APPLICATION NOTE

LSC

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Cocktails for Liquid Scintillation Counting

Components of the Cocktails

In this application note we want to give some information about the most important cocktails from PerkinElmer. This includes product lines of the former companies Lumac, NEN, Packard Bioscience and Wallac which are now all part of the PerkinElmer company. In addition to this application note you can get help from the PerkinElmer product specialists which you can contact at any time.

It is most important to assure 4 π–geometry in liquid scintillation counting for accurate results[1]. Usually this can be assured by dissolution of the sample in an appropriate cocktail. The cocktail does not only contain a solvent but also at least one scintillator and surfactants for aqueous samples because aqueous samples are completely insoluble in the pure organic solvents and scintillators. Depending on the sample preparation and the type of sample the decision for a special cocktail can be a very important one. Only an optimized cocktail in combination with the best sample preparation guarantees accurate and reproducible results. Parameters such as counting efficiency, sample uptake capacity, flash point, uptake of buffer solutions etc. are mainly influenced by the cocktail. Today's cocktails for liquid scintillation counting are subdivided into two major groups, so called "classical" and "safer" cocktails.

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Cocktails using solvents such as benzene, toluene, xylene, or pseudocumene are classical cocktails and those using linear alkyl benzene (LAB), PXE (phenylxylylethane), or DIPN (Diisopropylnaphthaline) are safer cocktails. The latter group of cocktails is less toxic and so far no cancerogeneity, mutageneity or teratogenic behavior could be found. These cocktails have a much lower vapor pressure and therefore they do not show this strong smell which can be observed with classical cocktails. The flash point of the safer cocktails is much higher, significantly higher than room temperature which makes handling of these cocktails in the lab much safer.

First of all we will talk about the components of the cocktail and discuss, why we offer a large number of different cocktails. You will see that usually it will not make sense to use a good LSC cocktail for a radio-HPLC application but instead you should use a special radio-HPLC cocktail.

In addition to vial LSC cocktails and radio-HPLC cocktails there are also special cocktails for microplate counters. A good cocktail has to show mainly the following properties:

1. Good uptake capacity
2. Low content of natural ^{14}C
3. High transmission for photons
4. High quantum yield
5. It should be a safer cocktail
6. The cocktail should be usable for a wide range of applications
7. Low price (good price/performance ratio)

It is extremely difficult, if not impossible, to develop a cocktail which guarantees all the seven points just mentioned. Also many users have different applications and therefore have different priorities. For a user in the field of environmental monitoring it can be very important to have a cocktail with very high uptake capacity, another user on the other hand might have a very low price for the cocktail as the highest priority. Over the decades this lead to a huge range of cocktails and it is difficult to give an overview for all these cocktails, even for a specialist. The product range includes some universal cocktails as well as cocktails for very special applications. The universal cocktails can be used for a wide range of applications, however, in some cases best performance can be obtained with cocktails for special applications. On the other hand these special cocktails are usually limited in the range of applications. Most of the important universal as well as special cocktails will be explained in this application note.

A cocktail contains in general four different components (4 s rule):

1. Solvent
2. Scintillator
3. Surfactant
4. Sample

Surfactants are not components of all cocktails. They are only part of those cocktails which are designed for the uptake of aqueous solutions. On the following pages we will discuss all the components of cocktails.

Solvent

There are mainly two reasons why we use solvents in cocktails. First of all we have to dissolve the sample and the scintillator and secondly the solvent is important for the energy transfer from the radioisotope to the scintillator. Solvents with large conjugated π–electron systems are very well suited for the energy transfer from a radionuclide to the solvent. These π–electrons are easily excited. A typical group of compounds with π–electron systems is the group of aromatic hydrocarbon compounds. Besides the ability to transfer the energy the solvents in a scintillation cocktail must have the following capabilities:

1. It has to dissolve the radioactive sample and the scintillator fast and completely.
2. It should contain a small amount of natural ^{14}C activity.
3. It should have a high transmission for photons emitted from the scintillator.

A list of the most used solvents is shown in Figure 1. Among the properties of the solvents the relative pulse height and the flash point are of special interest. Both properties are listed in the following figure.

The reference value for the relative pulse height is per definition 100 for toluene. The flashpoint is the lowest temperature which allows self ignition of the gases of a flammable liquid in air.

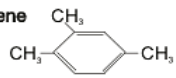
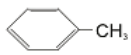
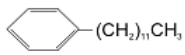
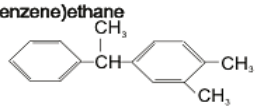
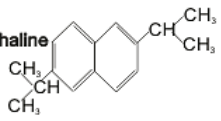
Solvent	Structure	Relative Pulse Height	Flash-Point (°C)
1,2,4-Trimethylbenzene (Pseudocumene)		112	50
1,4-Dimethylbenzene (P-Xylene)		110	30
Methylbenzene (Toluene)		100	5
Benzene		85	-11
1,4-Dioxane		65	12
Dodecylbenzene		91	150
1-Phenyl-1-(3,4-dimethylbenzene)ethane (PXE)		114	150
2,6-Di-isopropylnaphthaline (DIPN)		114	150

Figure 1. Solvents in liquid scintillation cocktails.

The relative pulse height (which is 100 per definition for toluene) is a very important value. If this value is below 100 the energy transfer and the number of resulting photons is reduced to a level which cannot be accepted for today's modern LSC cocktails. Therefore safer cocktails are based on DIPN or PXE and classical cocktails are mainly based on Pseudocumene.

Still we have some safer cocktails on the basis of linear alkylated benzenes (LAB´s) although they show relative low pulse height values. The flash point of the cocktail is not important for the measurement but for the safety in your laboratory. Solvents with higher flash point can not be easily ignited and are usually less toxic.

