PerkinElmer Tri-Carb LSA
Investigator Guide

Liquid Scintillation Counting at **any level**
using patented **TR-LSC Technology**
PerkinElmer Advances Liquid Scintillation Counting to a New Dimension!

Traditional liquid scintillation counting (LSC), uses coincidence counting to distinguish background events from true scintillation events. While this technology successfully eliminates much of the background counts due to electronic noise, it does not totally eliminate instrument background arising from cosmic interactions with the glass face of the PMT or counting vial. This cosmic component and noise can cause up to 70% of the remaining background counts. PerkinElmer's Tri-Carb® LSA uses a combination of coincidence counting and a patented technology named time-resolved liquid scintillation counting (TR-LSC®) to distinguish true decay events from background. LSC sensitivity is a function of sample counting efficiency and background. Higher efficiency and lower backgrounds dramatically increase counting sensitivity. TR-LSC technology reduces background by as much as 90%, thereby greatly increasing sensitivity for all LSC applications.

Why is TR-LSC Superior to Conventional Liquid Scintillation Counting?

The characteristics of beta scintillation pulses and background radiation pulses are substantially different. Both consist of a prompt or fast component, but a background pulse is followed by a series of low intensity afterpulses up to 5 µs after the prompt pulse. TR-LSC adds a third dimension, called the pulse index, to liquid scintillation. The pulse index is a measure, over time, of the afterpulses associated with background. With this 3-D spectral analysis (see center plot below), TR-LSC distinguishes true beta decay from background events, leading to increased sensitivity and superior counting performance.

Furthermore, TR-LSC is programmable to optimize counting any beta emitter in any cocktail. TR-LSC afterpulse discrimination is adjustable to accommodate the delayed component that often accompanies higher energy beta scintillation pulses to prevent this delayed component from being misclassified as background. The programmable feature of TR-LSC minimizes the misclassification of the beta activity as background, resulting in higher counting sensitivity for higher energy beta emitters such as ⁹⁰Sr/⁹⁰Y.

In this comparison of a true beta decay event versus a background event, both contain prompt or fast pulses. Unlike true events, background prompt pulses are followed by afterpulses for as long as 5 µs. True decay events can have a delayed or slow component for up to 900 ns, but do not have the distinguishing afterpulses.

Three dimensional plots of pulse height spectra. The pulse index is the third dimension (z). TR-LSC uses the pulse index of each scintillation event as one of the criteria to reduce background.

Illustration of programmable TR-LSC which allows adjustment of TR-LSC afterpulse time discrimination. Background is reduced and counting efficiency is retained for high energy radionuclides.
Provides Superior Counting Performance!

Different sample types and counting conditions require more or less counting sensitivity. For low count rate samples, background becomes increasingly important. To accurately determine the net count rate of a low activity sample in a reasonable time, the background count rate must be small relative to the sample count rate. PerkinElmer offers liquid scintillation detectors with four count modes, which use increasing levels of pulse index discrimination (TR-LSC), and provide faster and more accurate results for samples of virtually any activity.

Increase Your E²/B Up to 10 Times for Better Sensitivity!

A. **Normal Count Mode (NCM)** is standard on all PerkinElmer Tri-Carb systems and reduces background by more than 20–30% versus conventional liquid scintillation analyzers (LSA). Recommended for samples above 500 cpm.

B. **High Sensitivity Count Mode (HSCM)** is for low activity samples and reduces background by more than 40% versus conventional LSA. Recommended for samples between 50 and 500 cpm.

C. **Ultra Low Level Count Mode (ULLCM)** reduces background by more than 70% versus conventional LSA. Recommended for samples less than 50 cpm.

D. **Super Low Level Count Mode (SLLCM)** is standard on all PerkinElmer 3170TR/SL models and employs a patented Bismuth Germanium Oxide (BGO) background detector guard that surrounds the sample. It reduces background by more than 90% versus conventional LSA. This *Surround TR-LSC* technology provides the highest sensitivity of any commercial LSA. Recommended for extremely low activity samples, such as in radiocarbon dating studies or environmental ³H. (Refer to graphs on the right.)

<table>
<thead>
<tr>
<th>Amount of TR-LSC Discrimination</th>
<th>% ³H Efficiency</th>
<th>Background (CPM)</th>
<th>E²/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>34.2</td>
<td>22.3</td>
<td>52</td>
</tr>
<tr>
<td>Normal</td>
<td>33.8</td>
<td>17.8</td>
<td>64</td>
</tr>
<tr>
<td>High Sensitivity</td>
<td>33.9</td>
<td>12.8</td>
<td>90</td>
</tr>
<tr>
<td>Ultra Low Level</td>
<td>29.4</td>
<td>6.2</td>
<td>139</td>
</tr>
<tr>
<td>Super Low Level</td>
<td>26.7</td>
<td>2.8</td>
<td>255</td>
</tr>
</tbody>
</table>

³H performance data gathered using 8 mL water and 12 mL Ultima Gold LLT in glass vials. ³H energy window was 0–18.6 KeV.

