Physical and Chemical Nature of Nanoparticles

Non-engineered and engineered NPs.

Nanoparticles are two types:

Non-engineered NPs present in the environment are derived from natural events such as terrestrial dust storms, erosion, volcanic eruption, and forest fires.

Terrestrial dust storms

Dust storms appear to be the largest single source of environmental nanoparticles.

Approximately 50% of troposphere atmospheric aerosol particles are minerals originating from the deserts.

The size of particles produced during a dust storm varies from 100 nm to several microns.

Extraterrestrial dust

Nanoparticles exist widely in extraterrestrial space.

Examples of dust collected from space, from the moon, and on Mars.

The extraterrestrial dust poses major environmental problems for astronauts as well as for equipment.

Forest fires

Forest fires and grass fires are primarily caused by lightning strikes or by human activity.

Major fires can spread ash and smoke over thousands of square miles, and lead to an increase of particulate matter (including nanoparticles) exceeding ambient air quality standards.

Volcanoes

When a volcano erupts, ash and gases containing particulate matter ranging from the nanoscale to microns, are propelled high into the atmosphere, sometimes reaching heights over 18000 meters.

A single volcanic eruption can eject up to 30 million tons of ash.

Engineered NPs (ENPs)

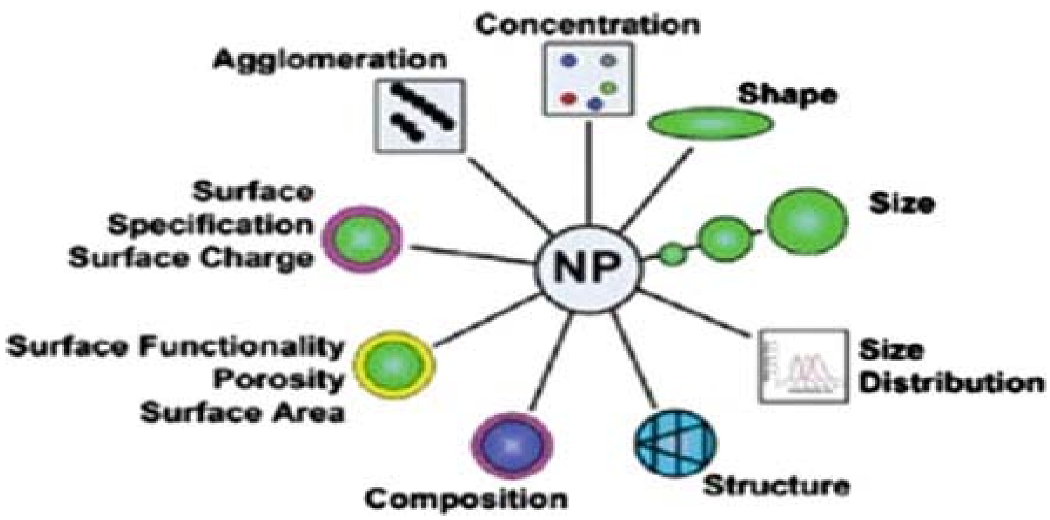
They are intentionally produced by man using many different materials, such as:

- Metals (including Au, Ag, Zn, Ni, Fe, and Cu).
- Metal oxides (TiO_2, Fe_2O_4, SiO_2, CeO_2, and Al_2O_3).
- Nonmetals (silica and quantum dots).
- Carbon (graphene and fullerene).
- Polymers (alginate, chitosan, hydroxyethylcellulose, and polyhydroxyalkanoates).
- Lipids (soybean lecithin and stearic acid).

<u>Physical Properties of Nanoparticles</u>

Physical properties of NPs include: shape, size, specific surface area, agglomeration, aggregation, state of size distribution, surface morphology/topography, and structure including crystallin, defect structure, and solubility.

The size, shape, surface area, and size distribution of NPs are important in their uptake by organisms.



