



## Physiochemical properties of nanoparticles

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### Abstract

Nanotechnology advancements have ushered in a new era of disease and traumatic injury detection, prevention, and therapy. Nanomaterials, especially those with clinical promise, have new physicochemical features that affect their physiological interactions at all levels, from the molecular to the systemic. For the detection and characterisation of nanomaterials, there are no established techniques or regulatory processes.

**Keywords:** Nanotechnology , Physiochemical , TiO<sub>2</sub> , polyethyleneimine

### Introduction

Since the mid-twentieth century, when Richard Feynman, Norio Taniguchi, and Eric Drexler first defined the fundamental notions of nanotechnology, a substantial body of literature on nanomaterials has evolved and grown dramatically. Rapid breakthroughs in methodology and technologies for characterizing nanomaterials and colloids have also resulted in significant material improvements (such as fullerene and carbon nanotubes) (Maskos & Stauber, 2011). Scientists are increasingly selecting nanoparticles with cutting-edge features over more traditional, time-consuming compounds as a result of these changes. Since the early 2000s, these cutting-edge materials have begun to pervade more areas of our daily lives, including fashion, cosmetics, home furnishings, and even food. Nanomaterials have risen to prominence as a valuable economic possibility in recent years. Titanium dioxide (TiO<sub>2</sub>) is a frequent element in sunscreen due to its nanoparticles' capacity to efficiently absorb ultraviolet (UV) radiation, protecting the skin from sun damage. They can also be found in a variety of cosmetics. Add a sprinkle of silicon dioxide to your cuisine to thin it down and balance the acidity (SiO<sub>2</sub>). Carbon nanotubes (CNTs) and silver (Ag) nanoparticles have been used in a variety of detergents and sports equipment due to their exceptional antibacterial and lightweight properties. Many scientists and

medical experts, however, are concerned about its safety (Maskos & Stauber, 2011). Nanomedicine is a relatively young field that use nanoparticles to enhance diagnosis, prevention, and treatment (Powers et al., 2006). According to the National Cancer Institute's Nanotechnology Characterization Laboratory (NCL), NPs there range in size from 1 to 100 nm (Jiang et al., 2008). A nanomaterial's size is typically characterized by at least one dimension ranging from one to 10 nanometers. Small molecules and other biological materials, although having dimensions in the 1-100 nanometer range, are often not considered nanomaterials. Because of its promise uses in a wide range of sectors, including science, technology, and medicine, research into synthetic nanomaterials in the 1-100 nm size range has increased (Shekunov et al., 2007).

Nanomaterials include liposomes, dendrimers, carbon nanorods, carbon nanotubes, fullerenes, graphene variations, titanium oxides, gadolinium nitride nanowires, silver NPs, gold NPs, platinum NPs, magnetic NPs, and quantum dots. As you cut through a solid, two new surfaces appear, and additional surfaces appear as you go deeper. When something is reduced in size, its surface area increases significantly in relation to its mass. Nanomaterials are distinct from other materials due to their extraordinarily high surface area to mass ratio. The surface area of a nanomaterial is regulated by its size and form, just as the surface area of a solid is dictated by its shape (a sphere, for example, has the smallest surface area

per unit mass). Nanomaterials' physicochemical and physiological properties can be affected by changes in size and form. The biodistribution, transit, phagocytosis, and endocytosis of nanomaterials across tissues may impact physiological interactions in ways that differ from the effects of traditional medications (Gref et al., 1994).

To fully realize the potential of nanomedicines, stringent criteria for identifying engineered/fabricated nanoparticles and other nanomaterials must be established, allowing for quality control and investigation of safety and toxicity. The molecular structure, chemical composition, melting point, boiling temperature, vapor pressure, flash point, pH, solubility, and water octanol partition coefficient of nanomaterials must be the same as those of bulk non-nano counterparts. All of the parameters that contribute to the overall characterisation of nanomaterials include size/size distribution, porosity (pore size), surface area, shape, wettability, zeta potential, adsorption isotherm (adsorption potential), aggregation, conjugated moieties distribution, and contaminants (Pleus, 2012).

### **Physicochemical characteristics of nanomaterials**

Engineered nanomaterials often serve as linkers between molecular level components and macroscopic wholes. Due to their similarity in size to biological molecules, nanomaterials have found use as both diagnostic and therapeutic nanomedicines (Hachani et al., 2013; Kim et al., 2010). Nanomaterials differ from their bulk material counterparts in a wide variety of physicochemical parameters, including size, surface qualities, shape, composition, molecular weight, identity, purity, stability, and solubility (Patri et al., 2006). Better knowledge of these physiological interactions may lead to favorable medical outcomes including decreased side effects and improved prevention and treatment (Hall et al., 2007).

