

## Index

- 
- advanced filtration, 226  
 aerodynamic diameter, 287–8  
 aerodynamic particle sizer, 66  
 aerosol, 290–1  
 aerosol particle sizer, 82  
 agglomeration, 8  
 aggregation, 10  
 airborne nanoparticles, 269  
   collection of particles, 91–3  
     sampling instruments for nano-sized particles, 93  
   deficiencies of measuring devices, 94–5  
     background noise, 94  
     contamination of sampled particles, 94–5  
     low volume flows, 94  
     particle losses, 94  
   measurement and sampling techniques, 78–106  
     case study, 95–105  
     comparison of measurement devices, 88–91  
     measurement of particles, 86–91  
     summary of widely used monitoring instruments, 86  
   release scenarios of nano-sized particles  
     from nanocomposites, 82–5  
     particle number concentration spectra measured during sanding, 83  
     particles released from surface coating, 82–4  
     particles released from surface nanocomposites, 84–5  
     TEM image of abraded particles, 85  
 aluminium diethyl phosphinate, 258  
 American Conference of Governmental Industrial Hygienist (ACGIH), 269, 272  
  
 American Society for Testing and Materials (ASTM) International, 75  
 ammonium polyphosphate (APP), 300–1  
 analytic physics methods, 286–92  
 antioxidants, 156–7  
 antisolvent addition, 226  
 apoptosis, 36  
 aquatic toxicity, 202–4, 206–7, 209  
 area sampling, 57  
 arsenates, 208  
 Association International Pour l'Etude des Argiles (AIPEA), 137  
 atomic absorption (AA) spectrophotometer, 53, 55  
 atomic absorption spectroscopy, 182–3  
 atomic force microscopy (AFM), 290–1, 301  
  
 background noise, 94  
 bentonites, 297–8  
 biodegradable polymers, 138  
 biopersistence, 30  
 biopolymers, 138  
 biotic degradation, 67  
 bone repair, 156  
 British Standards Institute, 272  
  
 CalTOX, 122  
 carbon black (CB), 298  
 carbon nanoparticles  
   safe recycling of materials containing persistent inorganic nanoparticles, 222–39  
   engineered nanomaterials applied in suspensions, 225–30  
   nanocomposites, 230–1

- nanomaterials present in wastes, 237–8
- recycling options range, 231–7
- released linked to recycling facilities, 238–9
- carbon nanotubes (CNT), 12, 122, 255, 298
  - antioxidants, 156–7
  - antioxidant activity CNT acts as scavengers towards hydroxyl radicals, 158
  - ecotoxicological effects and test methods and current research, 175–93
  - future trends, 190
  - methodological issues, 180–4
  - risks of nanoparticles, 184–90
  - future trends, 165–6
    - proposed strategy for design of safe CNT, 166
    - publications since their discovery compared with those addressing toxicity, 165
  - physico-chemical properties, 148–52
    - electrical, mechanical and thermal properties and applications, 150–1
    - properties and applications, 149
    - structural and chemical properties, 149
  - properties, applications and toxicity, 147–66
    - nanomedicine, 152–7
    - toxicity, 157–65
  - quantification in environmentally relevant media, 176–80
    - bioaccumulation factors of SWCNT, MWCNT and pyrene spiked to Chelsea oil, 179
    - MWCNT uptake by *Daphnia magna*, 180
    - selected techniques for identifying or quantifying CNT, 177–8
  - synthesis and modifications, 151–2
    - morphology TEM images of MWCNT, 152
- caspase protein families, 38
- cation exchange capacity (CEC), 14
- CEN/TC 352, 75
- cerium dioxide, 208–9
- char-virgin interface, 284–5
- chemical stress, 67
- chemical vapour deposition (CVD), 12, 151
- chemothermal oxidation, 176
- chronic toxicity, 160
- clay, 258
- clay-enabled nanotechnology, 142
- clay minerals
  - characteristics, 135–7
    - schematic representation of structure of montmorillonite, 136
  - nanolayered silicates usages and effects on health, 133–42
    - effects on environment, 137–9
    - future trends, 142
    - life cycle assessment of nanoclay-reinforced materials, 141–2
    - nanoclays toxicity on humans, 140–1
    - summary of research on clay minerals over the last 10 years, 134
  - 'click' chemistry, 17
  - Cloisite 20A, 300–1
  - Cloisite 93A, 140–1
  - Cloisite 30B, 140–1, 300–1
  - Cloisite Na, 140–1
  - coagulation, 101, 226, 289
  - colloidal solvents, 226
  - combustion, 237, 256, 280, 299–302
  - Comet assay test, 141
  - compatibilisers, 235
  - condensation particle counter (CPC), 53, 65, 66, 82–3, 86–7
  - cone calorimeter fire model, 290–1
  - cone calorimetry, 286–92
    - coupling of analytic physics methods, 286–92
      - AFM technology at LNE, 291
      - experimental approach to measure mass distribution and concentration, 288
      - experimental techniques available to measure gases and aerosol combustion, 289–90
      - methods, 262
  - contamination, 94–5
  - convection phenomena, 280
  - convergent growth process, 16
  - copper oxide nanoparticles, 208–9
  - corona, 31
  - coupled plasma-mass spectrometry, 182–3
  - cracking, 237
  - cradle- to-grave LCA, 115
  - cry cutting, 239
  - crystallinity, 11
  - cytochrome c, 38
  - cytotoxicity, 141, 202

