Why do particles at nanometer scale show drastically different properties?

Particles of the condensed matter are made up of atoms some of which reside on the surface, while bulk of them is locked in the interior. Surface of a particle not only has planar areas but also the edges and the corners. The atoms on the surface are exposed to the dissimilar surroundings while the interior atoms have homogeneous environment.. Since the surface area to volume ratio is small in the bulk state, the proportion of the surface atoms to total atoms is very low and hence the behavior of the material as a whole is less influenced by the surface atoms. As one makes particles finer and finer, the surface area to volume ratio keeps increasing and the properties related to the surface area continue to vary in accordance with the known relationships. This change in the properties with increasing surface area is fairly intuitive.

Further down in this subdivision of matter, a stage is reached when the proportion of surface atoms becomes significant and their thermodynamics is a dominant contributor in the properties of the whole material. At this very low length scale, there is also a great increase in total edge length and the number of corners; and the atoms on the edges and corners enhance the surface energy substantially.

If the size of an atom is assumed to be 0.1 nm (which is a fair approximation), the following Figure shows the simplified relationship between surface atoms (as a percentage of total atoms) and the particles size in nanometers.

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One can draw the following inferences from the graph:

- The relationship between % of surface atoms and the particle size is fairly linear in the region 100 nm to 20 nm.
- There is drastic increase in the dominance of surface atoms over interior atoms as we go down from 20 nm to 1 nm.
- There is a region approximately between 20nm to 2 nm where surface atoms increasingly govern the properties of matter.

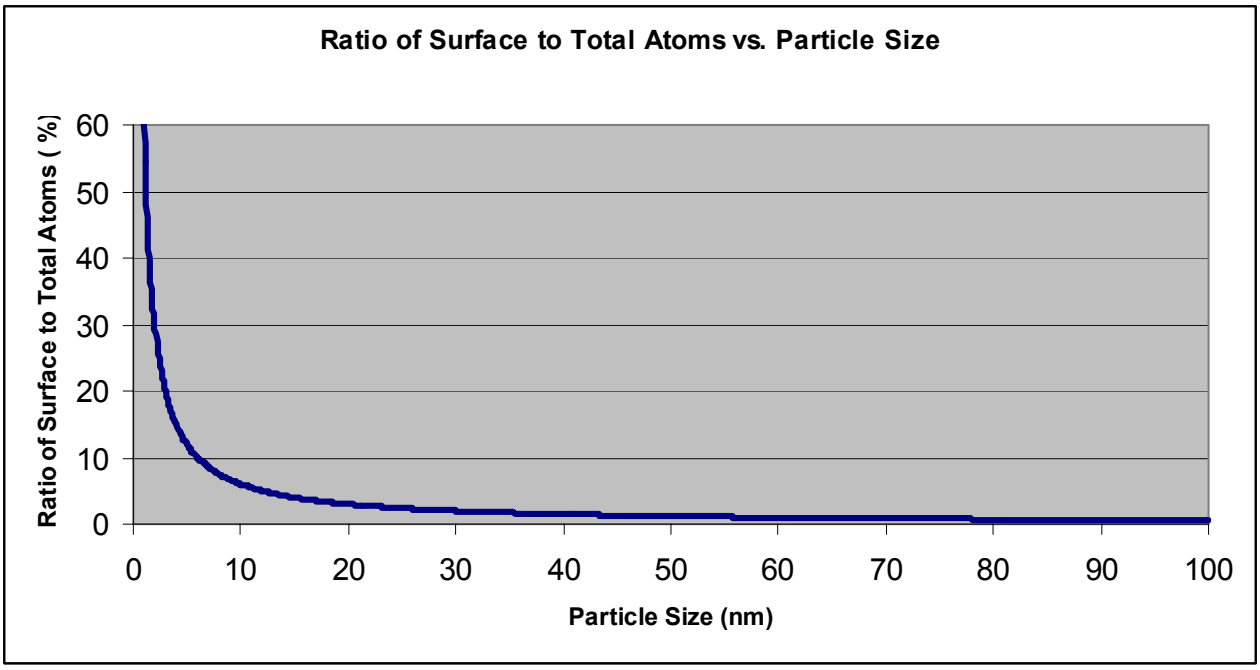

Figure: Surface to Total Atoms expressed as % against Particle Size in nm

This region of few nanometers (varying for different materials) corresponds to atomic clusters consisting of 10 to 100 atoms and is the domain of real nanotechnology. It is the region flanked by atomic scale on one side and bulk scale on the other. In these atomic clusters, since many of the atoms are on the surface, the surface behavior transforms into the bulk behavior thereby leading to a drastic change in properties. Additionally, when a crystalline material goes down in particle size to nano-region, it assumes closely packed structures with fewer defects such as interstitials, vacancies and dislocations.

This rearrangement in matter at nano-scale brings about alteration in properties like reactivity, adsorption behavior, color, UV absorption, catalytic activity, conductivity, hardness and microbiological activity.