Materials with low flash point in most cases also show high vapor pressure which results primarily for classical cocktails in a higher concentration of these materials in air. You also smell the classical cocktails and you should use a hood to avoid health problems. Table 1 shows possible concentrations of solvents in air.

Table 1. Possible concentrations of solvents in air.

Solvent	Vapor Pressure at 25 °C (mm Hg)	Equilibrium Constants at 25 °C (ppm)
1,4-Dioxane	40	52600
Toluene	28	36200
m-Xylene	8	10900
Pseudocumene	2	2760
DIPN	1	< 2

One of the first solvents used for liquid scintillation counting was benzene. It was mainly replaced by other solvents because of the toxic and carcinogenic properties and the very low flash point.

Dioxane was also one of the very early solvents in LSC cocktails. It was used in Bray´s cocktail together with naphthalene. However, this cocktail could not be used for aqueous solutions containing proteins.

Also many samples resulted in the crystallization of naphthalene in the measurement vials. Dioxane which is a cyclic ether also tends to show self oxidation under the influence of air. The produced peroxides are strong quencher and also cause problems with strong chemiluminescence. These problems together with the low flash point and the high toxicity resulted in the replacement of Dioxane.

In the following time a series of alkyl substituted benzenes were used as solvents. The simplest alkyl substituted compound is toluene (methylbenzene). Solvents on the basis of toluene together with TRITON X-100® became the first emulsifying cocktails which could be used for the measurement of aqueous samples. Toluene is commercially available for a low price and with high purity but the flash point of this material is still below room temperature and lately research seems to indicate that toluene shows carcinogenic effects.

If you add another methyl group to toluene you will get xylene (dimethylbenzene). If you have two methyl groups within the benzene ring you can have three different isomers. You can have ortho- (1,2-dimethylbenzene), meta- (1,3-dimethylbenzene) or para-Xylene (1,4-dimethylbenzene). You can use pure xylenes or xylenes in known ratios. Only pure para-xylene can not be used because it is a solid at 12-13 °C. The quantum efficiency as well as the relative pulse height is good for xylene. Xylene is classified as a highly flammable liquid (but this is true for almost all organic solvents) but the flash point is already above room temperature. Nowadays xylene is still used in the Aquasol- cocktails.

Also the classical Insta-Fluor cocktail used xylene in the past but in this cocktail the solvent has been replaced by pseudocumene. You get pseudocumene of you add a third methyl group to the benzene ring. Pseudocumene (1,2,4-trimethylbenzene) has some properties which make this solvent an ideal candidate for a cocktail solvent. First of all pseudocumene can be used for a very efficient energy transfer (see Figure 1). Also pseudocumene is only classified as a normal flammable liquid therefore the regulations for transportation of this solvent are less strict.

Another important point is that the diffusion into plastic vials is reduced significantly compared to benzene or xylene. Therefore pseudocumene cocktails can be used with plastic vials for many applications. Among the classical cocktails based on pseudocumene you will find PerkinElmer cocktails such as Pico-Fluor, Filter-Count, Hionic-Fluor, InstaGel Plus, and the Radio-HPLC cocktails of the Flo-Scint series (Flo-Scint A and Flo-Scint I to Flo-Scint IV).

All cocktails mentioned so far belong to the family of the so called "classical cocktails". Despite some excellent properties for LSC measurements customers more and more wanted to use "safer cocktails" in the laboratory.

Most customers did not like classical cocktails because they had very low flash points but also because of the strong smell mainly caused by the high vapor pressure. This resulted in the development of "safer cocktails" which meanwhile can be used for LS-counters as well as for the Radio-HPLC detector. Lately the safer cocktails more and more replaced some of the traditional classical cocktails.

The safer cocktails are based on linear alkyl substituted benzenes (LAB, Flo-Scint V), PXE or DIPN. Among these cocktails you will find the Ultima Gold series of cocktails and the Radio-HPLC cocktails of the Ultima-Flo series (Ultima-Flo M, F and AP). All these cocktails show very high flash points between 120 and 150 °C and at the same time they are degradable in the environment. Figure 2 shows the speed of degradation of today's solvents in safer cocktails[5].

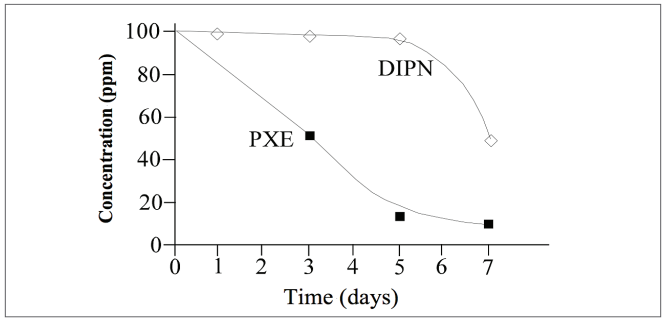


Figure 2. Biological degradation of solvents.

The Ultima-Flo M and AF Radio-HPLC cocktails which are based on PXE and LAB can be classified as easily degradable (ISO method 7827-1984(E) equivalent to OECD 301E). Ultima-Flo AP which is based on benzyltoluene (BT) and diphenylethane (DPE) can be classified as biodegradable using the Zahn/Wallens EMPA Test (equivalent to OECD 302B). With the safer cocktails you can get high counting efficiencies and high sample uptake capacities.

Despite the high flash point the viscosity of the safer cocktails is low allowing fast mixing of the cocktail with the HPLC eluents. In some rare cases the use of PXE seems to show allergic reactions after contact with skin. It is difficult to obtain PXE as a pure material and usually it contains a small amount of isomers (which is also true for other technical components in cocktails). Therefore it is difficult to determine which compound is responsible for the allergic reactions.

