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## Please read this disclaimer before proceeding:

# ENGINEERING CHEMISTRY (22CH101)

| | |
|---|---|
| **DEPARTMENT** | **ECE,EEE** |
| **BATCH/YEAR** | **2022-23/II** |
| **CREATED BY** | **CHEMISTRY DIVISION** |
| **DATE** | **JUNE 2023** |

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# COURSE OBJECTIVES

**Objectives:**

The goal of this course is to achieve conceptual understanding of the applications of chemistry in engineering and technology. The syllabus is designed to:

- To understand the water quality criteria and interpret its applications in water purification
- To gain insights on the basic concepts of electrochemistry and implement its applications in Chemical Sensors
- To acquire knowledge on the fundamental principle of energy storage devices and relate it to Electric Vehicles
- To identify the different types of smart materials and explore its applications in Engineering and Technology
- To assimilate the preparation, properties and applications of nanomaterials in various fields

**22CH101-ENGINEERING CHEMISTRY          L T P C    3 0 0 4**

**UNIT V   NANOCHEMISTRY                    8**

- **Introduction** – synthesis – top-down process (laser ablation, chemical vapour deposition), bottom-up process (precipitation, electrochemical deposition) – properties of nanomaterials – types - nanotubes - carbon nanotubes, Application of CNT, nanocomposites.
- General applications of nanomaterials in electronics, information technology, medical and healthcare, energy, environmental remediation, construction and transportation industries.

## COURSE OUTCOMES

| COs | Outcomes |
|---|---|
| **CO 1** | Interpret the water quality parameters and explain the various water treatment methods. |
| **CO 2** | Construct the electrochemical cells and sensors. |
| **CO 3** | Compare different energy storage devices and predict its relevance in Electric Vehicles |
| **CO 4** | Classify different types of smart materials, their properties and applications in engineering and technology. |
| **CO 5** | Integrate the concepts of nano chemistry and enumerate its applications in various fields. |

## Course Outcome mapping with POs / PSOs

| COs | PO1 | PO2 | PO3 | PO 4 | PO5 | PO 6 | PO7 | PO 8 | PO 9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | 1 | | | | | | | | 2 | | |
| CO2 | 2 | 2 | | | | | | | | 2 | | |
| CO3 | 2 | 1 | | | | | | | | 2 | | |
| CO4 | 2 | 1 | | | | | | | | 2 | | |
| CO5 | 2 | 2 | | | | | | | | 2 | | |

# LECTURE PLAN

| S.No. | Topics to be covered | No. of periods | Proposed date | Actual lecture date | CO | Taxonomy level | Mode of delivery |
|---|---|---|---|---|---|---|---|
| 1 | Introduction to nanomaterials and the terminologies | 1 | | | | | |
| 2 | Synthesis of Nanomaterials – types and difference | 1 | | | | | |
| 3 | Top down synthesis | 1 | | | | | |
| 4 | Bottom up synthesis | 1 | | | | | |
| 5 | Size dependent Properties of Nanomaterials | 1 | | | | | |
| 6 | Different types of nanomaterials, Carbon Nanotubes, Nanocomposites | 1 | | | | | |
| 7 | Applications of carbon nanotubes | 1 | | | | | |
| 8 | Applications of Nanomaterials | 1 | | | | | |

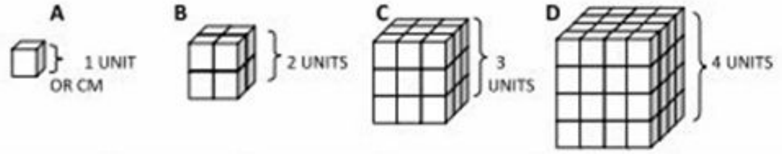
# ACTIVITY BASED LEARNING

•Activity based learning helps students express and embrace their curiosity.

•Once the students become curious, they tend to explore and learn by themselves.