- Dekati low-pressure impactor (DLPI), 287
- dendrimers, 16–17
- depolymerisation, 235–6, 281
- dermal toxicity, 159
- devulcanisation, 235–6
- Diels-Adler reaction, 233
- differential mobility analyser (DMA), 55, 86–7
- diffraction angles, 263
- diffusion, 289
- dispersing agents, 74
- divergent method, 16
- drug delivery system, 154
- DustTrak, 66
- EC mandate M/461, 75
- ecotoxicological effects, 205
  - carbon nanotubes test methods and current research, 175–93
  - future trends, 190, 193
  - methodological issues, 180–4
  - quantification in environmentally relevant media, 176–80
  - current research on risks of nanoparticles, 184–90
  - lack of accumulation by most multicellular organisms, 185–9
  - low toxicity in soils and sediments, 190
- electrical low pressure impactor (ELPI), 55, 84, 88, 287
  - vs SMPS, 91
- electron-hole pair, 207
- electron paramagnetic resonance (EPR) spectrometry, 157
- electrostatic force, 135
- electrostatic precipitator (ESP), 65, 97
- embedded engineered nanomaterials (ENMs), 63
- embryonic stem cell test (EST), 159–60
- embryotoxicity, 159–60
- endogenous oxidants, 153
- energy dispersive X-ray (EDX) spectrometry, 55, 58
- energy recovery, 237
- engineered nanomaterials, 225–30
  - case studies, 115–23
    - existing LCA studies of ENMs and nano-enabled products, 117–21
    - life cycle assessment, 112–25
    - methodology, 113–15
    - new developments, 123–5
  - engineered nanoparticles (ENPs), 78
- Environmental, Health and Safety Research Needs for Engineered Nanoscale Materials, 212
- environmental effects, 202–5
  - aquatic toxicity, 202–4
    - summary of lethal effects of metal-based nanomaterials to aquatic organisms, 203
  - metal oxide nanomaterials and health effects, 200–12
    - applications of metal oxide nanomaterials, 201
    - future trends and regulation and risk assessment, 211
    - nano-titanium dioxide, 205–8
    - nano-zinc oxide, 200–5
    - other metal oxides, 208–11
    - sources of further information and advice, 211–12
  - terrestrial toxicity, 204–5, 207–8
- environmental impact
  - nanostructured flame retardants
    - performance and toxicity, 251–73
    - conventional and nanostructured, 254–6
    - dispersion of filter with polymer, 252
    - fabrication of polymer nanocomposites, 252–4
    - flame retardant behaviour of polymer nanocomposites, 256–7
    - future trends, 272–3
    - health and environmental risks, 267–72
    - synergies from combination, 257–67
- EPA's Nanomaterial Research Strategy, 212
- ethylene-vinyl acetate copolymer (EVA), 264–5
- European Commission Second Regulatory Review on Nanomaterials, 212
- European Commission Types and Uses of Nanomaterials including Safety Aspects, 212
- European Union (EU), 211
- exfoliated nanocomposites, 15
- exposure assessment, 47–60
  - comparison of sampling methods used for non-nanoscale particles and nanoparticles, 49
  - data interpretation, 58–9
  - future trends, 59–60
  - initial evaluation, 55–6

