THE DEVELOPMENT OF AN ALPHA/BETA SEPARATION LIQUID SCINTILLATION COCKTAIL FOR AQUEOUS SAMPLES

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Scintillation cocktail components were studied with regard to their impact on pulse decay discrimination (PDD) and hence the separation of alpha from beta activity, using a Packard 2250 CA \( \alpha/\beta \). Di-isopropyl naphthalene (DIN) was found to be the most suitable solvent, both from safety considerations and also the fact that it acts in a very similar manner to naphthalene in stretching the pulses produced at the photomultiplier tube anode and hence enhancing the separation. Increasing the surfactant concentration and the use of dimethylanthracene (DMA) as secondary fluor degraded the cocktail’s performance. PMT anode pulse shapes were found to be a useful indicator of PDD efficiency but could not give a quantitative guide.

The separation of alpha from beta activity using liquid scintillation spectrometry is a relatively new feature in commercial instruments although the technique was first demonstrated experimentally around 20 years ago. The separation of the activities is based on pulse shape discrimination (PSD), a technique which had previously been widely used in neutron spectroscopy. However, until recently, the PERALS instrument developed at Oak Ridge National Laboratory by McDowell and coworkers, has been the only commercial liquid scintillation spectrometer to employ PSD. PERALS is used to separate alpha events from a \( \beta/\gamma \) background, but is unable to make quantitative measurements of beta activity. The past 5 years have seen the introduction of dual purpose instruments (i.e., with the ability to carry out beta measurements or simultaneous alpha/beta separation and measurement) by all the major LSC manufacturers.

Pulse shape discrimination or pulse decay discrimination (PDD) exploits the fact that pulses produced at the PMT anode of a liquid scintillation spectrometer are made up of two components – the prompt and the delayed. By studying the scintillation process at an electronic level, it is possible to understand the source of the two components. As ionising radiation passes through matter (in this case the scintillation cocktail) it gives up its energy causing electrons to be excited into singlet or triplet states. Excited singlet states rapidly (i.e., in less than 80 ns) lose their energy via fluorescence, giving rise to

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the prompt component of the pulse. The delayed component is derived from the decay of excited triplet states. The radiative process for triplet states (phosphorescence) is "forbidden", i.e. it has a very low probability of occurring. Therefore, for a triplet state to release its energy as a photon it must first collide with another triplet state in a process called triplet annihilation [Eq. (1)].\(^6\) As this process is bimolecular, the lifetime of a triplet state is much longer (>300 ns)\(^6\) than for an excited singlet. The higher specific ionisation of alpha particles causes a greater proportion of triplet states to be formed than for beta particles,\(^7\) hence, alpha particles give rise to a more delayed release of photons and thus longer duration pulses. This difference in pulse length forms the basis for PPD.

The 4π geometry of liquid scintillation spectrometry (LSS) results in approximately 100% counting efficiencies for alpha emitting radionuclides. This, combined with the low backgrounds obtainable with PDD, makes LSS a useful tool in the assay of alpha-activity. However, it has the distinct disadvantage of having much poorer resolution than conventional alpha-spectrometry using silicon surface barrier (SSB) or passivated implanted planar silicon (PIPS) detectors. This is due to the relatively inefficient light production of alpha-emitters\(^2\) (approximately a factor of 10 less energy to light production than with beta-emitters) and the relatively large amount of energy required to produce a photo-electron in the PMT. In an attempt to overcome this, many workers in this field have concentrated their efforts on extractive scintillators.\(^8\)-\(^10\) These systems extract the radionuclide of interest into the organic phase, minimising the problems associated with quenching, i.e., energy resolution is improved as the quenching is reduced while the associated problem of peak identification with variable quenching is eliminated. Also, extractive scintillators can make the preparative chemistry faster and simpler when a single radionuclide or isotopes of a single element are to be studied.

However, in many situations where LSS is applicable, the use of extractive scintillators is not appropriate. For example, gross alpha screening of air filters or surface wipes may simply require the separation of alpha from beta activity and a gross alpha count rate, with no differentiation between the nuclides present. Therefore, the selectivity of extractive scintillators makes them unsuitable for this purpose. Another example is that of alpha screening of reactor coolant water. In this case not only are extractive scintillators too selective, but their use complicates the preparative chemistry.

The development of a cocktail for aqueous media is particularly pertinent at this time since the recommendation for improving alpha/beta separation has, until now, largely