•To evoke curiosity in students the following activities are given

**1. Calculate the surface to volume ratio for the figures and fill out the table below:**




| Figure | Total number of cubes | Surface area | Volume | Surface to volume ratio |
|---|---|---|---|---|
| A | | | | |
| B | | | | |
| C | | | | |
| D | | | | |

a. **Nano silver** - It is a disinfectant and toxic to a wide range of bacteria, fungi and algae.

b. **Titanium dioxide** - It is used for its capacity to reflect and scatter UV radiation.

c. **Fullerenes** - It is a carbon allotrope which bind to free radicals and resist pressure deformation.

d. **Carbon nanotubes** - It is a cylindrical carbon molecules which have great strength and electrical conductivity.

**3. List some of the everyday uses of nanotechnology.**

# UNIT – V

# NANOCHEMISTRY

# NANOCHEMISTRY

## 5.1 Introduction

**Nanotechnology** can be defined as the manipulation of atoms and molecules at nano (one billionth) scale (1–100 nm) to produce materials having at least one novel or superior property. The materials having at least one dimension in the nano scale are called nanomaterials. The conceptualization of nanotechnology was done by Richard Feynman in 1959. The impact of nanotechnology is quite significant. When the bulk materials are reduced to nanometer size, the properties exhibited by these nanomaterials are of tremendous use. For e.g., opaque materials become transparent (copper), insoluble substances become soluble (gold), stable materials become combustible (aluminum). In fact, at normal scales, gold is chemically inert but at nanoscales, gold nanoparticles can serve as potent chemical catalysts. The study of these nanomaterials is known as nanoscience.

**Nanoscience** is a multifunctional discipline that embraces such wide areas as nanochemistry and nanotechnology.

**Nanoscience** is the study of the fundamental principles of molecules and structures with at least one dimension roughly between 1-100 nanometers.

**Nanoscience** refers to the study, manipulation and engineering of matter, particles and structures on the nanometer scale (one millionth of a millimeter, the scale of atoms and molecules).

**Nanochemistry** is an emerging sub-discipline of the chemical and materials sciences that deals with the development of new methods for fabricating nanoscale materials. Professor Geoffrey Ozin is regarded as the father of Nanochemistry. Nanochemistry emphasizes the synthesis and characterization of new nanomaterials, pharmaceutical products, structural materials, electronic device components, light-emitting materials, etc. These materials have been investigated in many different applications, including uses in electronics, composite materials, biotechnology, medicine, textile industry, etc.

**Nanomaterials** are really small. In fact, really, really small. Yet they may have a big impact on our everyday life that makes them exciting and important to know about. Nanomaterials are special for several reasons, but for one in particular – their size. Nanomaterials are up to 10,000 times smaller than the width of a human hair. And this tiny size makes them very valuable for all kinds of practical uses. So, it is all about size, alone? Not only the size. A nanomaterial may have different properties compared to the same substance in bulk form.

Materials with which an average size is less than 100 nanometer at least in one dimension are called nanomaterials.

## Interesting facts about nanotechnology

The word nano is from the Greek word 'Nanos' meaning Dwarf. It is a prefix used to describe "one billionth" of something.

A human hair is 80,000 nm in diameter.

We are already surrounded by billions of nano-particles, such as wind borne sea salt and chemicals generated by oceanic plankton.

A new form of carbon with a cylindrical nanostructure - the nanotube - was discovered in 1991.

The discovery of another nanoscale carbon form, C60 (buckyball) brought the 1996 Nobel Prize in Chemistry to Robert Curl, Sir Harold Kroto, and Richard Smalley.

Nanotechnology is already applied commercially in products ranging from mobile phones, computer discs, tennis rackets and golf clubs to sunscreens and cosmetics.

L'Oreal has developed nanosize vesicles called nanosomes. They are used to transport active ingredients such as pure Vitamin E through the skin.

