



LIQUID SCINTILLATION

- MEASURING PROCEDURES, NEW DEVELOPMENTS -

3rd completely revised and extended Edition 2024

DGFS e.V. German Society for Liquid Scintillation Spectrometry
Karlsruhe Institute of Technology, 2024 Karlsruhe

MOEBIUS Siegurd
MOEBIUS Tiana
TARANCON Alex
WENDEL Juergen

Many thanks for supporting the Handbook with regard to content to

ERAT Stephan (Layout), SANTIAGO Luz (Graphics),
WISSER Sascha (2.3.4.), MAYER Klaus (2.3.13.),
MOEBIUS Rolf (2.4.2.) and WOLF Sarah (2.4.4.)

This work is subject to copyright. Any kind of reproduction or translation, even partial, is permitted only with the consent of the authors.

The results of this book are based on literature compilations and experimental investigations to the best of our knowledge. The authors explicitly point out that in the implementation of the proposals and recommendations of this book the individual circumstances should be taken into account. "Good Laboratory Practice" and the state of the art in analytical quality management is a prerequisite for the reliability of analytical results.

The authors, DGFS e.V. and Karlsruhe Institute of Technology KIT exclude any liability for damages which may arise from the use of the information in this book.

Copyright by Karlsruhe Institute of Technology – Campus North
Hervorgegangen aus dem Zusammenschluss des Forschungszentrums Karlsruhe GmbH und
der Universität Karlsruhe (TH)
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen

Printed in Germany

ISBN 978-3-923704-97-2
3rd completely revised and extended Edition
Available as well as CD-ROM

PREFACE

This handbook on Liquid Scintillation (LS) presents a compilation of the contemporary most important radioanalytical procedures applying this modern measuring technology. It serves as a manual for the determination of radioisotopes by LS. New developments are described including our research work on natural radionuclides published recently in two other handbooks. It was also featured on the Proceedings of the "International Conferences on Liquid Scintillation Spectrometry" LSC2001, 2005, 2008, 2010, 2013, 2017 and 2020. Literature is evaluated until 2023.

Multifold radioanalytical procedures for the environmental survey have been published worldwide. However, only a few of them really concern the liquid scintillation technology. Liquid Scintillation Spectrometry (LSS) presents nowadays an effective, efficient and universal method for the measurement of radionuclides, especially with the recent developments of extractive sample preparation, α/β -Pulse Shape Discrimination and Triple-to-Double Coincidence Ratio (TDCR) for absolute counting. The latter in combination with Cerenkov counting is focused in more detail as it avoids an otherwise tedious and time-consuming quench correction.

Modern LSS is summarized in the first part of the handbook together with practical equipment calibration techniques. Measuring procedures are dedicated to natural radionuclides as well as radionuclides from nuclear fission activities like decommissioning. Applications in radiation protection and medicine as well as solid microsphere applications round up the spectrum of content.

Quality assurance aspects are discussed in the last part. A comprehensive literature survey facilitates further studies.

The request of the "LSC-Handbuch" edited in 2008 in German language, and recently in 2012 in English, as well as the steady request from participants of international training activities was the motivation for the German Society for Liquid Scintillation Spectrometry DGFS e.V. to publish these measuring procedures.

The authors wish that this fully revised and extended third handbook edition would further spread this modern and future prospective methodology of Liquid Scintillation Spectrometry.

LIQUID SCINTILLATION

- MEASURING PROCEDURES, NEW DEVELOPMENTS -

Summary

The most important radioanalytical procedures for Liquid Scintillation (LS) as a modern measuring technology are compiled in a practice-oriented way. The methods cover α/β -discrimination, extractive scintillation and TDCR for both natural radionuclides as well as for activation/fission nuclides resulting from the nuclear fuel cycle.

Following an introduction of the present state of the art of LS technology with TDCR and Cerenkov counting, calibration procedures are covered. They include quench correction, α/β -pulse shape discrimination and working procedures for dual and multi labeled samples.

In the main part measuring procedures are presented for natural radionuclides with special emphasis on rapid methods for Radon, $^{226,228}\text{Ra}$ and ^{210}Pb in water samples, satisfying the worldwide request for drinking water analysis. An excursion to Low Level Tritium and Radiocarbon in bio-based products follows.

Procedures for the determination of radionuclides in the nuclear fuel cycle address to $^{89,90}\text{Sr}$ fission nuclides, from conventional to TDCR Cerenkov counting (^{89}Sr and ^{90}Y), but include as well ^{241}Pu as low β -energy built up actinide nuclide. The determination of ^{55}Fe , ^{63}Ni and $^{41,45}\text{Ca}$ isotopes as EC and low energy β -emitting activation products in decommissioning activities includes also their comprehensive sample preparation. Medical applications with respect to α -therapy and $^{99\text{m}}\text{Tc}$ quality control are included additionally.

The part on Radiation Protection covers laboratory contamination and incorporation control, Radon in air, effluent measurements for Tritium and Radiocarbon as well as NORM materials in phosphogypsum and in the oil and gas industries.

The recent progress in radioanalysis applying solid microspheres has been summarized in a separate chapter.

The last part of this manual is dedicated to quality assurance aspects like method validation with uncertainty budget, error analysis and the calculation of lower limits of detection.

A comprehensive literature survey facilitates applying this handbook for further studies on modern Liquid Scintillation Spectrometry.