- instrumentation, 51–4
    - classification of instruments, 54
    - nanoparticle monitoring devices, 52–3
  - international standards and guidance
    - relating to nanoparticle exposure assessment, 50–1
  - main evaluation, 56–8
    - area sampling, 57
    - conducting filter-based area sampling, 57
    - personal air samples, 57–8
    - quality assurance and quality control, 58
    - sampling particle number concentration, 56
  - physicochemical properties of
    - nanomaterials recommended by ISO/TR 13014 and ISO/TR 13329, 50
    - physicochemical properties of nanomaterials relevant to exposure assessment, 49–50
  - sample collection strategies, 54–5
  - terms and definitions for nanotechnologies, 48
- fast mobility particle sizer (FMPS), 66, 82, 87
- vs SMPS, 88–91
- Fenton reaction, 229
- fibre paradigm, 36–7
- field emission displays (FED), 150
- field emission scanning electron microscopy, 97, 102
- filter-based area air sampling, 57
- fire toxicity
  - degradation products of nanocomposites and assessments, 292–4
    - main asphyxiating and irritant gases, 292
- flame retardants
  - behaviour, 256–7
  - conventional, 254–6
  - nanostructured, 254–6
- flaming ignition, 256
- flammability
  - thermal degradation and potential
    - toxicity of polymer nanocomposites, 278–303
  - fire toxicity of degradation products and assessments, 292–4
  - future trends, 302–3
  - instrumentation and techniques for investigation, 285–92
  - intrinsic toxicity of nanoparticles, 294–9
  - thermal stability of nanoparticles, 281, 283–5
  - ultrafine particle production during combustion, 299–302
- flocculated nanocomposites, 15
- flocculation, 226
- Fourier transform infrared (FTIR) spectroscopy, 262, 285, 286
- fractional effective dose (FED), 293
- frustrated phagocytosis, 37, 160–1
- fullerene, 258
- functional unit, 113
- gallery, 14
- gas chromatography (GC), 286
- gasoline vehicle particulate matter emissions, 92
- gel electrophoresis, 226
- 'grafting from' method, 10
- 'grafting to' method, 10
- graphenes, 255, 266
- graphite, 255
- Guidance on Sample Preparation and Dosimetry for the Safety Testing of Manufactured Nanomaterials, 69
- Guidelines and Protocols for Sampling (PROSPECT 2010), 67
- hand-held condensation particle counter (HCPC), 51
- hand-held optical particle counter (HOPC), 51
- hazards, 267
- health effects
  - metal oxide nanomaterials and environmental effects, 200–12
    - future trends and regulation and risk assessment, 211
    - nano-titanium dioxide, 205–8
    - nano-zinc oxide, 200–5
    - other metal oxides, 208–11
    - sources of further information and advice, 211–12
  - nanolayered silicates and clay minerals usages, 133–42
    - characteristics, 135–7
    - effects on environment, 137–9
    - future trends, 142
    - life cycle assessment of nanoclay-reinforced materials, 141–2
    - nanoclays toxicity on humans, 140–1
- heat flux ratio, 284–5