Primary Scintillators

Scintillators can be excited by taking over the energy of excited solvent molecules. For a short time the scintillators will stay in an excited energy level and on their way back to the ground state excess of energy will be emitted as photons. A detector (Photomultiplier Tube, PMT) can measure the amount of light. The process of energy transfer to the scintillator has to be very efficient to allow very sensitive detection of radio nuclides. The process should also be very quantitative and the energy of the β-particle should be proportional to the energy of the resulting photons which are emitted from the scintillator. Figure 3 shows some of the used primary scintillators.

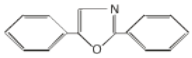
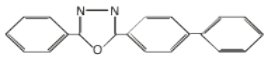
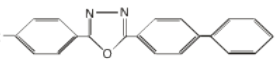
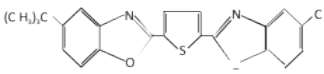
Name	Structure	λ (nm)	t (nsec)	Φ
PPO		375	1.4	0.83
PBD		375	1.0	0.69
Butyl-PBD		385	1.0	0.69
BBOT		446	1.6	0.61

Figure 3. Properties of primary scintillators.
λ = fluorescence maximum, t = decay time, Φ = quantum yield, PPO = 2,5-diphenyloxazole, PBD = 2-phenyl-5-biphenyl-1,3,4,-oxadiazole, butyl-PBD = 2-(4-tert-butylphenyl)-5(4-biphenylyl)-1,3,4-oxadiazole, BBOT = 2,5-bis-2-(tert-butylbenzoxazolyl)-thiophene

Primary scintillators are added to cocktails in concentrations between 5 and 12 g/L. If the scintillator concentration is too high this can negatively influence the cocktail because it can result in quench of photons. One of the older primary scintillators is naphthalene which is only used in special cases nowadays. This scintillator has not been used for Radio-HPLC cocktails but was added to classical cocktails. In comparison to cocktails based on DIPN the classical cocktails show a very short pulse length. Naphthalene was added to the classical cocktails to increase the pulse length and therefore improve the α/β–discrimination.

This discrimination is much easier if the pulses are stretched. DIPN cocktails do not need this addition of naphthalene anymore because the solvent itself is a derivative of naphthalene and shows the corresponding pulse length increase.

Secondary Scintillators

Some of the primary scintillators show an emission wavelength clearly below 400 nm. However, the PMT´s used in modern liquid scintillation analyzers are especially sensitive at a wavelength around 420 nm. Secondary scintillators are also electron rich compounds which can be excited very easily. The main advantage of secondary scintillators is the wavelength of the emitted light, which is much closer to the sensitive area of the PMT. Secondary scintillators are mainly used to shift the wavelength of the light to the sensitive range of the PMT.

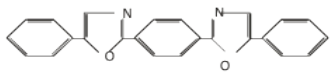
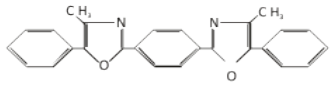
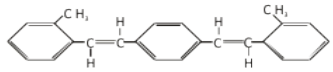
Name	Structure	λ (nm)
POPOP		415
M_2-POPOP		427
Bis-MSB		425

Figure 4. Secondary scintillators.

The name POPOP, 1,4-(di-2-(5-phenyloxazolyl))-benzol, belongs to the alternating phenyl- and oxazole-units. In some cases POPOP is also used in the twofold methyl substituted derivative. The name bis-MSB is an abbreviation for p-bis-(ortho-methylstyryl)-benzene.

Emulsifier (Surfactants)

Many samples which will be measured in classical LSC´s, microplate counters or radio-HPLC systems with reversed phase columns will be disolved in aqueous solution. Therefore an absolute necessity for many cocktails is a very high sample uptake capacity for aqueous solutions. In addition, sometimes these solutions can also contain high amounts of buffers. The following figure shows some typical emulsifiers which are used in cocktails for liquid scintillation counting. Typically the structure of emulsifiers contains a polar end to dissolve the aqueous part and a nonpolar end to dissolve the organic solvent. The real art of cocktail manufacturing is finding the optimum composition of all the parts which make up a complete cocktail. The cocktail should have enough emulsifier to improve the sample uptake capacity but not too much emulsifier to prevent a reduction in counting efficiency. Figure 5 shows some of the emulsifiers which can be found in cocktails.

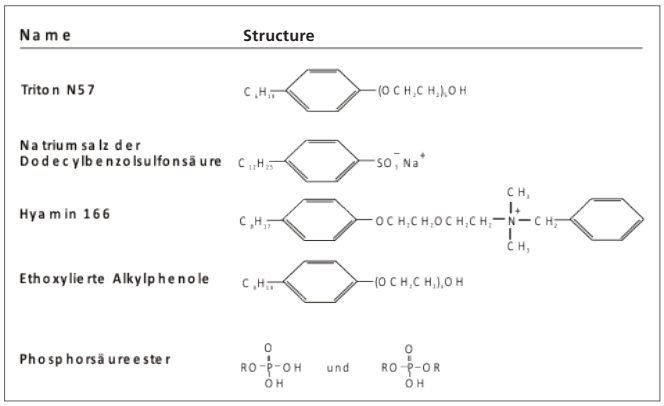


Figure 5. Typical surfactants in scintillation cocktails.

In most cases Radio-HPLC cocktails for aqueous eluents show lower counting efficiencies compared with cocktails for classical counters. Radio-HPLC cocktails contain a very high amount of emulsifiers. The reason for this is that these cocktails not only have to take up a lot of aqueous sample but it is also necessary that a stable homogeneous phase is created instantly without mixing.

Viscosity of the Cocktails

A very important point for the decision of the optimum cocktail is the viscosity of the cocktail. In general the viscosity of radio HPLC cocktails from PerkinElmer is lower than the viscosity of classical LSC cocktails. The lower viscosity helps to get faster a stable homogeneous solution. The increase of emulsifier concentration on the other hand results in lower viscosities. Classical LSC cocktails which are sometimes cheaper can usually not be used for radio HPLC applications.

