tr>
<td>No. 10</td>
<td>0.490</td>
<td>0.4989</td>
</tr>
<tr>
<td>No. 11</td>
<td>0.103</td>
<td>0.1009</td>
</tr>
<tr>
<td>No. 12</td>
<td>0.508</td>
<td>0.5000</td>
</tr>
<tr>
<td>No. 13</td>
<td>0.975</td>
<td>0.9957</td>
</tr>
<tr>
<td>No. 14</td>
<td>1.923</td>
<td>2.0097</td>
</tr>
<tr>
<td>No. 15</td>
<td>1.955</td>
<td>2.0213</td>
</tr>
<tr>
<td>No. 16</td>
<td>0.979</td>
<td>1.0002</td>
</tr>
<tr>
<td>No. 17</td>
<td>0.985</td>
<td>1.0019</td>
</tr>
<tr>
<td>No. 18</td>
<td>0.1925</td>
<td>0.1970</td>
</tr>
<tr>
<td>No. 19</td>
<td>0.1910</td>
<td>0.1935</td>
</tr>
<tr>
<td>No. 20</td>
<td>0.500</td>
<td>0.4989</td>
</tr>
</tbody>
</table>

Mean dev. 2.2 per cent
Average −1.33 per cent
Std. dev. ±2.26 per cent

Mean dev. 2.0 per cent
Average +0.11 per cent
Std. dev. ±2.39 per cent

Usually the two analyzers are not exactly in calibration with each other. Moreover, slight drifts in amplifier gain, high-voltage supply, and photomultiplier tube performance cause the channels to deviate somewhat from optimum conditions. As a result, the constants $K_1$ and $K_2$ are subject to fluctuations. Typical variation of the $K$'s with tube voltage is shown in Fig. 5. In order to correct for such drifts, the instrument is frequently realigned against a pure Cr$^{51}$ source. Minute drifts in gain are usually corrected by a change of 1 V or less in the high-voltage supply.

Two-channel counting has also been carried out with only one analyzer, employing the pulse height discriminator circuit of the linear pulse amplifier for the I$^{131}$ channel. However, the background is then increased from about 0.5/sec to approximately 5/sec.

The authors have evaluated the accuracy of this two-channel method by the assay of mixed Cr$^{51}$ + I$^{131}$ sources prepared gravimetrically. The results of this study are presented in tables 1, 2 and 3.

This method of two-channel counting has proved useful in blood circulation studies where continuous sampling of rapidly fluctuating activity makes other methods impractical or statistically inaccurate.

The pip-interval method of recording these rapidly changing counting rates has been developed and previously reported by the authors.(3)

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