4. The role of nanotechnology in catalysis

Catalysis is a process of accelerating a chemical reaction without the catalyst being consumed in the reaction process. The term catalysis (derived from the Greek word 'kata meaning down' and 'lyein meaning to loosen') was coined first by the Swedish chemist Jons Jacob Berzelius in 1835 to name some chemical reactions which he observed, such as the use of noble metals like gold and platinum to 'fasten' some reaction processes. In a broader sense, a catalyst works by lowering the activation energy barrier of a chemical reaction so that the reaction proceeds faster. Catalysts function by providing an alternative route to complete the reaction that proceeds either via a different transition state or by lowering the activation energy barrier.

Nanotechnology has a profound impact on increasing the catalytic activity on account of its high surface area to volume ratio, which helps the catalysts at the nanoscale to interact better with the reactants due to the availability of a large number of atoms on surfaces. It is not only the size that makes nanomaterials attractive candidates for catalysis, but it has also been found that exposure to selective planes on crystals is effective in particular catalytic applications.

Applications of nanotechnology in the area of clean energies are as follows:

a) Hydrogen is much in demand as a clean source of energy because of its high storage energy content and non-polluting nature. Carbon nanotubes (CNTs) that are cylindrical shaped molecules of carbon have been explored as sources for hydrogen storage as they are porous, light weighted and inexpensive[1]. Darkrim et al. showed that at room temperature conditions, more hydrogen was absorbed by carbon nanotubes than any other carbon material.

b) Water purification: Nanoparticles made from titanium dioxide are used in water purification due to their effective photocatalytic activity[2]. Titanium dioxide belongs to a class of semiconductor materials with smaller band-gaps. It absorbs visible light and an electron can be excited from the valence band to the conduction band. A hole is created in the valence band and the conduction band acquires a negative charge on account of the electron. In liquid solutions, redox reactions may take place. The possibility of coating polyurethane foam with silver nanoparticles to prevent bacterial contamination in water filters has also been explored due to the antibacterial properties of silver nanoparticles[3].

c) Use of nanomaterials for CO oxidation in catalytic converters: The main aim is to reduce the emission of exhaust gasses and emissions from automobiles by using nanoparticles as small as 5 nanometers. However, the major challenge that scientists now face is to prevent the nanoparticles form agglomerating.

Reading links:

a) https://en.wikipedia.org/wiki/Catalysis
b) https://www.chemguide.co.uk/physical/catalysis/introduction.html
c) https://academic.oup.com/nsr/article/2/2/183/2097938
d) https://www.nanowerk.com/spotlight/spotid=18846.php
e) https://www.chemistryworld.com/news/catalytic-converters-go-nano/3000781.article

1) Which is the most common nanoparticle used to curb pollution in catalytic converters in automobiles and why?

2) What are the benefits of catalysis based on nanoparticles in comparison to bulk counterparts?

References

1. Shalini Chaturvedi a, Pragnesh N. Dave a, * NKS. Applications of nano-catalyst in new era. *J Saudi Chem Soc*. 2012; 16:307-325.

2. Savage N, Diallo MS. Nanomaterials and water purification: Opportunities and challenges. *J Nanoparticle research* 2005; 7: 331-342

3. Jain P, Pradeep T. Potential of Silver Nanoparticle-Coated Polyurethane Foam As an Antibacterial Water Filter. *Biotechnology and Bioengineering* 2005; 90: 59-63.