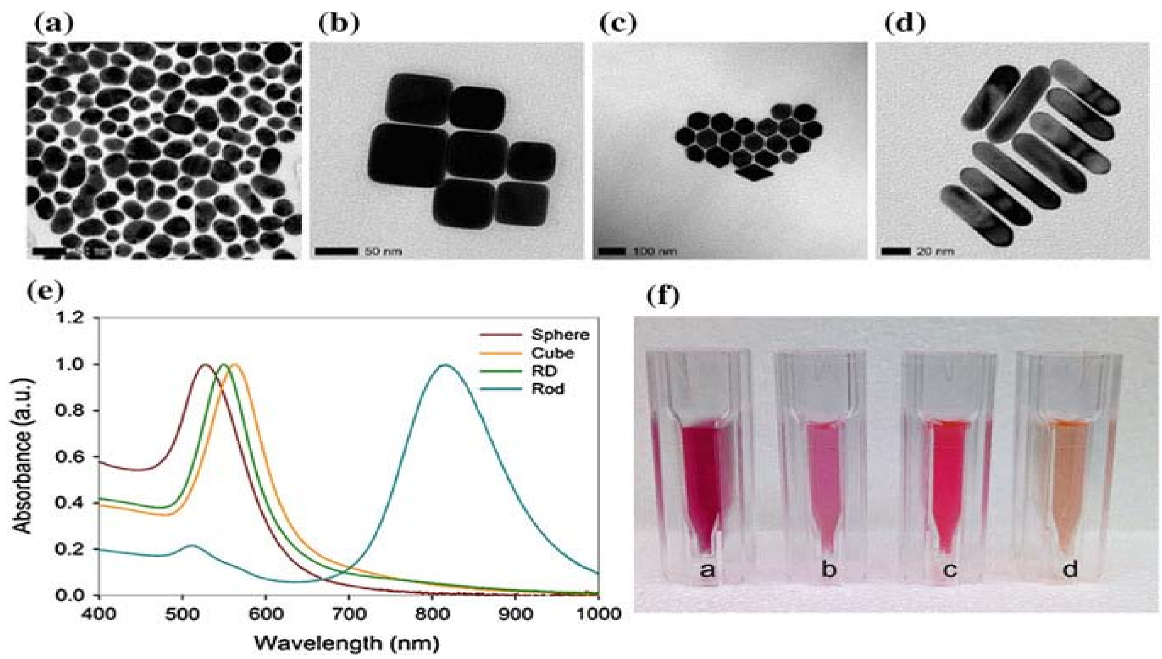
Size and Shape

The size and shape can be identified as the most important parameter to define the nanomaterial in general.

NPs below 20–30 nm in size are characterized by an excess of energy at the surface and are thermodynamically.

The design of NPs has gained a lot of attention, resulting in particles with various shapes such as spheres, rods, tubed, fibers, and disks, etc. and more extraordinary geometries such as worms, squares, urchins, and ellipsoids.

The optical properties of NPs also depend on its size and shape.



Difference in the optical properties of gold NPs for different shapes

Surface and Size Distribution of Nanoparticles

The surface morphology and surface area of NPs can be analyzed using Scanning electron microscope (SEM).

To get a higher resolution of approximately 0.2 nm, atomic force microscopy (AFM) can be used. It provides real topographical images of sample surfaces.

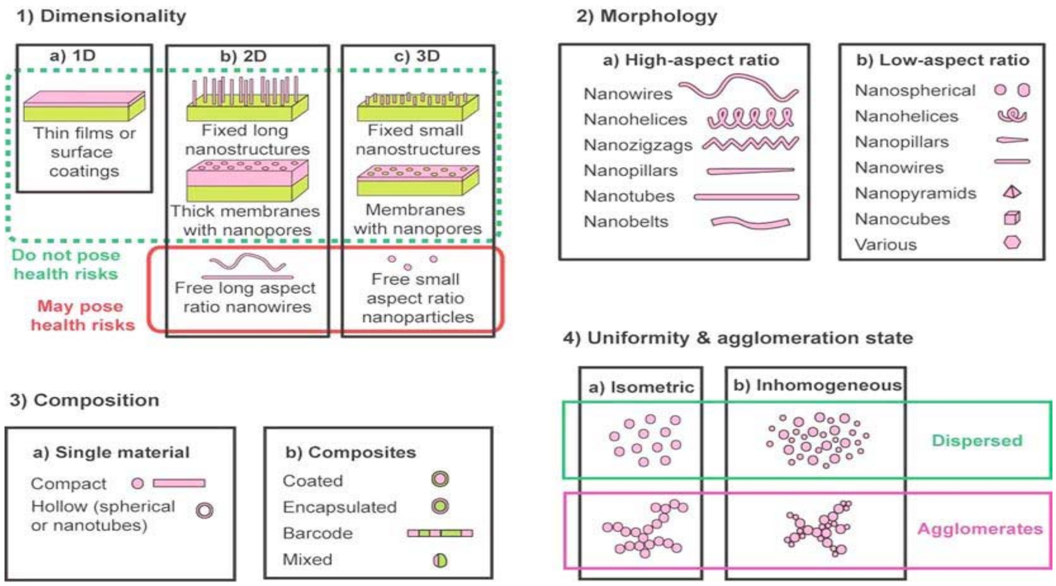
The attachment of NPs to cell membrane seems to be most affected by the surface charge of the NPs.