- heat transfer, 256–7
- Hoffman Degradation reaction, 283
- human embryonic stem cells (hESCs), 155–6
- hydrolysis, 67
- hydrophobic organic chemicals (HOC), 185
- 8-hydroxy-deoxyguanosine (8-OHdG), 33
- ignition, 280
- implantable devices, 155–6
- implantable materials, 155–6
- in situ* polymerisation, 253
- incineration, 280
- indoor particles, 90
- inductively coupled plasma (ICP), 53
- inductively coupled plasma mass spectrometry (ICP-MS), 66
- inductively coupled plasma mass spectrophotometer (ICP-MS), 55
- inhalation toxicity, 141
- intercalated nanocomposites, 14
- interlayer, 14
- International Organisation for Standardisation (ISO), 272
- intrinsic toxicity
- nanoparticles, 294–9
    - different anatomical regions of respiratory tract, 295
    - exchange surface area between air and human organism, 295
    - total fraction and fractions settled in each zone for person breathing through nose, 296
- ISO 13344, 293
- ISO 13571, 293
- ISO 14040, 113
- ISO 19702, 286
- ISO 3892–2:2006, 84
- ISO 5660–1, 287
- ISO/DIS 29904, 286
- ISO/DTS 12901–2, 51
- ISO/TC 229, 51, 63, 75
- ISO/TR 12885, 51
- ISO/TR 13014, 50
- ISO/TR 13329, 50
- ISO/TR 27628, 53, 55
- ISO/TR 9122–1, 292
- ISO/TS 19700, 300
- ISO/TS 27687, 47
- ISO/TS 12901–1, 51
- ISO/TS 80004–1, 47
- Knoevenagel condensation, 229
- layered silicates, 13–15
- 'lego' chemistry, 16
- life cycle assessment (LCA), 141–2
  - engineered nanomaterials, 112–25
    - case studies, 115–23
    - new developments, 123–5
  - methodology, 113–15
    - expanded framework indicating scope and impact assessment points, 116
    - framework, 114
  - life cycle impact assessment (LCIA), 114
  - life cycle inventory (LCI), 114
  - ligand exchange technique, 10
  - limiting oxygen index (LOI), 262
- lipid peroxidation, 38
- lipidomics, 38
- low heat capacity, 150
- low-temperature oxidation, 236
- low toxicity
  - soils and sediments, 190
    - summary of studies on ecotoxicity of CNTs, 191–2
- low volume flows, 94
- lung toxicity, 157–9
- magnesium hydroxide composites, 258–9
- magnetite, 17
- mass spectroscopy (MS), 286
- material flow analysis, 202–3
- Material Safety Data Sheets (MSDS), 272
- mechanical stress, 67
- melt processing, 253
- metal oxide nanomaterials
  - health and environmental effects, 200–12
    - future trends and regulation and risk assessment, 211
    - nano-titanium dioxide, 205–8
    - nano-zinc oxide, 200–5
    - sources of further information and advice, 211–12
  - other metal oxides, 208–11
    - human health effects, 209–11
- metal oxides, 17, 264
- methodological issues, 180–4
  - characterisation, 180–2
    - selected techniques for carbon nanotubes, 181
    - dispersing carbon nanotubes, 183–4
    - potential for release of metals from catalyst particles, 182–3
- microcatheters, 156

