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INORGANIC COMPOUNDS

Radiolabelling of engineered nanoparticles for in vitro and in vivo tracing applications using cyclotron accelerators

N. Gibson · U. Holzwarth · K. Abbas · F. Simonelli · J. Kozempel · I. Cydzik · G. Cotogno · A. Bulgheroni · D. Gilliland · J. Ponti · F. Franchini · P. Marmorato · H. Stamm · W. Kreyling · A. Wenk · M. Semmler-Behnke · S. Buono · L. Maciocco · N. Burgio

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Abstract We present in this article an outline of some cyclotron-based irradiation techniques that can be used to directly radiolabel industrially manufactured nanoparticles, as well as two techniques for synthesis of labelled nanoparticles using cyclotron-generated radioactive precursor materials. These radiolabelled nanoparticles are suitable for a range of different in vitro and in vivo tracing studies of relevance to the field of nanotoxicology. A basic overview is given of the relevant physics of nuclear reactions regarding both ion-beam and neutron production of radioisotopes. The various issues that determine the practicality and usefulness of the different methods are discussed, including radioisotope yield, nuclear reaction kinetics, radiation and thermal damage, and radiolabel stability. Experimental details are presented regarding several techniques applied in our laboratories, including direct light-ion activation of dry nanoparticle samples, neutron activation of nanoparticles and suspensions using an ion-beam driven activator, spark-ignition generation of nanoparticle aerosols using activated electrode materials, and radiochemical synthesis of nanoparticles using cyclotron-produced isotopes. The application of these techniques is illustrated through short descriptions of some selected results thus far achieved. It is shown that these cyclotron-based methods offer a very useful range of options for nanoparticle radiolabelling despite some experimental difficulties associated with their application. For direct nanoparticle radiolabelling, if care is taken in choosing the experimental conditions applied, useful activity levels can be achieved in a wide range of nanoparticle types, without causing substantial thermal or radiation damage to the nanoparticle structure. Nanoparticle synthesis using radioactive precursors presents a different set of issues and offers a complementary and equally valid approach when laboratory generation of the nanoparticles is acceptable for the proposed studies, and where an appropriate radiolabel can be incorporated into the nanoparticles during synthesis.

Keywords Nanoparticles · Toxicity · Radiolabelling · Radiotracer · Ion beam irradiation · Neutron irradiation

N. Gibson (✉) · U. Holzwarth · K. Abbas · F. Simonelli · J. Kozempel · I. Cydzik · G. Cotogno · A. Bulgheroni · D. Gilliland · J. Ponti · F. Franchini · P. Marmorato · H. Stamm
European Commission, Joint Research Centre, Institute for Health and Consumer Protection, Nanobiosciences Unit, Via Enrico Fermi 2749, 21027 Ispra (VA), Italy
e-mail: neil.gibson@jrc.ec.europa.eu

W. Kreyling · A. Wenk · M. Semmler-Behnke
Comprehensive Pneumology Center, Institute of Lung Biology and Disease, Helmholtz Zentrum Muenchen, German Research Center for Environmental Health (GmbH), Ingolstaedter Landstr. 1, 85764 Neuherberg/Munich, Germany

S. Buono · L. Maciocco
Advanced Accelerator Applications (AAA), 20 Rue Diesel, 01630 Saint Genis Pouilly, France

N. Burgio
C.R. Casaccia, ENEA, Via Anguillarese 301, S. Maria di Galeria, 00060 Rome, Italy

Introduction

Nanotoxicology and radioactive nanoparticles

In recent years, the field of nanotechnology has attracted enormous attention from scientists, industry, funding bodies, and the public due to its widely advertised potential for