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Physico-chemical properties of nanoparticles. A brief review.

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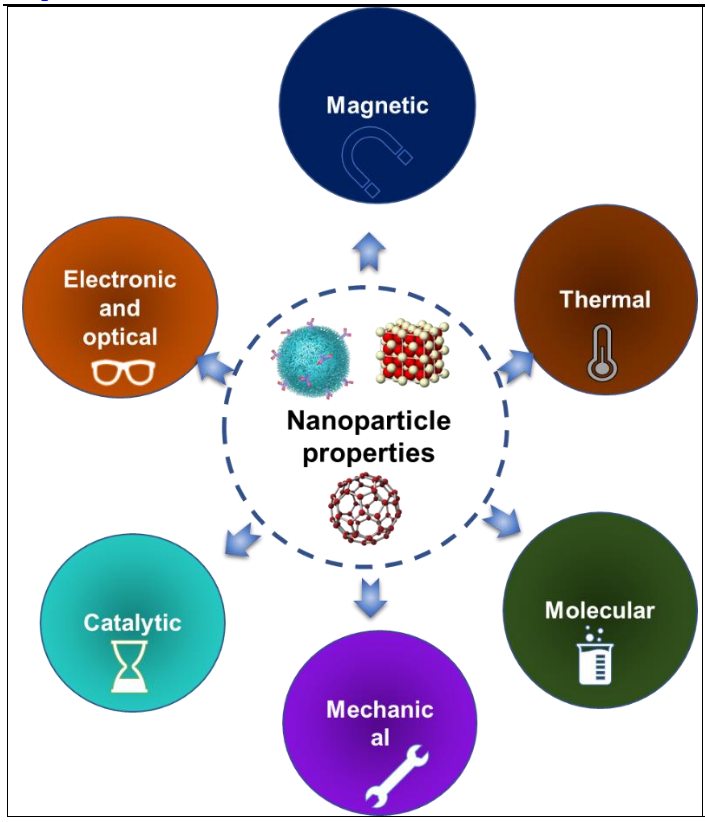
Graphical Abstract	Abstract.
	This document discusses the physicochemical properties of nanoparticles (NPs) and their importance in various applications. NPs are



materials formed by particles with dimensions between 1 and 100 nm, which possess unique properties due to their relatively large surface area. However, characterization of these properties is challenging due to the polydispersity and wide distribution of sizes, shapes and defects that occur in their synthesis. Size, shape, surface charge and porosity are key parameters that determine the properties of NPs. The physicochemical properties of NPs include electronic and optical, magnetic, mechanical and thermal properties.

Introduction

Nanomaterials are materials consisting of nanoparticles (NPs), which possess one or more dimensions between 1 and 100 nm, that exhibit distinctive properties due to their relatively large surface area [1]. These unique properties make NPs attractive for various applications in fields such as catalysis, energy storage, and medicine [2-12]. However, characterization of the physicochemical properties of NPs is challenging due to the polydispersity and wide distribution of sizes, shapes, and defects that occur in their synthesis. Characterization techniques provide a partial picture of nanoparticle characteristics and can affect the measured quantities [13-15]. In this brief review, the main physicochemical properties of NPs are presented, including size, shape, surface charge and porosity, as well as their relationship to electronic, optical, magnetic, mechanical and thermal properties.

Materials and Methods

For the present work, an exhaustive search was carried out in scientific databases, such as PubMed, Scopus, or Web of Science, using key terms related to nanoparticles and their properties. After reading and understanding the selected articles, special attention was paid to the research objectives, the methods used, the results obtained, and the conclusions in order to identify the key findings. Subsequently, the findings of each article were grouped and organized according to physicochemical, electronic, optical, magnetic, mechanical, and thermal properties. Finally, a synthesis and writing of the main results and conclusions found in the reviewed articles were carried out.

Results and Discussion

NPs are nanometer-sized structures that can be composed of a variety of materials, from micelles to metals and synthetic polymers. Their behavior and characteristics are closely related to their size, shape, surface charge, and porosity, making the characterization of these particles critical to understanding and predicting their behavior. The dispersibility and functionalization properties of NPs are influenced by their size and shape, while surface charge plays a role in stability and interactions with the environment

[16-18]. In addition, NPs offer a broad external and internal surface area, which makes them suitable for functional applications and smart drug delivery systems. In summary, NPs exhibit a wide range of chemical compositions, and their behavior is determined by their size, shape, surface charge, and porosity [19-22]. The characterization of these particles is essential to understanding their behavior and potential applications, since their dispersibility, functionalization, and interactions with environment depend on these properties. In addition, their large surface-to-volume ratio makes them ideal candidates for various functional applications and advanced drug delivery systems [3,23-26].

Nanoparticle parameters

Table 1 present the main Nanoparticle parameters. They included parameter as size and size distribution, shape, and surface load.