Today, low viscosity cocktails are absolutely necessary for radio HPLC detectors in narrow and microbore applications. If cocktails show too high viscosity these cocktails will result in high back pressure and can damage the expensive flow cells. The most used cocktail for narrow and microbore HPLC is Ultima-Flo M. Ultima-Flo AF should be avoided due to the higher viscosity compared to Ultima-Flo M. Table 4-1 shows that the viscosity of Ultima-Flo AF is lower than the viscosity of the normal LSC cocktail Ultima Gold but the difference is not significant. Ultima-Flo AP is the best cocktail in terms of viscosity but some acidic components can damage the microbore mixing-T after longer usage therefore Ultima-Flo M is the cocktail of choice for this separation technique.

The viscosity η will be described in units of Nsm^{-2} or $kg\ m^{-1}\ s^{-1}$ or in P (Poise) = $g\ cm^{-1}s^{-1}$.

Often the fluidity is used η^{-1} which is the inverse of the viscosity. Sometimes the kinematic viscosity is used to describe the viscosity of a sample. This value can be calculated using the following equation:

Kinematic viscosity $= \frac{\eta}{\rho}$ [$cm^2\ s^{-1}$ = Stokes]

From the following table you can find the viscosities of some cocktails and typical HPLC eluents. Instead of Stokes (St) often centi Stokes (cSt) are used to get numbers larger than 1.

From Table 2 you clearly see that all Ultima-Flo cocktails show significantly lower viscosities than Ultima Gold which is used for measurements in classical liquid scintillation analyzers. Despite this optimization of cocktails the viscosity is still much higher than typical HPLC solvents such as water, methanol or acetonitrile. For this reason you should avoid flushing your radio-HPLC detector at high flow rates because it will probably result in overpressure.

Cocktails for Classical Scintillation Counters

Cocktails for classical scintillation counters for the measurement in scintillation vials with volumes between 6 and 20 ml are still the main application for scintillation cocktails. The difference here is the relatively large measurement volume and the possibility to shake a vial very efficient in your hand or a shaker. As we have already mentioned above cocktails contain solvents of low vapor pressure. This on the other hand results in a higher viscosity of LSC cocktails. The amount of emulsifiers is restricted to avoid the reduction of the counting efficiency. As we will see on the following pages, this is the most important difference between radio HPLC cocktails and LSC cocktails. On the following pages we will briefly describe many of the available cocktails from PerkinElmer.

Table 2. Kinematic viscosity of cocktail- and alcohol-water mixtures[6].

		Ratio of Cockail: Water			
		No Sample	3:1	2:1	1:1
Kinematic viscosity (cSt)	Ultima-Flo M	17	22	23	23
	Ultima-Flo AP	14	20	22	19
	Ultima-Flo AF	22	40	37	**
	Ultima Gold	26	48	**	**
	Water	1	-	-	-
	Methanol	0.7	1.8	1.9	1.9
	Ethanol	1.5	2.5	2.9	3.1

Table 3 gives an overview of some of the available scintillation cocktails.

Table 3. Table of cocktails.

	Cocktail	Solvent	Flash point (°C)	Eff. Without Sample	Eff. with 10% Solubilizer	Eff. with 10% Water	Uptake Capacity for Water (ml)*
Cocktails for aqueous and organic samples	**Ultima Gold †**	DIPN	~ 150	56	49	52	2,5
	Ultima Gold XR	DIPN	~ 150	50	-	46	10
	Ultima Gold LLT	DIPN	~ 140	52	-	46	12
	Ultima Gold uLLT	DIPN	~ 140	52	-	46	12
	Ultima Gold MV	DIPN	~ 110	57	-	55	1
	Ultima Gold AB	DIPN	~ 140	52	-	46	10
	Ultima-Flo M	PXE/LAB	~ 120	47	-	-	10
	Ultima-Flo AF	PXE/LAB	~ 120	43	-	-	10
	Ultima-Flo AP	BT/DPE	~ 120	43	-	-	10
	Opti-Fluor	LAB	~ 150	44	-	40	1,5
	Emulsifier-Safe	LAB	~ 150	43	-	39	1,5
	Formula 989	LAB	~ 140	-‡	-	-	-
	OptiPhase HiSafe II	DIPN	144	52	-	46	3
	OptiPhase HiSafe III	DIPN	144	47	-	43	11
	OptiPhase Supermix	DIPN	144	43	-	40	25
	LumaSafe	PXE	149	51	-	-	-
	LumaSafe Plus	PXE	149	48	-	-	-
	Lumagel Safe	PXE	149	46	-	-	-
	SafeFluor-S	LAB	149	41	-	-	-
	Insta-Gel Plus§	Pseudocumol	48-50	56	-	48	1,3 & 3-10
	Pico-Fluor 15(not available)	Pseudocumol	48-50	57	-	53	1,5
	Pico-Fluor 40	Pseudocumol	48-50	51	-	45	3
	Filter-Count	Pseudocumol	48-50	57	-	53	1
	Hionic-Fluor	Pseudocumol	48-50	51	48	45	1
	Monophase S	Pseudocumol	48-50	-	-	-	-
	Permafluor E+	Pseudocumol	48-50	-	-	-	-
	Atomlight	Pseudocumol	48-50	-	-	-	-
	Biofluor	Pseudocumol	48-50	-	-	-	-
	Aquassure	Pseudocumol	48-50	-	-	-	-
	Aquasol-2	Xylol	24-26	-	-	-	-
	Flo Scint II	Pseudocumol	46	55	-	-	-
	Flo Scint III	Pseudocumol	46	46	-	-	-
Cocktails for pure organic samples	**Ultima Gold F**	DIPN	~ 150	65	-	Only for pure organic samples	
	Opti-Fluor O	LAB	~ 150	59	-		
	OptiScint HiSafe	DIPN	~ 150	61	-		
	Insta-Fluor Plus	Pseudocumol	48-50	65	57		
	Econofluor-2	Pseudocumol	48-50	-	-		
	High Eff. Min. Szint.	Pseudocumol	79	-	-		

* This column shows the uptake capacity for aqueous samples in 10 ml of cocktail.
† All "Safer" cocktails are in blue boxes.
‡ This sign „-„ means, that no data are available.
§ All classical cocktails are in green boxes.