- micronucleus assay, 141
- monomer reversion, 281
- montmorillonite (MMT), 95, 140
- multi-criteria decision analysis (MCDA), 123
- multi-walled carbon nanotubes (MWCNT), 12, 149, 298
- multicellular organisms, 185–9
  - summary of studies of uptake, elimination and biodistribution of CNTs, 186–9
- nano-enhanced products
  - measurement and sampling techniques of airborne nanoparticles, 78–106
    - case study, 95–105
    - collection of particles, 91–3
    - deficiencies of measuring devices, 94–5
    - measurement of particles, 86–91
    - release scenarios of nano-sized particles from nanocomposites, 82–5
- nano-ferric oxides, 208
- nano-magnesium oxides, 208
- nano-object agglomerated or aggregated (NOAA), 50
- nano-titanium dioxide, 205–8
  - environmental effects, 206–8
    - aquatic toxicity, 206–7
    - terrestrial toxicity, 207–8
  - human health effects, 205–6
- nano-zinc oxide, 200–5
  - environmental effects, 202–5
    - aquatic toxicity, 202–4
    - terrestrial toxicity, 204–5
  - human health effects, 201–2
- nanoadditives, 253–4
- nanoclay-reinforced materials, 141–2
- nanoclays toxicity, 140–1
- nanocomposites, 230–1
- nanolayered silicates
  - clay minerals usages and effects on health, 133–42
    - characteristics, 135–7
    - effects on environment, 137–9
    - future trends, 142
    - life cycle assessment of nanoclay-reinforced materials, 141–2
    - nanoclays toxicity on humans, 140–1
- nanolayers, 13
- nanomaterials
  - common physical and chemical properties, 7–11
  - agglomeration, 8
    - classification based on agglomeration state, 8
    - classification based on phase composition criteria, 8
  - composition, 8
  - deposition, 9
  - diffusion, 9
  - general classification of particle ratios, 7
  - morphology and dimensions, 7–8
  - particle chemistry and crystalline structure, 11
  - surface coating and functionalisation, 10–11
- key terms and definitions, 6–7
- mechanisms of toxicity, 28–40
  - future trends, 39–40
  - mechanisms of nanomaterial-induced cellular damage independent of oxidative stress, 34–6
  - mechanisms of nanomaterial-induced cellular damage mediated by oxidative stress, 31–4
- shape and toxicity: the fibre paradigm, 36–7
- size and non-size-related toxicity mechanisms, 28–31
- use of lipidomics, proteomics and transcriptomics to understand nanomaterial toxicity, 37–9
- nanocomposites selected examples, 18–23
  - in-situ* polymerisation process, 20
  - logarithmic isolines of interfacial area/volume of particles with respect to aspect ratio, 19
  - morphology of nanoclay composites, 20
  - nanocomposites filled with nanoparticles, 22–3
  - nanocomposites filled with nanoplates, 18–22
- nanofillers, 11–17
  - dendrimers, 16–17
  - formation of polymer nanocomposites based on the filler's morphology, 14
  - layered silicates, 13–15
  - metal oxides, 17
  - nanotubes, 12–13
  - nanowires, 13
  - polyhedral oligomeric silsesquioxanes, 15
  - quantum dots, 11–12