# 5.1.1 Classification of nanomaterials:

# Classification of nanomaterials according to origin

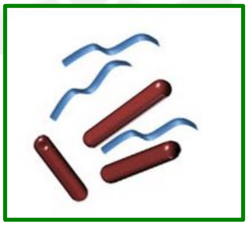
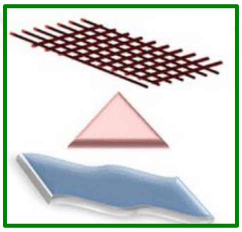
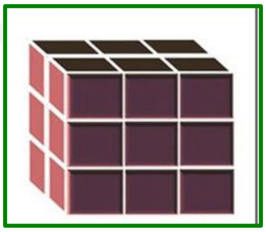
- Natural
- Anthropogenic - This category can be divided into incidental and engineered nanomaterials, depending on whether their formation is intentional or not.

**Natural :** Nanoparticles that have a natural and incidental origin are generally referred to as ultrafine particles. Natural sources of inorganic nanomaterials include, for example, erupting volcanoes, breaking sea waves, forest fires, sand storms, as well as soils. Some nanomaterials are also naturally found in living organisms, for example - ferritin is an iron storage protein, and calcium hydroxyapatite, the hard nanocrystalline constituent of bones. Nanomaterials can also be found as unintentional by-products of human activity, for example, metal fumes, polymer fumes.

**Anthropogenic :** Compared to natural and incidental nanomaterials, manufactured nanomaterials are characterized by their controlled dimension, shape, and composition. Nanomaterials can be nanoscale in one dimension, two dimensions, or three dimensions.

Hence, nanomaterials can be categorized into:

| **Zero dimensional** | **One dimensional** | **Two dimensional** | **Three dimensional** |
|---|---|---|---|
| All dimensions at nanoscale<br>Length, breadth and heights are confined at single point. | Nanomaterials have two external dimensions at the nanoscale, the third one being usually at the microscale.<br>It has only one parameter either length (or) breadth (or )height | Nanomaterials have one external dimension at the nanoscale and other two being at the microscale.<br>It has only length and breadth | Display internal nanoscale features but no external dimension at the nanoscale.<br>It has all parameter of length, breadth and height. |
| E.g. Spheres, Clusters, etc. | E.g. Nanofibers, nanotubes, nanowires, nanorods, etc. | E.g. Thin films, nanocoatings, nanoplates, etc. | E.g. Nanocomposites, nanostructured materials, etc. |

**The properties of nanomaterials are size-dependent because:**

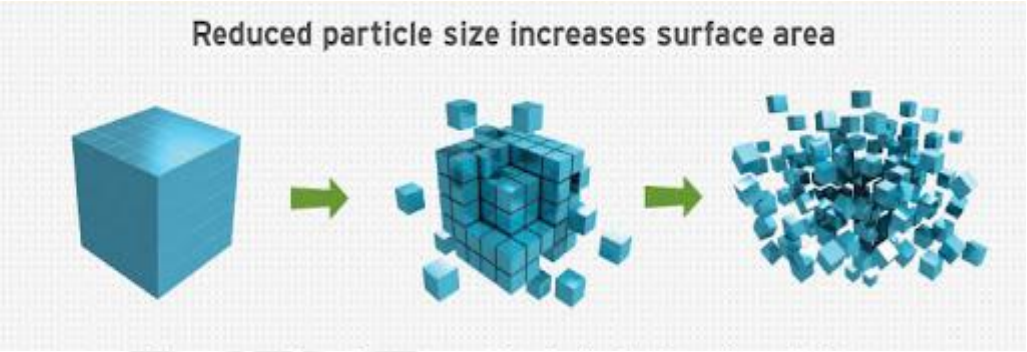
1. The surface area to volume ratio of the nanomaterials is relatively larger than that of bulk materials of the same mass. This increases the chemical reactivity and affects strength and electrical properties of the material.

2. The quantum confinement (size reduction typically less than 10 nm) is observed at nanometer size that changes the optical, electronic and magnetic properties of the material. The band gap increases as the size of the material is reduced to nanometer range.