Safer Cocktails on Basis of DIPN, PXE or LAB

The following cocktails are based on one or more of the above mentioned solvents. All these cocktails are good or very good biodegradable. None of these solvents show diffusion into polyethylene vials. This means that measurements in polyethylene vials can be done even for longer measurement times.

Ultima Gold (Part No. 6013329)
This cocktail is a safer cocktail based on diisopropylnaphthalene (DIPN) originally developed by Packard and shows good counting efficiency for ^{3}H in organic and aqueous samples of up to 56%. This is the cocktail of choice if you want to avoid using many different cocktails for samples of different nature. This cocktail is also very quench resistant. The flash point is 150 °C

OptiPhase HiSafe 2 (Part No. 1200-436)
This cocktail is comparable with Ultima Gold but has been developed by Wallac Oy in Turku, Finland. Typically you get counting efficiencies for ^{3}H of 52%. The cocktail is based on DIPN and has a flash point of 144 °C.

Formula-989 (Part No. 6NE9899)
This cocktail has been developed by NEN. As Emulsifier Safe, this cocktail is based on LAB as the solvent. It is a multi purpose cocktail for organic and aqueous samples. The cocktail forms homogeneous solutions and has a uptake capacity of up to 20-30% of aqueous sample. The cocktail has a flash point of 140 °C.

Emulsifier Safe (Part No. 6013389)
Emulsifier Safe is a cost reducing alternative for Ultima Gold or OptiPhase HiSafe 2. The cocktail is based on LAB as the solvent. It forms homogeneous solutions with organic and aqueous samples with a maximum uptake capacity of 10-15%. This cocktail has a high flashpoint of 150 °C.

Ultima Gold XR (Part No. 6013119)
This cocktail has especially been developed for extremely high uptake capacities for aqueous samples but can also be used for organic samples. The cocktail has been developed by Packard. In some cases a ratio between cocktail and sample of 1:1 is possible which allows the user to place much more sample into a measurement vial. Sometimes it is possible to reduce the amount of cocktail and to switch from a 20 ml vial to a 6 or 8 ml vial. This can significantly reduce the waste volume and the costs for waste disposal. This way the user can save a lot of money although the cocktail is slightly more expensive than Ultima Gold. The cocktail also uses DIPN as the solvent and shows high quench resistance and a flash point of 150 °C. The counting efficiency is slightly reduced to 50% for ^{3}H. This is a result of the higher amount of emulsifiers. Because of the much higher uptake capacity of this cocktail you will overall find a clearly better lower limit of detection for this cocktail.

OptiPhase HiSafe 3 (Part No. 1200-437)
This cocktail, originally developed by Wallac Oy, which is based on DIPN, accepts samples with high ionic strength and can take up large volumes of aqueous sample. The cocktail is comparable with Ultima Gold XR. The flash point is 148 °C.

Ultima Gold LLT (Part No. 6013377)
If you are interested in low level applications this might be the cocktail of choice for you. It has originally been developed by Packard. You will get low background rates and high sample capacities comparable with Ultima Gold XR.

Uptake capacity is up to 54%, this means the sample can contain a little bit more water than cocktail.

Besides this, the cocktail also shows very high uptake capacities for heavy metals and strong mineral acids such as 2M HNO3 (up to 18%) HCl or H_3PO_4. The α–/β–discrimination is also very good. Therefore Ultima Gold LLT can be used as an alternative for Ultima Gold AB. The cocktail shows high quench resistance and a flash point of 140 °C.

Ultima Gold uLLT (Part No. 6013687)
In terms of performance practically identical with Ultima Gold LLT but this cocktail gives lowest background values. No raw materials containing any biogenic materials will be used during the production process thus reducing the amount of ^{14}C and ^{40}K in the final cocktail.

Ultima Gold MV (Part No. 6013159)
Ultima Gold MV is the cocktail with the lowest viscosity within the Ultima Gold series of cocktails and has originally been developed by Packard. This cocktail shows very good counting efficiency for ^{3}H of 57%. It is used if you need very easy dissolution of your sample in cases of very small volumes or for the measurement of filters. The ability to moisten filters is reduced in some of the more viscous cocktails and here Ultima Gold MV might work. As all cocktails within the Ultima Gold series this cocktail also shows high quench resistance. The flash point of this cocktail is at 110 °C.

Ultima Gold F (Part No. 6013179)
This cocktail has the best counting efficiency for ^{3}H of up to 63% for unquenched samples and has also been developed by Packard. The high counting efficiency is mainly due to the fact that this cocktail does not contain any emulsifiers. Therefore this cocktail can only be used for pure non-polar organic material. This cocktail can not be used for aqueous samples. But also highly polar organic samples such as methanol or acetylacetate can not be used. Completely dry filters or Filtermats can be measured. This cocktail shows high quench resistance and has a flash point of 150 °C.

OptiScint HiSafe (Part No. 1200-434)
Wallac originally developed this cocktail which is comparable with Ultima Gold F and is also a pure organic cocktail based on DIPN. As this cocktail does not contain emulsifiers, this cocktail is not suitable for aqueous samples. We already saw for Ultima Gold F that cocktails without emulsifiers, show high counting efficiencies. OptiScint HiSafe shows a counting efficiency of up to 61% for ^{3}H in unquenched organic samples. The flash point is above 140 °C.