- types and properties, 3–23
- nanomedicine, 152–7
- nanometre, 6
- nanometric alumina oxide, 264–5
- nanoparticle combustion, 268–9
- nanoparticle tracking analysis (NTA), 65, 97
- nanoparticles, 4
  - comparison of different measurement devices, 89
  - exposure assessment, 47–60
    - comparison of sampling methods used for non-nanoscale particles and nanoparticles, 49
    - data interpretation, 58–9
    - future trends, 59–60
    - initial evaluation, 55–6
    - instrumentation, 51–4
    - international standards and guidance relating to nanoparticle exposure assessment, 50–1
    - main evaluation, 56–8
    - physicochemical properties of nanomaterials relevant to exposure assessment, 49–50
    - sample collection strategies, 54–5
    - terms and definitions for nanotechnologies, 48
  - literature on nanoparticle release scenarios, 81–2
  - peer-reviewed journal articles related to nanotoxicology, 81
  - release of nanoparticles from products and applications, 79
- nanoplates, 18
- nanoscale dust particles, 99–105
  - normalised particle size distributions, 102
  - sequential alteration of number concentration of a sampling cycle, 101
  - SMPS on-line measurement of particle size, 100
- nanosilica particles, 255
- nanosilicate plates, 141
- nanostuctured flame retardants, 254–6
  - health and environmental risks of conventional and nanostructured, 267–72
  - standardisation and safety regulations, 269
  - toxicological and environmental issues affecting conventional flame retardants, 267–8
- performance, toxicity and environmental impact, 251–73
  - conventional and nanostructured, 254–6
  - dispersion of filter with polymer, 252
  - fabrication of polymer nanocomposites, 252–4
  - flame retardant behaviour of polymer nanocomposites, 256–7
  - future trends, 272–3
  - synergies from combination, 257–67
    - appearance of whole surfaces of fire residues from PMMA with filter nanoparticles, 260
    - cone calorimeter experiments, heat release rate vs time curves, 267
    - heat release rates of polystyrene and silical nanocomposites, 261
    - results of limiting oxygen index and vertical burning experiments, 259
    - schematic representation of effect of clay network structure, 266
    - SEM images of cone calorimetry residues, 261
    - smoke production curves for PVC and metallic oxides and OMMT nanocomposites, 265
    - TGA and FTIR data for 10% clay polystyrene nanocomposite, 262
    - XRD patterns of pristine OMMT, 263
- toxicological and environmental issues, 268–9
  - different pathways of nanoparticles, 270
  - principal hypothesis of cardiopulmonary toxicity of nanoparticles, 271
- nanotube diameter, 161
- nanotubes, 12–13
- nanovectors, 154
- nanowaste, 238
- nanowires, 13
- near infrared (NIR) light irradiation, 154–5
- NEPHH Consortium, 69
- neurotoxicity, 159–60
- NIOSH Method 5040, 57
- NIOSH Method 7303, 57
- NIOSH Method 7402, 57
- NIOSH Method 7404, 57
- ObservatoryNano, 212
- occupational exposure levels (OELs), 47
- octahedrally substituted layered silicated, 14

- OECD Working Party of Manufactured Nanomaterials, 75
- OECD WPMN SG8, 51
- 'omics' analysis, 37
- one-dimensional nanomaterials, 7
- optical particle counter (OPC), 53
- organic-modified montmorillonite (OMMT), 18
- organo-bentonite, 258
- organo-montmorillonite (OMMT), 262
- organomodified montmorillonites, 297–8
- organomodifiers, 283
- oxidative stress, 31
  
- p53, 38
- particle, 36
- particle losses, 94
- persistent inorganic nanoparticles
  - safe recycling of materials containing carbon nanoparticles, 222–39
  - engineered nanomaterials applied in suspensions, 225–30
  - nanocomposites, 230–1
  - nanomaterials present in wastes, 237–8
  - recycling options range, 231–7
  - released linked to recycling facilities, 238–9
- personal air samples, 57–8
- personal breathing zone (PBZ), 57
- pesticides, 139
- pH-induced aggregation, 226
- phase separation, 226
- Philips X-Pert diffractometer, 97
- phosphates, 208
- photo-induced toxicity, 207
- photoacoustic imaging, 179
- photocatalytic properties, 205
- photodynamic therapy, 154–5
- photolysis, 67
- photosensitiser, 154–5
- photothermal imaging, 179
- physico-chemical properties
  - modulating carbon nanotube toxicity, 160–4
  - affecting toxicity of CNT, 162–4
- phytotoxicity, 208
- PilkingtonAktiv, 232
- polyamide-6/OMMT, 18
- polyamide-6 (PA6), 300
  - case study, 95–105
  - apparatus and set-up for the experiment, 96
  - experiment, 95–7
  - results, 97–105
  - SEM images, 98, 103
  - SEM/TEM micrographs, 104
- poly( $\epsilon$ -caprolactone) (PCL), 138–9
- polyethylene glycol (PEG), 39
- polyhedral oligomeric silsesquioxanes, 15, 256, 266
- polylactide (PLA) nanocomposites, 259–60
- polymer-clay nanocomposites, 138
- polymer-layered silicate (PLS), 13
- polymer nanocomposites
  - fabrication, 252–4
  - flame retardant behaviour, 256–7
  - schematic representation of combustion mechanism and ablative assembly, 257
- instrumentation and techniques to investigate degradation products, 285–92
  - coupling of analytic physics methods with cone calorimetry, 286–92
  - coupling of chemical analytic methods with thermal analysis, 286
- sampling protocols for safety testing, 63–75
  - approaches for release simulation, 64–6
  - characterisation of samples, 68–72
  - collection of samples, 67–8
  - future trends, 75
  - preventing contamination of stored samples, 73–4
  - protocol validation and standardisation, 75
  - sample pre-treatment before testing, 74
  - sample storage and labelling, 72–3
  - simulating the release of particulate materials, 66–7
- thermal degradation, flammability and potential toxicity, 278–303
- fire toxicity of degradation products and assessments, 292–4
- future trends, 302–3
- intrinsic toxicity of nanoparticles, 294–9
- thermal stability of nanoparticles, 281, 283–5
- ultrafine particle production during combustion, 299–302
- poly(methyl methacrylate) (PMMA), 258–9
- polypropylene (PP), 258, 300