## 5.2 Size-Dependent Properties

### 5.2.1 Particle-Size vs. Surface Area:

If a macroscopic object is divided into smaller parts, the ratio of surface atoms to interior atoms becomes a significant number of the total fraction of atoms. For example, a cube of iron with side 10 cm long, the percentage of surface atoms is only $10^{-5}$%. When the same cube is cut into smaller cubes with side length 10 nm, the percentage of surface atoms increases to 10%. When the cube is further cut into cube with side length 1 nm, every atom comes on the surface. This inverse relation between the particle size and surface area is responsible for the remarkable changes in the physical and chemical properties of nanomaterials.




### 5.2.2 Physical properties:

Properties such as color, melting point, ionization potential and electron affinity, electrical conductivity, or magnetism which are not otherwise dependent on size, become size dependent when the size of a particle falls below nanoscale in at least one dimension. On this basis, the properties of matter can be tuned to their desired values by adjusting the size of nanoparticles.

### 5.2.3 Optical properties:

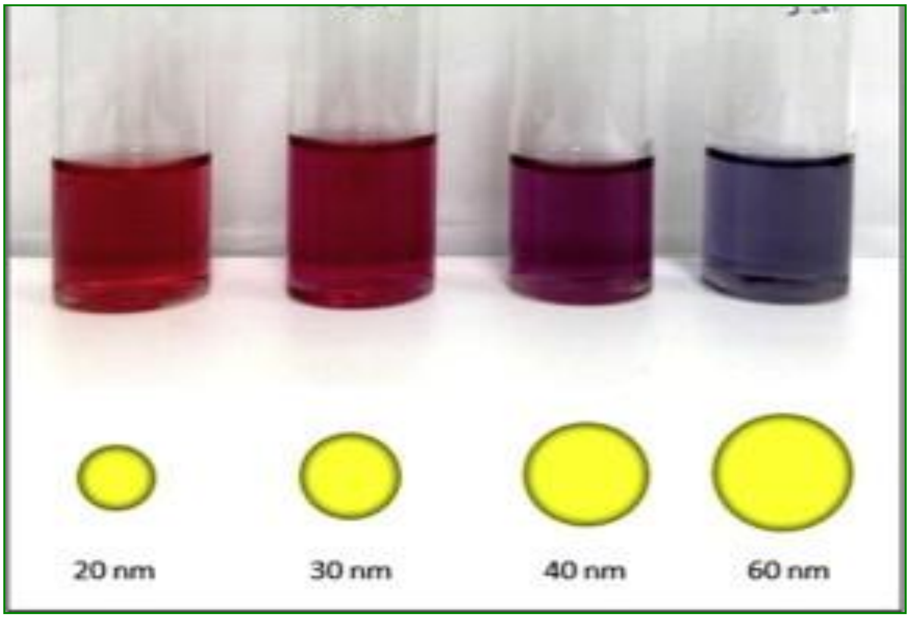
Optical properties of nanomaterials were the first to be exploited by our ancestors who used them as dyes for textiles as well as pigments for stained glass windows, glassware, and wall painting.

Nanomaterials, in general, have peculiar optical properties as a result of the way light interacts with their nanostructure.

At the nanoscale, matter may change color; for example, gold nanospheres turn blue or red depending on their diameter and wall thickness.

Opaque substances such as titanium dioxide, zinc oxide, and copper may also become transparent.

Colloidal suspensions of gold nanoparticles have a deep red color. Furthermore, color of gold colloids varies with the size: 2–5 nm (yellow), 10–20 nm (red), >20 nm (purple), similar is the case with silver nanoparticles: 40 nm (blue), 100 nm (yellow), whereas prism-shaped silver particles exhibit red color.




Gold nanoparticles change colour with size

For example, this unique property is used in the applications like flexible displays, in cosmetics with transparent UV absorbers like titanium dioxide and zinc oxide nanoparticles.