Ultima Gold AB (Part No. 6013309)
We already mentioned this cocktail when we discussed Ultima Gold LLT. This cocktail is the only one in the market especially developed by Packard for α–/β–discrimination. The counting efficiency of ^{3}H in unquenched samples can be as high as 52%. This cocktail also accepts high amounts of mineral acids and has a high sample uptake capacity. It shows high quench resistance and has a flasch point of 140 °C.

Optifluor (Part No. 6013199)
This cocktail originally came from Packard and is a multi purpose cocktail. This cocktail is also a safer cocktail but based on LAB. The cocktail shows only small photo and chemiluminescence. The flash point is at 150°C.

Optifluor O (Part No. 6013339)
This is also a safer cocktail based on LAB but does not contain any emulsifiers. It is a pure organic cocktail not suitable for aqueous samples. The cocktail shows low photo and chemiluminescence. It can be used for the measurement of Radon if you prefer to use an organic cocktail. The flash point is at 150 °C.

LumaSafe (Part No. 3087)
This cocktail has originally been developed by Lumac in the Netherlands. It is a safer cocktail based on PXE as the main solvent.With the exception of LumaSafe, LumaSafe Plus and Lumagel Safe the solvent PXE has only been used for radio HPLC cocktails so far. The advantage of this cocktail is the very good biodegradability. In terms of sample uptake this cocktail is comparable with Ultima Gold however; the counting efficiency is slightly lower for ^{3}H. The cocktail has a flash point of 149 °C.

LumaSafe Plus (Part No. 3097)
As mentioned for LumaSafe this cocktail has been developed by Lumac. This cocktail also uses PXE as the solvent. Due to the higher amount of emulsifiers the counting efficiency is slightly lower than for LumaSafe but this can by more than compensated with the increased sample uptake of more than 50%. This cocktail is comparable with Ultima Gold XR but it does not reach the counting efficiency of the latter. The flash point is at 149 °C.

LumaGel Safe (Part No. 3077)
This is the third cocktail from Lumac and comparable with Insta-Gel Plus. It forms stable gels and is mainly used for measurements of insoluble but suspended solids. LumaGel Safe is currently the only biodegradable gel forming cocktail based on PXE. In the gel phase the uptake capacity is very high up to 50% but the counting efficiency is lower compared with Insta-Gel Plus. Very important is also using the correct ratio of sample to cocktail otherwise there will be no stable gel. Depending on the ratio four different phases are possible (homogeneous phase, two phase system, two gel phases). If you use this cocktail please make sure that you use the necessary amount of cocktail for a stable gel phase. The flash point of this cocktail is at 149 °C.

SafeFluor-S (Part No. 3067)
SafeFluor-S also originally was a Lumac cocktail. This cocktail has improved sample uptake capacity compared with SafeFluor and there is no problem with phase separation with small amounts of sample anymore in this cocktail. The cocktail is still based on LAB and has a flash point of 149 °C. SafeFlour-S is a cheap cocktail but has the lowest ^{3}H counting efficiency among all cocktails and should be replaced by cocktails with better performance, for example Ultima Gold XR or OptiPhase HiSafe III.

Classical Cocktails Based on Xylene or Pseudocumene

Although the use of classical cocktails decreases since more and more safer equivalents are available still some classical cocktails are useful for special applications. There are even some classical cocktails for which safer alternatives are not available.

Insta-Gel Plus (Part No. 6013399)
This is one of the classical cocktails which are still in widespread use. This cocktail came originally from Packard in Groningen, Netherlands and is a cocktail which forms gels. In the gel phase this cocktail has a very high uptake capacity of up to 50% which is comparable with the uptake capacity of the safer cocktails for aqueous samples such as Ultima Gold XR and Ultima Gold LLT. The cocktail can be used in homogeneous phase with small sample volumes (0-2 ml water) or in the gel phase with larger volumes (4-10 ml water) per 10 ml of cocktail. After shaking of the mentioned volume of water and cocktail the gel appears in a few seconds. Between homogeneous and gel phase there is a two phase heterogeneous system where measurements are not possible. In the gel phase the cocktail can be used to measure ^{14}C scratched from TLC´s or other suspended solids. The cocktail shows only little diffusion into polyethylene vials and has a flash point at 50 °C.

Aquasol-2 (Part No. 6NE9529)
This cocktail came from NEN and is comparable with Insta-Gel Plus. It is a gel forming cocktail but uses xylene as solvent and has a very low flash point at 24-26 °C. This is the last cocktail from PerkinElmer which is still using xylene. In all other cocktails this solvent has been replaced by pseudocumene. The uptake capacity of this cocktail in the gel phase can reach up to 50% for aqueous samples. If you need longer measurement times we suggest the use of glass vials to avoid diffusion into the polyethylene vials.

Aquassure (Part No. 6NE9659)
This is also a NEN cocktail based on pseudocumene. This cocktail shows in comparison whith Aquasol reduced diffusion into polyethylene vials and has a higher flash point at 50 °C. It is a multi purpose cocktail with high uptake capacity for aqueous samples in the gel phase. The cocktail is comparable with Insta-Gel Plus.

Pico-Fluor 15 (Part No. 6013059) (no longer available)
This was originally a Packard cocktail. This cocktail for universal use is a classical cocktail based on pseudocumene and comparable with the safer cocktail Ultima Gold. Pico-Fluor 15 has a ^{3}H counting efficiency of up to 57%. The "15" indicates that for many samples the uptake capacity is 15% or even better. The cocktail shows only little diffusion into polyethylene vials and has a flash point of 50 °C. At high ionic strength of the sample Pico-Fluor 15 as well as Ultima Gold is not the recommended cocktail. In such a case Hionic Fluor might be the better choice.

Biofluor (Part No. 6NE9619)
This product originally came from NEN and is also based on pseudocumene. In terms of uptake capacity this cocktail is comparable with Ultima Gold or Pico-Fluor 15. It shows a flash point at 50 °C and shows only little diffusion into polyethylene vials.