- polystyrene, 262
- poly(vinyl chloride) (PVC), 264
- post-synthesis treatments, 151–2
- potential toxicity
  - thermal degradation and flammability of polymer nanocomposites, 278–303
  - fire toxicity of degradation products and assessments, 292–4
  - future trends, 302–3
  - instrumentation and techniques for investigation, 285–92
  - intrinsic toxicity of nanoparticles, 294–9
  - thermal stability of nanoparticles, 281, 283–5
  - ultrafine particle production during combustion, 299–302
- Project for Emerging Nanotechnology, 212
- proteomics, 38
- pyrolysis, 237, 280
  
- quantitative nanostructure–activity relationship (QNAR), 122–3
- quantitative structure–activity relationship (QSAR), 122
- quantum dots, 11–12
  
- radioactive labelling, 179
- Raman spectroscopy, 185
- random scission, 281
- REACH Article 13.1, 75
- reactive oxygen species (ROS), 154–5
- recycling
  - nanocomposites, 230–1
    - steps in generalised resource cascade consisting of nanoparticles and polymers, 231
  - persistent inorganic and carbon nanoparticles, 222–39
    - engineered nanomaterials applied in suspensions, 225–30
    - nanomaterials present in wastes, 237–8
    - released linked to recycling facilities, 238–9
- recycling options range, 231–7
  - combustion with energy recovery, 237
  - current resource cascading of nanocomposites, 237
  - extension of product use and product reuse, 232–3
  - nanocomposite materials recycling, 234–5
  - pyrolysis and cracking, 237
  - recovery of inorganic and carbon nanomaterials with depolymerisation and devulcanisation, 235–6
  - remanufacturing, 234
  - steps in generalised resource cascade for nanocomposites, 232
- redox active metals, 161
- Regulation of Nanomaterials Today and Tomorrow, 212
- released particulate material, 63
- remanufacturing, 234
- repeated toxicity, 160
- Research into Safety of Manufactured Nanomaterials, 212
- resource cascading, 228, 237
- revulcanisation, 236
- risk assessment, 211
  
- Salmonella* gene mutation assay, 141
- sample collection strategies, 54–5
- sample post-manufacturing checks, 68–9
- sample stability checks, 69
- samples in test medium, 69
- sampling particle number concentration, 56
- sampling protocols
  - approaches for release simulation, 64–6
  - characterisation of samples, 68–72
  - collection of samples, 67–8
  - future trends, 75
  - minimum physico-chemical characteristics of ENM that should be assessed, 70–1
  - preventing contamination of stored samples, 73–4
  - protocol validation and standardisation, 74–5
  - sample pre-treatment before testing, 74
  - sample storage and labelling, 72–3
  - simulating the release of particulate materials, 66–7
    - different approaches to generating samples from nanocomposites, 67
    - experimental set-up, 66
    - measurement of background sample, 66–7
    - testing the safety of polymer nanocomposites, 63–75
- scanning electron microscopy (SEM), 84, 185, 290–1
- scanning mobility particle sizer (SMPS), 82–3, 86–7