NPs of the different parameters such as dispersion, surface properties, agglomeration and de-agglomeration can be controlled using:

Ultrasonication, ionic strength and pH of aqueous solutions, physiological buffers, and cell culture media.

Structural and Species Specifics of Nanoparticles, Determinations of purity of NPs are important in biological application.

X-ray diffraction (XRD) is the most essential tool used to characterize crystal structures.



Chemical Properties of Nanoparticles

Chemical properties include the elemental composition of nanomaterials and its surface chemistry such as zeta potential and photocatalytic properties.

The chemical properties of a material are determined by the type of motion of its electrons.

Metallic Nanoparticles

Compared with other nanostructures, metallic NPs have been proven to be the most flexible nanostructures owing to the synthetic control of their size, shape, composition, structure, assembly, and encapsulation, as well as the resulting tunability of their optical properties.

Compared with other metallic nanostructures, colloidal gold and silver NPs are especially promising in nanobiotechnology because of their simple and fast preparation and bioconjugation.

The electromagnetic field enhancement near the metal surface and the dependence on the size, shape, and local dielectric properties of NPs.

Such nanoparticles work as platform materials for biomolecular ultrasensitive detection, hyperthermal treatment for cancer cell, protein labeling, and targeted delivery of therapeutic agents within the cells.

Metal Oxide Nanoparticles

Metal oxide NPs can exhibit unique chemical properties due to their limited size and a high density of the corner or edge surface sites.

The properties such as structural characteristics, cell parameters, and effect of size, are related to the electronic properties of the oxide, and structural and electronic properties obviously derive the chemical properties of the solid.

Metal oxide particles serve many functions in the various fields of technology.

Magnetic NPs exhibit a wide variety of attributions, which make them a highly promising connection with biological system and bioapplications usually exists or can be prepared in the form of either single domain or magnetite ($Fe2O3$) or greigite ($Fe3S4$).

Due to their favorable beneficial effects, magnetic NPs approved for clinical use by the Food and Drug Administration.

Quantum dot

Its semiconductor crystals with a diameter of a few nanometers, having many properties.

Structurally quantum dots (QDs) consist of a variety of metal complexes such as semiconductors, metals, and magnetic transition metals.

The bioactivity of QDs can be improved by suitable surface coating with biocompatible material and/or modification with desired functional groups.

Depending on their size, it fluoresences with different colors.

To make them biologically compatible/active, newly synthesized QDs are functioned or given secondary coatings, which improves water solubility.

Carbon nanotubes

About a decade after the discovery, the knowledge available increased the interest in biological and biomedical applications of carbon nanotubes.

Polymeric nanoparticle

The term polymer nanoparticle is given for any type of polymer NPs, but specifically for nanospheres and nanocapsules.

These are obtained from **synthetic polymers**, such as polycaprolactone , polyacrylamide, and polyacrylate or **natural polymers**, albumin, DNA and chitosan, and gelatin.

The various polymer NPs had been used to improve the pharmacokinetics and pharmacodynamics properties of various drugs,

Merits and Demerits of Nanoparticles

Due to instability of the NPs, retaining the size and shape of NPs is highly challenging.

Encapsulation of NPs becomes necessary when they are synthesized in a solution.

Synthesis of pure NPs becomes highly difficult. Hence, retaining high purity in NPs can become a challenge hard to overcome.

It is noticeable that most experimental studies with NPs have been carried out with aggregates/agglomerates of NPs.