Decrease Counting Time Up to 100 Times for Low Level ³H Samples

The effect of TR-LSC on the time required to achieve 5% 2Sigma accuracy. Background sample = 12 mL Ultima Gold LLT, 8 mL "dead" water; ³H (0–18.6 keV region of interest).
Sensitivity for ALL Low Level Applications

Compact Cosmic Guard Lowers Background to Unprecedented Levels
PerkinElmer offers a dedicated low level counter, which combines TR-LSC technology with BGO sample guards, creating Surround TR-LSC, to provide the ultimate in low activity sample detection. Surround TR-LSC delivers the lowest background of any multi-purpose LSA. Not only is Surround TR-LSC sensitivity unsurpassed, but it is also simple to implement since it requires minimal programming to use in a multi-user environment.

Works with Low Cost, Disposable Vials
BGO sample guard technology allows you to use ordinary, disposable glass or plastic vials, while still achieving the highest level of sensitivity. The BGO guard closely surrounds the sample vial, rejecting background events before they interact with the sample. With Surround TR-LSC you simply discard your vials when assay analysis is completed.

Space-Saving Benchtop Unit
The Tri-Carb 3170TR/SL benchtop unit uses Surround TR-LSC and is the world’s only work-anywhere, go-anywhere, true environmental LSA. Best of all, you won’t require a special underground counting room to achieve extraordinary sensitivity.

Radon Analysis in Drinking Water
Liquid scintillation is an approved EPA method\(^1\) for measuring radon in drinking water. The EPA has proposed concentration limits as low as 300 pCi/L. PerkinElmer Tri-Carbs easily achieve this detection level. Detection limits of 18 pCi/L or less can be achieved in 60 minutes. Tri-Carbs equipped with the alpha/beta discrimination feature can achieve a detection limit of 11 pCi/L or less in 60 minutes.

\(^1\) EPA method 913.0 (SM 7500-Rn)
### 222Rn Results for Conventional LSC Method

<table>
<thead>
<tr>
<th>Sample/Vial Type</th>
<th>Counting Efficiency</th>
<th>Background (CPM)</th>
<th>E/V/B</th>
<th>Minimum Age* Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 g benzene/7 mL glass</td>
<td>64.8</td>
<td>0.31</td>
<td>54,181</td>
<td>48,900</td>
</tr>
<tr>
<td>4 g benzene/7 mL glass</td>
<td>63.0</td>
<td>0.41</td>
<td>154,888</td>
<td>49,300</td>
</tr>
</tbody>
</table>

*Based on a minimal detectable amount (MDA) in dpm.g⁻¹ carbon which corresponds to A₀ and is calculated using \( \frac{[2.71 + 4.65 (N_{bkgnd})^{1/2}]}{T} \) where \( N_{bkgnd} \) is the total number of background counts and \( T \) is the total count time (2,000 minutes). This expression given by Curie (1968).

\[ A_0 = 12.517 \text{ dpm.g}^{-1} t = \frac{1}{\lambda} \ln(A_0/A_t) \]

Performance of the Tri-Carb 3170TR/SL for radiocarbon age dating (optimized region of interest). Data acquired at the Scottish Universities Research and Reactor Center, East Kilbride, Scotland.

### 222Rn Results for Alpha/Beta LSC Method

<table>
<thead>
<tr>
<th>Cocktail</th>
<th>Optimized Region (KeV)</th>
<th>Efficiency^ (%)</th>
<th>Background (CPM)</th>
<th>MDA Bq/L</th>
<th>MDA pCi/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultima Gold F</td>
<td>300–950</td>
<td>243</td>
<td>0.200</td>
<td>0.21</td>
<td>6</td>
</tr>
<tr>
<td>Opti-Fluor O</td>
<td>250–750</td>
<td>240</td>
<td>0.867</td>
<td>0.42</td>
<td>11</td>
</tr>
<tr>
<td>Insta-Fluor Plus</td>
<td>250–750</td>
<td>224</td>
<td>0.700</td>
<td>0.41</td>
<td>11</td>
</tr>
<tr>
<td>Mineral Oil Scintillator</td>
<td>200–600</td>
<td>219</td>
<td>1.02</td>
<td>0.49</td>
<td>13</td>
</tr>
</tbody>
</table>

10 mL cocktail + 10 mL sample; count time 60 minutes.

^Alpha efficiency calculated from total alpha emissions only.