- vs ELPI, 91
- vs FMPS, 88–91
- sediments, 190
- segregation errors, 67–8
- shifting of burden, 115
- side group scission, 281
- silver nanoparticles, 297
- single-walled carbon nanotubes (SWCNT),
  - 12, 34, 149, 298
- size-exclusion chromatography, 226
- smectite, 136–7
- SMPS + C, 65
- soils, 190
- solvent bending, 253
- solvent evaporation, 226
- sonication, 74
- spectrofluorimetry, 176
- spin trapping technique, 157
- statistical errors, 68
- stochastic multi-criteria acceptability analysis (SMAA-TRI), 124
- Stokes number, 287
- submicron alumina trihydrate, 264–5
- surface coatings, 184
- surface modification, 161
- synergistic phenomenon, 257–8
  
- Taber abraser, 85
- tapered element oscillating microbalance (TEOM), 88
- temperature manipulation, 226
- terrestrial toxicity, 204–5, 207–8, 209, 211
- tetrahedrally substituted layered silicates, 14
- thermal conductivity, 150
- thermal decomposition, 280
- thermal degradation
  - flammability and potential toxicity of polymer nanocomposites, 278–303
  - fire toxicity of degradation products and assessments, 292–4
  - future trends, 302–3
  - instrumentation and techniques for investigation, 285–92
  - intrinsic toxicity of nanoparticles, 294–9
  - thermal stability of nanoparticles, 281, 283–5
  - ultrafine particle production during combustion, 299–302
  - polymers and nanocomposites, 280–1
    - classification according to degradation mechanism, 282
- thermal gravimetric analysis, 176
- thermal optical transmittance, 176
- thermal stability
  - nanoparticles, 281
    - examples of organic modifiers with enhanced degradation temperature, 284
    - Hoffman degradation reaction of alkylammonium ions, 283
- thermal stress, 67
- thermal therapy, 154–5
- thermogravimetric analysis (TGA),
  - 283, 286
- thermoplastic nanocomposite, 234
- thermoplastic polyurethanes, 263–4
- three-dimensional nanomaterials, 8
- tissue engineering, 155–6
- thermo-chemical analyses, 286
- toxicity, 28–40
  - future trends, 39–40
  - mechanisms of nanomaterial-induced cellular damage independent of oxidative stress, 34–6
  - reorganisation of rhodamine phalloidin-labelled actin inside SWCNT-treated cells, 35
  - mechanisms of nanomaterial-induced cellular damage mediated by oxidative stress, 31–4
- shape and toxicity: the fibre paradigm, 36–7
- size and non-size-related toxicity
  - mechanisms, 28–31, 32
  - relevance for toxicity of size- and non-size related properties of nanomaterials, 32
  - use of lipidomics, proteomics and transcriptomics to understand nanomaterial toxicity, 37–9
  - relevant pathogenic mechanisms of nanomaterials, 39
- transcriptomics, 38–9
- transmission electron microscopy (TEM),
  - 84, 151, 185, 290–1
- Triton X, 183
- two-dimensional nanomaterials, 7–8
- two-photon excitation spectroscopy, 179
  
- ultra centrifugation, 226
- ultrafine particle production
  - combustion, 299–302
  - particle sizes evaluated directly from dimensional measurement by AFM, 302
- ultrasonication, 183

- ultraviolet irradiation, 233
- universal nanoparticle analyser (UNPA), 84
- US National Institute for Occupational Safety and Health (NIOSH), 269
- USEtox, 122
- van der Waals force, 135
- Versailles Project on Advanced Materials and Standards (VAMAS), 75
- vertically aligned carbon nanotube (VACNT), 151
- volatilisation, 258, 280
- WAXD diffractogram, 97–8
  - PA6 bulk panel and PA6/nanoclay bulk panel, 105
  - PA6/nanoclay composites, 99
- wide-range aerosol sampling system (WRASS), 66
- X microanalysis, 290–1
- X-ray diffraction (XRD), 97, 262
- X-ray fluorescence, 290–1
- zinc oxide, 297