A PERFORMANCE COMPARISON OF NINE SELECTED LIQUID SCINTILLATION COCKTAILS

Background

In the selection of an optimal liquid scintillation counting (LSC) cocktail, two important aspects are generally taken into consideration: overall cocktail performance and specific laboratory needs.

Overall performance can be assessed by studying parameters like counting efficiency, intrinsic background contribution, quench resistance, sample stability over time, sample load capacity, sample compatibility and α/ß discrimination. These performance indicators then have to be balanced against the specific laboratory needs such as required detection limits, acceptable measurement uncertainty, sample volume used for routine measurements, chemical and/or physical properties of routinely measured samples, desired sample throughput and waste treatment regulations.

Objectives

The aim of this comparison study is to determine a single cocktail that best suits all measurement requirements of the liquid scintillation counting laboratory at SCK•CEN for the determination of low levels of radioactivity in biological and environmental samples.

The results presented in this publication only intend to give information about some of the most important, overall performance indicators for 9 selected, commercially available LSC cocktails. The indicators presented here are sample load capacity, sample compatibility, counting efficiency, figure of merit (FOM), quench resistance and sample stability. The cocktails tested are Ecoscint A, Insta-Gel Plus, OptiPhase Hisafe 3, OptiPhase Trisafe, Ready Gel, SafeScint 1:1, Ultima Gold, Ultima Gold LLT and Ultima Gold XR. For the data acquisition a Packard TriCarb Model 1900CA and a Quantulus 1220 liquid scintillation counter are used. All samples are prepared in either 20 mL low potassium, borosilicate glass vials or 20 mL high density, polyethylene vials.

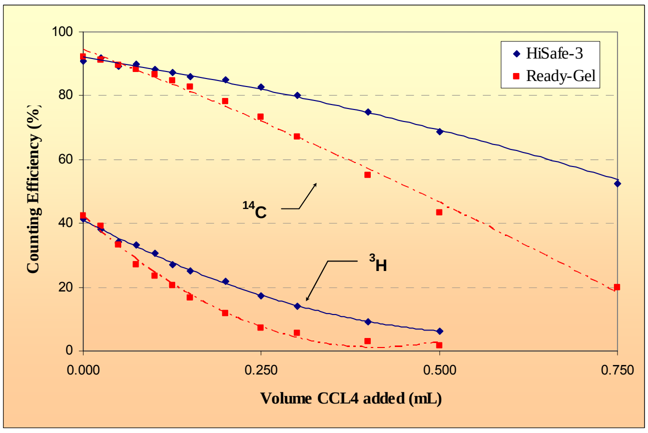
Principal results

To determine the Sample Load Capacity (maximum amount of sample a liquid scintillation cocktail will accept to form a homogeneous, single phase mixture), a set of 14 glass vials were prepared by mixing the appropriate volumes of each possible combination of liquid scintillation cocktail and sample solution. Sample solutions used were: pure reverse osmosis (RO) water, NaCl (1 mol/L), NaOH (1 mol/L), HCl (1 mol/L), HNO_3 (1 mol/L) and human urine. The volume of sample solution in each series of vials increases in steps of 1 mL starting at 1 mL in the first vial, up to 14 mL in the last one. Scintillation cocktail is finally added to obtain a final volume of 20 mL. This way sample load ranges from 5% up to 70% in 5% increments. Finally a visual check is performed, registering the physical appearance of the mixture in the vials (homogeneity, transparency, viscosity, phase separation).

Sample Load Capacity experiment with OptiPhase TriSafe and HCl 1M

The expected decrease in counting efficiency with increasing sample load is caused by two different phenomena, acting in parallel. The first and most important aspect is quenching. The second effect is the stability of the cocktail/sample mixture and the possible occurrence of phase separation.

A reliable way to assess the quench resistance of liquid scintillation cocktails is the determination of the volume of a quenching agent needed to reduce the counting efficiency by a factor of two (the quench half-volume, $V_{½}$). For the presented results, carbon tetrachloride (CCl_4) was used as quenching agent.