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Alpha/Beta Radionuclide Counting

Many samples for environmental monitoring, nuclear power station monitoring, drinking water analysis, and nuclear waste clean-up require analysis of total beta and total alpha radionuclides. However, in liquid scintillation counters, the pulse height spectra of alpha-emitting radionuclides overlap the spectra of higher energy beta emitters, such as $^{137}$Cs, $^{89}$Sr, and $^{90}$Sr/$^{90}$Y. Therefore, it is necessary to employ a form of pulse shape discrimination to differentiate alpha from beta emissions and compensate for this interference.

PerkinElmer’s Time-Resolved Pulse Decay Analysis (TR-PDA), differentiates alpha from beta pulses according to their pulse decay characteristics. The pulse duration for alpha particles is typically longer than for betas. TR-PDA can run simultaneously with low level count modes, thereby achieving extremely low misclassification of beta and alpha particles, without compromising sensitivity.

TR-PDA provides automatic or manual adjustment of the pulse decay discriminator (PDD). The automatic alpha/beta standard mode scans the range of possible PDDs without operator intervention, for both alpha and beta pulses, and determines the optimum PDD for minimum spillover. In the manual alpha/beta mode, the range and number of PDD values are set by the operator.

TR-PDA Benefits

- Uses time resolution technology to analyze pulse decay characteristics and discriminate alpha/beta decay events.
- Automatic optimization of alpha/beta separation and counting, minimizing misclassification in a variety of counting samples.
- Settings can be optimized and configured independently for each protocol and stored for application to any other counting protocol.
Environmental Sample Preparation

Sample Oxidizer and Reagents: Oxidizer Simplifies Sample Preparation

PerkinElmer’s sample oxidizer makes it easy to prepare many samples containing \(^{3}H\) and \(^{14}C\). Organic matter in vegetation, animal tissue, solid waste, and even soil is easily and rapidly oxidized into \(^{3}H_{2}O\) and \(^{14}CO_{2}\), and completely prepared for counting. After combustion \(^{3}H\) and \(^{14}C\) are physically separated, therefore, dual label analysis is simplified considerably. Several successive combustions can be performed to enhance counting sensitivity. PerkinElmer sells a complete line of reagents to ensure superior performance and consistency.

LSC Cocktails

Ultima Gold LLT for Low Level

Ultima Gold LLT™ is suitable for the direct determination of low levels of \(^{3}H\) in a wide range of water samples. Direct addition removes the need for distillation. Ultima Gold LLT accepts up to 54% distilled water, deionized water, tap water, rain water, river water and has a large capacity for sea water, with \(^{3}H\) counting efficiencies of approximately 26% and low backgrounds. When used with PerkinElmer’s TR-LSC technology, minimum detectable activities of <1.1 BqL\(^{-1}\) are attainable.

Ultima Gold AB for Alpha/Beta

Ultima Gold AB was specifically designed for use in alpha/beta separation. The use of a slow pulse decay solvent with optimized detergent type and concentration combine to produce a cocktail with all the characteristics necessary for effective alpha/beta separation. The outstanding sample holding capacity of Ultima Gold AB for aqueous and acidic sample types makes it the cocktail of choice for most alpha/beta LSC applications.

Optimized Windows (0.4– 4.5 keV)

<table>
<thead>
<tr>
<th>Water to Cocktail Ratio</th>
<th>(^{3}H) Efficiency</th>
<th>Bkg CPM</th>
<th>E/B</th>
<th>E/V B</th>
<th>MDA (BqL(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 mL : 12 mL</td>
<td>24.6%</td>
<td>1.15</td>
<td>526</td>
<td>33680</td>
<td>1.22</td>
</tr>
<tr>
<td>10 mL : 10 mL</td>
<td>21.2%</td>
<td>1.11</td>
<td>405</td>
<td>40490</td>
<td>1.11</td>
</tr>
<tr>
<td>11 mL : 9 mL</td>
<td>18.1%</td>
<td>0.95</td>
<td>345</td>
<td>41730</td>
<td>1.06</td>
</tr>
</tbody>
</table>

Performance of Ultima Gold LLT for low level \(^{3}H\) using a Tri-Carb 3170TR/SL. Results generated at the Scottish Universities Research and Reactor Center, East Kilbride, Scotland.