The therapeutic and/or diagnostic effectiveness of nanomedicines will be affected by the physiological features of nanoparticles. To this end, knowing how various physicochemical characteristics of nanomaterials affect their distribution and behavior in biological beings is essential. We need solid and trustworthy analytical tools to understand more about the physicochemical properties of nanomaterials and nanomedicines. In the following paragraphs, we will go through the many methods that may be used to characterize nanomaterials. To ensure quality and the safe, rational development of nanomedicines and theranostics, a comprehensive yet practical approach for trustworthy characterisation of nanomaterials is required (Kim et al., 2013)

### **Size**

The size of developed nanomaterials affects their pharmacokinetics (how well they function in the body), pharmacodynamics (how well they work in the body), pharmacokinetics, pharmacodynamics, pharmacokinetics, and

pharmacodynamics (Jiang et al., 2008). The diameter of a spherical particle whose specified physical properties, such as diffusivity, are equal to those of the nanomaterial in the same environment is typically used to estimate the size of a nonspherical nanomaterial (Shekunov et al., 2007). The Stokes-Einstein equation and the diffusion coefficient define the effective size of molecules; for example, the hydrodynamic diameter (Powers et al., 2006).

Nanomaterial toxicity and the negative health repercussions associated with it, such as severe lung inflammation, have recently received public and governmental attention (Horváth et al., 2013). Negatively charged 100 nm silica nanoparticles are less of a worry than their 20 nm counterparts, although smaller silver nanoparticles have been related to an increase in apoptosis in specific cell types (Kim et al., 2012; Park et al., 2013). Despite reports that NPs with specific chemical compositions are more toxic than their larger counterparts with the same composition, a consensus on the increased toxicity and potential health risks of nanomaterials may not emerge due to the lack of obvious size-related toxicity in other NPs, such as titanium oxide and iron oxides. Because different nanomaterials behave so differently, research on the toxicity or usefulness of nanoparticles in nanomedicine must be done on a case-by-case basis (Horváth et al., 2013).

### **Surface properties**

Many characteristics of an interface are determined by the atomic or molecular composition of a nanomaterial's surface and the physical surface structures that respond to interactions with other species (Powers et al., 2006). Characteristics of surfaces in the presence of biological fluids, as used in nanomedicine. The composition of the surface, its surface energy, its wettability, its surface charge, and the species' ability to absorb or adhere to the surface are often cited as the most crucial surface features (Patri et al., 2006; Powers et al., 2006)

The dissolution, aggregation, and buildup of nanomaterials are all influenced by their surface energy. Zeta potential is commonly used as a proxy for surface charge, which controls the dispersion stability or aggregation of nanomaterials and so influences receptor binding and physiological barrier penetration. Absorption or adhesion to the surface of nanomaterials can change the structure and activity of the attached species, concluding the review. Prioritizing surface features needs separate validation for each nanomaterial system (Powers et al., 2006; Ratner et al., 2004), yet exploring the complete spectrum of surface parameters is impracticable.

Nanomaterials with a positive charge are more readily taken up by cells and lysosomes than their neutral or negatively charged counterparts, according to recent research (Liu et al., 2011; Luyts et al., 2013). Positively charged NPs are desirable as tumor medication delivery agents because of their enhanced absorption. Poly(D,L-lactide-co-glycolide)

and cationic chitosan NPs have been shown to enhance gene trafficking to the alveolar epithelium (Baoum et al., 2010). In contrast, some research suggests that positively charged nanomaterials are more harmful than their negatively charged counterparts. Positively charged amino-modified polystyrene NPs were discovered to be cytotoxic to some cell lines, leading to DNA damage in those cells (Liu et al., 2011)

It was discovered that certain species of bacillus were particularly vulnerable to Ag NPs coated with positively charged branching polyethyleneimine, which caused membrane damage (El Badawy et al., 2010). Macrophage cytotoxicity from positively charged Si NP-NH<sub>2</sub> was caused by effects on phagocytosis, mitochondrial disruption, and elevated levels of intracellular reactive oxygen species (Bhattacharjee et al., 2010). Negatively charged silica NPs of 20 nm size had a greater effect on cytotoxicity and reactive oxygen species production than did silica NPs of the same size but less negative charge (Park et al., 2013). Although in vitro studies have shown a correlation between higher cellular absorption of positively charged NPs and enhanced cytotoxicity, the evidence for this in vivo is less. The relationship between NP toxicity and surface charge/zeta potential is not always linear (Luyts et al., 2013).