Effect of Quenching on Counting Efficiency for ^{3}H and ^{14}C in OptiPhase HiSafe-3 and Ready-Gel

A series of 15 polyethylene counting vials was prepared for each scintillation cocktail tested. To each vial, 18 mL of the cocktail and 1 mL of a certified reference solution (either ^{3}H or ^{14}C) were added. Finally, an increasing volume of carbon tetrachloride was added, ranging from 0 µL to the first vial up to 1500 µL to the last vial. All vials were counted for 15 minutes each and the obtained spectral data recorded and used to calculate the corresponding counting efficiencies. These data were then plotted on a graph against the volume of CCl_4 and fitted to a second order polynomial fit. The fit parameters were used to calculate the value of $V_{½}$.

Cocktail	$V_{½}$ (µL) for ^{3}H	$V_{½}$ (µL) for ^{14}C
Ecoscint A	190	713
Insta-Gel	148	608
OptiPhase HiSafe-3	208	833
OptiPhase Trisafe	178	757
Ready Gel	124	493
SafeScint	188	673
Ultima Gold	145	642
Ultima Gold LLT	175	739
Ultima Gold XR	134	551
Average (± StDev)	166 ± 29	668 ± 107

Quench Resistance equations and calculated $V_{½}$ *for the different cocktails for* ^{3}H *and* ^{14}C

The detection limit of any measurement device is determined by the signal to noise ratio. In LSC this signal to noise ratio is expressed as a function of counting efficiency (E) and background contribution (B) and is generally known as the Figure of Merit ($FOM = E^2/B$). To assess the values of FOM, a set of 7 polyethylene vials was prepared for each of the nine cocktails. Each vial contained 20 mL of the cocktail. To the first vial 100 µL of RO water was added. This vial was used to measure the background contribution B. To the next three vials 100 µL of a tritiated reference solution was added (2121 ± 63 Bq/mL) and finally, to the last three vials 100 µL of a ^{14}C reference solution was added (1902 ± 48 Bq/mL). These replicates were used to calculate the counting efficiency E after correction for the background contribution B. The small volumes of aqueous phase added to the vials were considered to have only a small or negligible influence on the behaviour of the scintillation cocktail (more specific to the quenching level). Two different sets of counting windows were used to determine the observed count rate: one for the ^{3}H spiked vials and one for the ^{14}C spiked vials. Once set, the same window was used for all vials to allow fair comparison and the values for E, B and finally FOM were calculated.

Cocktail	TriCarb 1900CA		Quantulus 1220	
	FOM ^{3}H	FOM ^{14}C	FOM ^{3}H	FOM ^{14}C
Ecoscint A	193 ± 6	398 ± 27	748 ± 87	1282 ± 155
Insta-Gel	223 ± 7	425 ± 30	950 ± 122	1432 ± 182
OptiPhase HiSafe-3	178 ± 6	421 ± 32	820 ± 106	1573 ± 211
OptiPhase Trisafe	211 ± 7	423 ± 30	903 ± 118	1561 ± 208
Ready Gel	202 ± 6	388 ± 26	766 ± 89	1190 ± 139
SafeScint	163 ± 5	407 ± 28	766 ± 100	1689 ± 237
Ultima Gold	185 ± 6	425 ± 30	789 ± 99	1612 ± 219
Ultima Gold LLT	191 ± 6	411 ± 28	695 ± 78	1423 ± 181
Ultima Gold XR	135 ± 4	361 ± 23	527 ± 60	1025 ± 112
Average (± StDev)	187 ± 26	406 ± 21	774 ± 121	1421 ± 218

Figure of Merit calculated for the different cocktails for ^{3}H *and* ^{14}C

With the results of all tests taken into consideration, and balancing the performance of all tested LSC cocktails against the laboratory's requirements and field of application, the most suitable cocktail for use at the liquid scintillation counting laboratory of SCK•CEN was found to be OptiPhase Hisafe 3 (Perkin Elmer). This conclusion confirms the conclusion of a similar study, carried out over 10 selected LSC cocktails in 1991.

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Main reference

BLG report nr. 1052 (to be published first quarter of 2008);
http://www.sckcen.be/sckcen_en/publications/other_reports/blgreports/BLG_1052.pdf