**5.2.4 Thermal Properties -Melting Temperature**

At macroscopic length scales, the melting temperature of materials is size-independent. For example, an ice cube and a glacier both melt at the same temperature. But in nanocrystals, if the size decreases, surface energy increases which in turn decreases the melting point. Surface atoms require less energy to move because they are in contact with fewer atoms of the substance.

E.g. Melting point of gold (bulk) is 1064°C; Melting point of 4 nm gold particles is 581° C.

## Surface Plasmon Resonance (SPR)

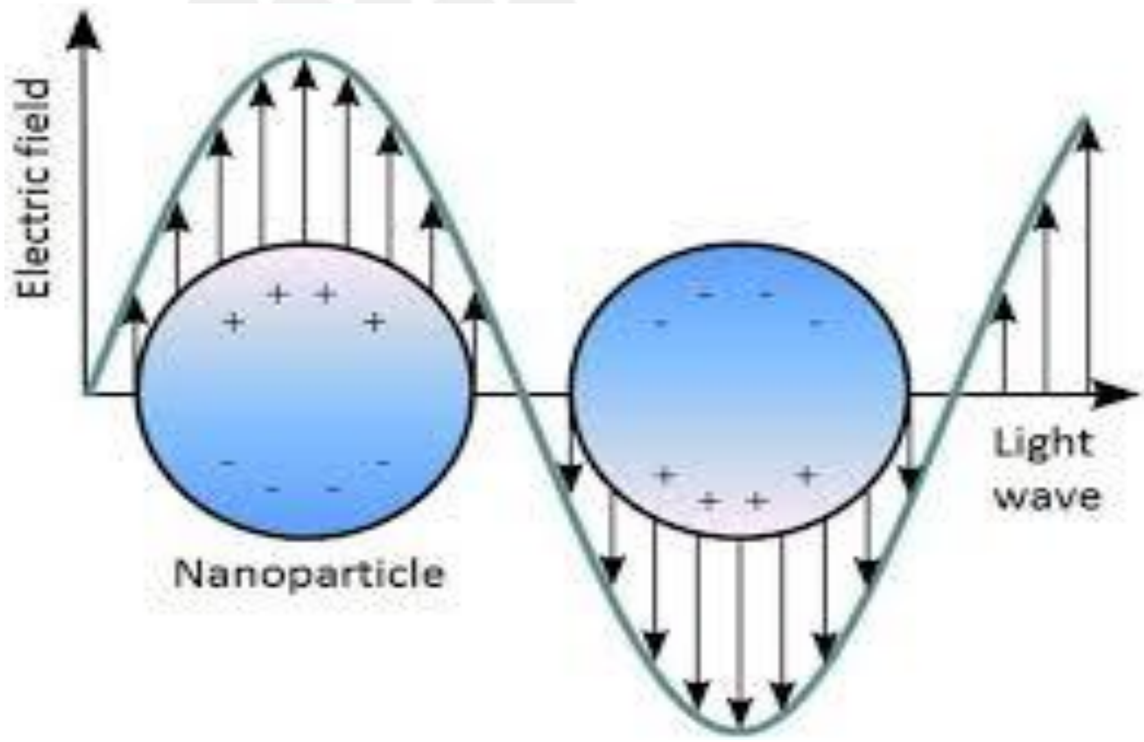
Surface plasmon resonance (SPR) is the **manifestation of a resonance effect due to the interaction of conduction electrons of metal nanoparticles** with incident photons. The interaction relies on the size and shape of the metal nanoparticles and on the nature and composition of the dispersion medium.

SPR is a process, which takes place when there is coherent oscillation of conduction band electrons upon interaction with an electromagnetic field.

It takes place when size of nanoparticle is smaller than wavelength of incident radiations.

It occurs mostly in case of metal nanoparticles such as gold nanoparticles.

Surface plasmon resonance (SPR) is a powerful technique to retrieve information on optical properties of biomaterial and nanomaterials. Biosensor based on SPR is a versatile technique for biological analysis applications.