<table>
<thead>
<tr>
<th>Water</th>
<th>1.0 M HCl</th>
<th>2.0 M HCl</th>
<th>1.0 M HNO(_{3})</th>
<th>2.0 M HNO(_{3})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample uptake capacity</td>
<td>10.0 mL</td>
<td>5.0 mL</td>
<td>2.25 mL</td>
<td>3.25 mL</td>
</tr>
<tr>
<td>Miscellification with max sample</td>
<td>1.8%</td>
<td>1.7%</td>
<td>1.0%</td>
<td>3.8%</td>
</tr>
</tbody>
</table>

Performance of Ultima Gold AB with samples at 20°C using a low level Tri-Carb equipped with alpha/beta discrimination (0–2000 keV region of interest).
**Glass and Plastic Vials**

Glass vials, 7 mL and 20 mL, are manufactured from low potassium glass to ensure low backgrounds. Glass prevents solvent permeation and provides chemical inertness with excellent visibility. Plastic vials, 4 mL to 20 mL, are manufactured from virgin polyethylene originating from petrochemicals, and therefore contain minimal measurable background. Plastic vials are preferred for low level counting applications. Anti-static versions of most plastic vials are available for applications where induced static is a potential problem.

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**The Complete Counting Solution!**

Every PerkinElmer Tri-Carb delivers verified, reliable results. That’s because every Tri-Carb employs patented TR-LSC background reduction; double light seals for maximum PMT stability; low energy $^{133}$Ba external standardization for the best quench monitoring; and safe, gravity-assisted sample downloading to prevent vial jamming and breakage.

**Instruments and Electronics**

- Linear MCA
- Patented, programmable TR-LSC background reduction
- Powerful, integrated computer system control and data management
- 21 CFR Part 11 compatibility
- Optimized and matched photomultipliers
- Luminescence detection

**QuantaSmart™ Operating Software**

- Windows® XP operating system.
- SpectraBased counting of isotopes selected from radionuclide libraries.
- Validated instrument performance assessment (IPA™) for compliance with the EPA’s GLP recommendations and the FDA’s GMP regulations.
- Automatic calibration and normalization with sealed standards whose activity is verified against NIST (National Institute of Standards and Technology) material.

QuantaSmart assays are easily associated or disassociated with numeric protocol hardware flags through the associate assays dialogue.
**SpectraWorks™ Analysis Software**

- Real-time visualization and plotting of sample spectrum.
- Helps fine-tune regions for single, dual and triple label assays.
- Display and analyze up to four spectra.
- Calculate detection limits.
- Confirms presence of luminescence.
- Provides evidence of quenching problems.

**PerkinElmer Tri-Carbs Meet Any Counting Need, from Basic Research to Environmental Applications**

<table>
<thead>
<tr>
<th>Models</th>
<th>Normal Count Mode</th>
<th>High Sensitivity Count Mode</th>
<th>Ultra Low Level Count Mode</th>
<th>Super Low Level Count Mode</th>
<th>Alpha/ Beta Discrimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>2800TR</td>
<td>S</td>
<td>O</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>2900TR</td>
<td>S</td>
<td>O</td>
<td>O</td>
<td>NA</td>
<td>O</td>
</tr>
<tr>
<td>3100TR</td>
<td>S</td>
<td>S</td>
<td>O</td>
<td>NA</td>
<td>O</td>
</tr>
<tr>
<td>3170TR/SL</td>
<td>S</td>
<td>NA</td>
<td>NA</td>
<td>S</td>
<td>O</td>
</tr>
</tbody>
</table>

S=Standard  O=Option  NA=Not Available
PerkinElmer is recognized worldwide for advanced instrumentation systems and outstanding customer support. We continue to be your partner in life science research providing instruments for scintillation, gamma, and microplate counting; quantitative imaging; and liquid handling. We are committed to providing the best instrument application support, field service, and telephone support. We are proud of our tradition of working with laboratories to accelerate the pace of life science research.

**People Putting Technology to Work for You — All Over the World**

With over 10,000 instrument installations worldwide, we provide researchers with a total solution of high quality instrumentation and application expertise. We have more than 300 highly trained service engineers in more than 60 countries. This makes PerkinElmer the largest, most well trained liquid scintillation analyzer instrument service organization in the world.

**Tri-Carb Bibliography and Application Notes**

PerkinElmer’s instruments are the most cited liquid scintillation analyzers worldwide. Our current application bibliography, available on request, cites over 1,000 articles in open scientific literature, describing results of research conducted using liquid scintillation analyzers. We continually publish application papers from researchers and our own application specialists help inform researchers about the latest in liquid scintillation technology. PerkinElmer products are designed and manufactured under an ISO 9001 certified system. They are designed, built, and tested in conformance with appropriate CSA, FCC, and IEC standards.

**LSA Reliability and Performance You Can Count On**

Make the only choice, the Tri-Carb LSA, only from PerkinElmer. You’ll get superior low level sensitivity and performance for every research or environmental application challenging your lab. For more information or for help placing an order, call 1-800-762-4000 or visit www.perkinelmer.com/LSAS.