Pico-Fluor 40 (Part No. 6013349)
This is a cocktail of the Pico-Fluor series and as already mentioned for Pico-Fluor 15 this cocktail has been developed by Packard and also uses pseudocumene as the solvent. In contrast to Pico-Fluor 15 the amount of emulsifier in this cocktail is significantly higher resulting in a sample uptake capacity of up to 40%. At the same time this has an influence on the ^{3}H counting efficiency which is decreased to 51% for unquenched samples. Pico-Fluor 40 can also be used in combination with tissue solubilizers such as Soluene-350. The cocktail shows very low diffusion into polyethylene vials and the flash point is also close to 50 °C.

Insta-Fluor Plus (Part No. 6013127)
Packard in the Netherlands originally developed this cocktail. It is only suited for pure organic samples because it does not contain any emulsifiers. This cocktail can not be used with aqueous solutions. Only recently xylene has been replaced by pseudocumene in this cocktail. The ^{3}H counting efficiency can be very high, up to 65% in unquenched samples. The cocktail is stable against chemiluminescence and can be used for two phase extractions. Therefore we recommend this cocktail for the measurement of radon in so called Pico-Rad detectors. In these detectors radon bound to active carbon can be extracted with Insta-Fluor Plus. The viscosity of this cocktail is relatively low. This allows using this cocktail in radio HPLC applications with the exception of narrow or microbore HPLC. However, eluents have to be purely organic which means that reversed phase chromatography is not possible with this cocktail. The cocktail has a flash point of approximately 50 °C and shows only low diffusion into polyethylene vials.

Econofluor-2 (Part No. 6NE9699)
This cocktail is comparable with Insta-Fluor Plus, is also based on pseudocumene and also restricted to organic samples without traces of water. The cocktail can also be used for two phase extractions and typical sample types are fatty acids, lipids, steroids, terpenes and prostaglandins. The cocktail shows low diffusion into polyethylene vials and has a flash point of 50 °C.

High Efficiency Mineral Oil Scintillator (Part No. 6NE9579)
This cocktail does not contain any emulsifiers and is therefore only suitable for organic samples. It is an excellent cocktail for the measurement of radon in water (extracting all the radon into the cocktail) and soil samples. Counting efficiencies for radon are comparable with solid scintillators. The cocktail mainly consists of mineral oil and up tp 20% of pseudocumene. The flash point is 79 °C.

FilterCount (Part No. 6013149)
This is a very special cocktail developed by Packard and there is no safer alternative available. The cocktail is based on pseudocumene and has been especially developed to dissolve cellulosenitrate membrane filters. It can also be used to dissolve mixed cellulose esters and PVC filters but the latter will need more time. Complete dissolution of filters guarantees a perfect and homogeneous 4π–geometry. This means that quench curves can be used and that physical quench can be avoided. Physical quench can be a problem for ^{3}H labeled samples and can result in a significant reduction in the ^{3}H counting efficiency (potential danger to oversee ^{3}H contaminations in wipe tests). FilterCount can be used for organic and aqueous samples and ^{3}H counting efficiencies in unquenched samples of up to 57% are possible. The cocktail shows low amount of diffusion into polyethylene vials.

Hionic Fluor (Part No. 6013319)
This cocktail came originally from Packard and is based on pseudocumene. It has especially been developed to accept samples with high ionic strength. This cocktail accepts high amounts of sucrose and cesiumchloride. It can also be used for tissue solubilizer such as Soluene-350 and Solvable. Hionic-Fluor shows high quench resistance especially in presence of trichloroaceticacid. Chemiluminescence decays much faster with this cocktail than with any other cocktail. It shows low diffusion into polyethylene vials and has a flasch point of 50 °C.

Atomlight (Part No. 6NE9689)
NEN developed this cocktail which is very comparable with Hionic-Fluor. It also accepts sample with high ionic strength. This cocktail is based on pseudocumene and the flash point is at 50 °C. It can be used with solubilizers such as Solvable.

Cocktails for Oxidizers

Monophase S (Part No. 6013109)
This cocktail has been developed by Packard for use in the sample oxidizer models 306, 307 and 387. The cocktail can be used with pure aqueous samples and has an uptake capacity of 23%. It is not foaming und does not produce gels. The cocktail is based on pseudocumene and only shows little diffusion into polyethylene vials. The flash point is at 50 °C.

Permafluor E+ (Part No. 6013187)
As already mentioned for Monophase S this cocktail has also been developed for the use with the PerkinElmer oxidizers. It is for the use with ^{14}C samples ($^{14}CO_2$) which are bound to Carbosorb. The cocktail is based on pseudocumene and only shows little diffusion into polyethylene vials. The flash point of this cocktail is at 50 °C.

Cocktails for Radio-HPLC
Caution: Because of the high viscosity of classical LSC cocktails and the problems to get homogeneous mixtures with the low viscosity HPLC eluents classical LSC cocktails are usually not suitable for radio-HPLC applications. For radio-HPLC please only use one of the following cocktails.

Safer Radio-HPLC Cocktails
In the following section you will see that the radio-HPLC cocktails have significantly lower ^{3}H counting efficiencies than normal LSC cocktails. As already mentioned, radio-HPLC cocktails include a much higher amount of emulsifiers. The emulsifier component can be as large as 50% of the total cocktail volume. This reduces the relative amount of solvent and scintillator thus reducing the counting efficiency.

Ultima-Flo M (Part No. 6013579)
This is a multi purpose cocktail developed by Packard which can be used for a lot of different HPLC eluents. Due to the low viscosity this is the cocktail of choice for narrow and microbore applications. ^{3}H counting efficiencies are as high as 47% in unquenched samples. Ultima-Flo M is a safer cocktail based on phenylxylylethane (PXE) and LAB. The flash point of this cocktail is approximately 120 °C.