### Shape

Drug delivery, degradation, transport, targeting, and internalization are all profoundly impacted by nanomaterial forms, in addition to their sizes and surface features (Jiang et al., 2013; Mitragotri, 2009). The capacity to alter carrier morphologies had a major impact on drug delivery efficiency, and macrophage phagocytosis of drug delivery carriers was also controlled by carrier shape (Champion and Mitragotri, 2009). Changes in the morphologies of nanomaterials can have an effect on the in vivo circulation time of a nanomedicine and on its capacity to transport medicines (Doshi et al., 2010).

The form of a nanomaterial is important for several reasons, including its cellular absorption, biocompatibility, and retention in tissues and organs (George et al., 2012). As a result, nanomaterials' form, size, and aggregation state may influence their distribution and movement (Powers et al., 2009). Shape-driven agglomeration, for example, was revealed in an in vitro investigation of silica NPs as a possible first step in pulmonary pathophysiology. Also, unlike their spherical counterparts, nickel NPs with a dendrimer form are toxic to growing zebrafish. When tested against *Escherichia coli* and zebrafish embryos, plate-shaped silver nanoparticles were shown to be more hazardous than spherical, rod-shaped, or wire-shaped silver nanoparticles (George et al., 2012). Similarly, recent investigations have shown that animals given carbon nanotubes longer than 20 μm experienced pathogenic symptoms reminiscent of those caused by asbestos (Takagi et al., 2008).

### Composition and purity

Nanomedicines, both those now on the market and those still in development, make use of a wide variety of nanomaterials. Nanoparticles (NP) and their derivatives, liposomes, micelles, dendrimers/fleximers, virosomes, emulsions, quantum dots, fullerenes, carbon nanotubes, and hydrogels are just some of the numerous structural shapes these nanomaterials can take (Etheridge et al., 2013). The distribution, uptake, and elimination of a nanomaterial throughout the body are all affected by its make-up. Two or more nanomaterials may need to be combined to form a complex, such as a chelate, conjugant, or capsule, for use in biomedical applications. Consequently, analyzing the chemical composition of a nanomaterial complex is more difficult than analyzing the chemical composition of a single entity (Patri et al., 2006)

Several studies have been conducted to address toxicological concerns concerning NPs with varied compositions. The toxicity of NPs depends on several factors, including their size, shape, and chemical makeup (Buzea et al., 2007; Hardman, 2006). TiO<sub>2</sub> administered intratracheally induced a neutrophil inflammatory response in the lungs of rats and mice (Sohaebuddin et al., 2010). Core metalloid complexes of commonly used metals such as cadmium and selenium in quantum dots have also been found to be toxic. However, core coatings can render quantum dots safe, and in vivo and in vitro evidence of cytotoxicity from quantum dots was only found after the coating was broken (Buzea et al., 2007; Hardman, 2006).

### Stability

The ability of a medicine to retain its qualities after it has been manufactured is known as its "pharmaceutical stability." Similarly to single-molecule pharmaceuticals, the stability of nanomedicines can be compromised by factors such as temperature, moisture, solvents, pH, particle/molecular size, radiation (both ionizing and non-ionizing), enzymatic degradation, and the addition of other excipients and contaminants (Briscoe and Hage, 2009). In various investigations, oxidative or photolytic destruction of quantum dots during manufacture, storage, or even in vivo was associated to cytotoxicity, suggesting that the stability of nanomaterials may alter their potential for toxicity (Hardman, 2006).

### Relation between nanomaterials and biological environments

Aggregation, coagulation, and non-specific absorption are just a few of the unwanted side effects that can occur when nanoparticles are introduced into biological systems or used in biomaterials. Many different fluid-mediated interactions and intermolecular interactions between nanomaterials and biomolecules are possible causes. Chemical make-up, form,

surface geometry and crystallinity, porosity, heterogeneity, and hydrolytic stability in a particular medium are all characteristics of nanomaterial surfaces. Other characteristics, including as surface charge, dissolution, hydration, size distribution, dispersion stability, agglomeration, and aggregation, are principally controlled by ionic strength, pH, temperature, and the presence of bicarbonates (French et al., 2009). Therefore, physicochemical characterization of nanomaterials should be profiled based on the different physical states of nanomaterials (e.g., solution, suspension, or dry powder) and before and after being exposed to the in vitro or in vivo test environment (Hull and Bowman, 2009).

## Conclusion

Because nanomaterials have the ability to alter physiological interactions on numerous sizes, from the molecular to the systemic, the in vivo delivery of nanomedicines is a fascinating area of study. Since nanomaterials are being rapidly developed and manufactured for use in nanomedicines, regulation of their production and usage is required and sensible.

## Conflict of Interest

The author hereby declares no conflict of interest.

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