Table 1. Nanoparticle parameters and description.

Parameter	Description	Reference
Size and size distribution	NPs have different definitions of size depending on their shape. High-resolution microscopy techniques can measure the size and morphology of NPs at the individual level, but have limitations. Light scattering, diffusion and sedimentation are used to analyze colloidal suspensions, but do not provide direct information on the shape.	[27-29]
Shape	Particle shape affects properties such as surface binding, cellular uptake and release, and optical and plasmonic effects. Scattering-based techniques are used to obtain information about the shape of particles in solution, but only allow quantitative inference of the anisotropy factor.	[30-36]
Surface load	NPs have a dynamic boundary between solid and fluid phase, and their net charge on the surface is essential for their behavior and stability. Zeta potential is a measure of surface charge and colloidal stability, and surface charge influences interactions between nanoparticles and biological fluids. Porosity is investigated by considering the size of openings, cavity dimensions and volume, interconnectivity of the structure, surface area, surface-to-volume ratio, and functionalization of the inner and outer surface. Specialized approaches are needed to characterize and obtain new information about porous NPs in solution.	[37-44]

Physicochemical properties of NPs:

Several physicochemical properties, such as large surface area, mechanically strong, optically active, and chemically reactive, are grouped together make the NPs unique applicants suitable for various applications. Electronic and optical, magnetic, mechanical, thermal, thermal, catalytic, and other molecular properties will be addressed [45]. **Table 2** shows the physicochemical properties of NPs:

Table 2. Physicochemical properties of NPs. Classification and examples.

Physicochemical properties	Description and examples	Reference
Electronic and optical properties	NPs have both electronic and optical properties, such as the localized surface plasmon resonance (LSPR), which depends on the size, shape and dielectric environment of the particles. Plasmons, collective excitations of conducting electrons in metals, play a fundamental role in the optical properties of NPs. These aspects have a significant impact on the absorption, scattering and emission of light in NPs.	[46-49]
Magnetic properties	Magnetic NPs have magnetic properties that depend on their size, shape, composition and crystalline structure. Superparamagnetism	[50-60]

	and magnetic coercivity are key factors, and understanding and controlling these properties will enable more advanced applications.	
Mechanical properties	NPs have different mechanical properties than microparticles and bulk materials, making them the subject of research in fields such as tribology, surface engineering and nanofabrication. Studying parameters such as modulus of elasticity, hardness, stress and strain is essential to understand their behavior in contact situations. Interaction forces such as van der Waals and electrostatic forces play a crucial role in the emergence of these new properties.	[50-60]
Thermal properties	NPs have been shown to significantly improve the thermal conductivity of conventional heat transfer fluids. Nanofluids, consisting of nanoscale solid particles dispersed in liquids, exhibit superior properties due to their large surface area and heat transfer. They also offer superior thermoelectric and thermal properties compared to bulk materials. Experimental studies have shown improvements in thermal conductivity, thermoelectric power, heat capacity and thermal stability. These findings support the potential of NPs and nanofluids as promising heat transfer agents.	[61-68]
Catalytic properties	Nanocatalysis is a rapidly developing field of chemical catalysis that uses NPs as catalysts. It is influenced by factors such as size, shape, composition, interparticle spacing, oxidation state and support. Smaller NPs are more catalytically active due to quantum size effects, shape, composition, interparticle spacing and support.	[69-76]
Some Molecular Properties	Various properties and molecular descriptors related to nanostructures and nanoproperties. They include colloidal properties of non-solid nanoparticles and the random nature of the crystalline structure of the material. It is highlighted that surface modifications of NPs have a significant impact on their cytotoxicity. In addition, water solubility (LogS) and oxygen content by weight (OP) are known to influence the availability of metal cations and electrons, which affects their toxicity. Other descriptors such as electronegativity (Xc), enthalpy of formation of a gaseous cation (ΔHme+), oxidation number (Z), ionic potential (Z/r), HOMO/LUMO, zeta potential and size are also considered relevant in the interpretation of NP toxicity. In the literature review, it is mentioned that descriptors related to quantum mechanics can be used to explain the toxicity of metal oxide NPs. These descriptors provide valuable information to understand and predict the toxic effects of nanostructures on organisms.	[77-87]

Conclusions

NPs are nanometer-sized structures with properties and behaviors determined by their size, shape, surface charge and porosity. The characterization of these particles is essential to understand their behavior and potential applications, since their dispersibility, functionalization and interactions with the environment depend on these properties. In addition, NPs exhibit unique physicochemical properties, such as optical, magnetic, mechanical and thermal properties, which make them suitable for various applications in fields such as biomedicine, catalysis and nanofabrication. Understanding and controlling these properties will enable the development of more advanced and efficient NP-based applications.

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