Ultima-Flo AP (Part No. 6013599)
The ending "AP" for this cocktail has been chosen because Packard developed this cocktail for ammoniumphosphate buffers. However, this cocktail also shows excellent performance with a wide range of different eluents and therefore nowadays "AP" is used for "all purpose". ^{3}H counting efficiencies of up to 43% are possible. The cocktail is based on benzyltoluene and diphenylethane and has a flash point at 120 °C.

Ultima-Flo AF (Part No. 6013589)
This cocktail has mainly been developed for high concentrations of ammoniumformiate buffers. It can accept two molar buffer solution in a 1:1 ratio with cocktail. The maximum counting efficiency can be 43%. The cocktail is based on PXE and LAB and has a flash point at 120 °C.

Classical Radio-HPLC Cocktails

Flo-Scint II (Part No. 6013529)
This cocktail has been developed by Packard. This cocktail shows strong resistance against chemiluminescence and accepts diluted buffers. It consists of pseudocumene and petroleum. The flash point is at 46 °C. ^{3}H counting efficiencies can be as high as 55%, however, this requires a 4-5 fold excess of cocktail.

Flo-Scint III (Part No. 6013539)
This cocktail has been developed by Packard for samples with medium buffer concentrations. The solvents ar pseudocumene and petroleum as well as an increased amount of ethoxylated alkylphenols compared to Flo-Scint II. This allows higher buffer concentrations. Maximum ^{3}H counting efficiencies are up to 46%.

Cocktails for Microplate Scintillation Counters

BetaPlate and MicroBeta

Optiphase SuperMix (Part No. 1200-439)
This cocktail has been developed by Wallac on the basis of DIPN. The cocktail shows relatively low viscosity which makes this an ideal cocktail for mixing samples with cocktail in a microplate. It is therefore a very suitable cocktail for measurements in the MicroBeta. As this cocktail contains almost 50% emulsifiers it has a very high uptake capacity for samples. The flash point of this cocktail is at 148 °C.

BetaPlate Scint (Part No. 1205-440)
This is also a safer cocktail which has been developed by Wallac Oy in Finland. The name indicates that it has been used with the older BetaPlate counter but can also be used for measurements in the MicroBeta. This cocktail does not contain any emulsifiers and can therefore not be used with aqueous samples but it is an excellent cocktail for harvested samples on dried filter membranes. The flash point of this cocktail is at 140 °C.

Meltilex (Part No. 1450-441)
Meltilex is a very special cocktail. It is the only solid, meltable cocktail which has been developed by Wallac. As in standard cocktails the scintillators are PPO and bis-MSB. The basis of Meltilex is paraffine and poly (vinyltoluene-α-methylstyrene). The melting point is at 58-62 °C. This scintillator will mainly be used for the measurement of filters. The solid scintillator will be placed on top of the dried filter and heated to 90 °C on a heating plate. While the scintillator is melting it migrates into the filter and completely surrounds the activity on the filter. This way a contamination during the work with this filter can almost be excluded. Partly Meltilex can also be used for the measurement of α–emitters or high energy β–emitters in the gas phase. Applications are the measurement of ^{222}Rn or ^{85}Kr. In this case meltilex will be melted on the wall of a polyethylene vial. The travelling range of α– or high energy β–emitters is high enough to excite the Meltilex and yield good counting efficiencies.

Special Cocktails for the TopCount

Caution: MicroScint cocktails contain a special formulation resulting in very long pulse durations. This is of high importance for the time resolved background reduction. Therefore you should only use MicroScint cocktails in the TopCount.

All MicroScint cocktails have been developed by Packard. They all contain PPO as the scintillator as well as DIPN and 9, 10-dimethylanthracene as the solvent. Further components are included for special performance. All MicroScint cocktails are safer, biodegradable cocktails.

MicroScnt O (Part No. 6013611)
This cocktail is based on DIPN and 9,10-dimethylanthracene to increase the pulse length. The cocktail does not contain any emulsifiers and can not be used with aqueous samples. It is the ideal cocktail for organic samples or dried filters. With MicroScint O you can get ^{3}H counting efficiencies of up to 58%. The flash point of MicroScint O is at 152 °C.

MicroScint 20 (Part No. 6013621)
This cocktail uses the same solvent as MicroScint O but also emulsifiers such as ethoxylated alkylphenols. The uptake capacity for aqueous samples is 20%. The maximum ^{3}H counting efficiency in a white 24 well OptiPlate is 52%. It is the best cocktail for wet filters. Mixing of the cocktail with sample is simple on an orbital shaker. The flash point of MicroScint 20 is at 152 °C.

MicroScint 40 (Part No. 6013641)
This cocktail has been developed for especially high sample uptake of up to 40% aqueous sample. Additional emulsifiers are added to this cocktail to get this high uptake capacity. In case of high sample volumes extended shaking might be necessary to obtain a homogeneous solution. Maximum ^{3}H counting efficiency in a white 24 well OptiPlate is 40%. The flash point of this cocktail is at 152 °C.

MicroScint PS (Part No. 6013631)
This cocktail is comparable with MicroScint 20 but it is especially compatible with polystyrene plates. Many other cocktails can dissolve polystyrene during longer measurement times. Part of the DIPN has been replaced by mineral oil in this cocktail. With MicroScint PS you can get ^{3}H counting efficiencies in white 24 well Optiplates of up to 48%. MicroScint PS has a flash point of 162 °C.

MicroScint E (Part No. 6013661)
This cocktail has been developed for extraction of organic samples, especially lipids from aqueous phases within a microplate. It contains mainly non-polar components. Besides DIPN it contains petroleum. After addition of cocktail the plate can be measured in the TopCount. Maximum ^{3}H efficiencies of up to 50% are possible in white 24 well OptiPlates. The flash point of this cocktail is at 98 °C.

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