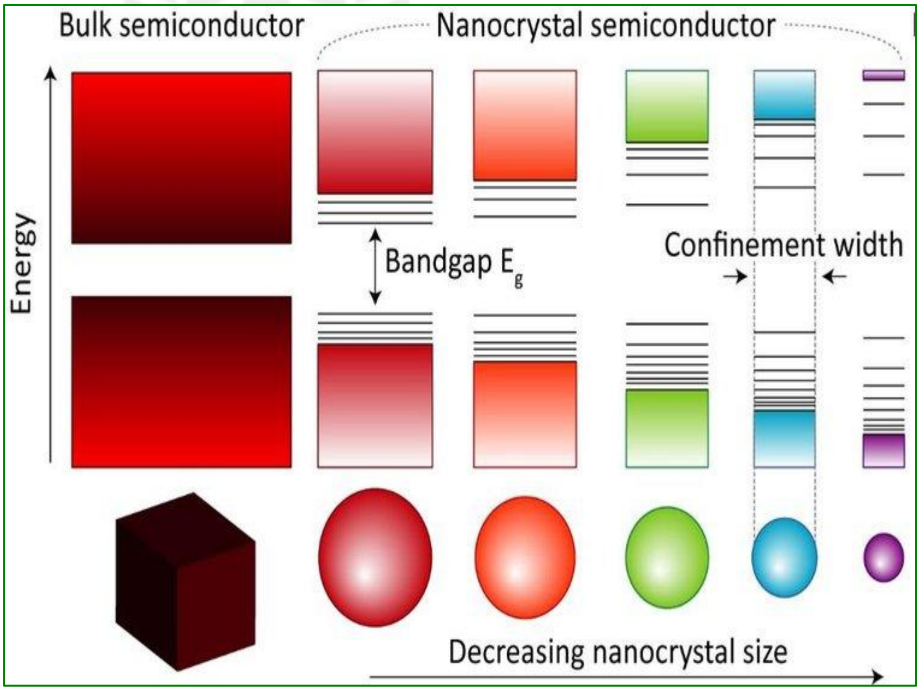
### 5.2.5 Electrical properties:

Electrical conductivity of the material depends on the number of free electrons and their speed. But, in case of nanomaterials, due to the peculiar size, the electrical conductivity is complex and conductivity changes due to many parameters:

- Change in area of cross-section.
- Increase in perfection
- Reduction in impurity
- Less structural defects
- Less dislocations

Apart from the above, electrical conductivity also decrease due to increase in band gap. However electrical conductivity of nanomaterial can be increased by formation of ordered microstructure. It is also observed that conductivity changes when some shear force (in simple terms twist) is given to nanomaterial.

E.g. Carbon nanotubes can act as conductor or semiconductor in behavior, but bulk carbon (graphite) is good conductor of electricity. Similarly, bulk silicon is an insulator but becomes a conductor at nanoscale.



### 5.2.6 Mechanical properties:

Nanomaterials and nanostructured materials show excellent mechanical properties due to the volume, surface and quantum effects.

The very high strength of carbon nanotubes, nanorods, and nanocrystalline materials is caused by the fact that they contain no dislocations.

Nanomaterials generally show a reduction in ductility and tenacity because their large grain boundary surface area restricts dislocation movement.

Mechanical applications of nanocomposites include sport equipment, household items, windmill blades, and construction materials like concrete and asphalt.

**Tensile Strength**

- It is a measure of the amount of stress needed to pull a materials. CNTs are very strong. The tensile strength of CNTs is 100 times stronger than that of steel of the same diameter.
- There are two things accounts for greater strength of CNTs.
- The strength is provided by the interlocking of carbon to carbon covalent bonds.
- Each CNT is one large molecule. It means that, it does not have any weak spots like grain boundaries, dislocation etc. which all the other materials have.

**Young's modulus**

- It is a measure of how stiff or flexible a material is. The larger the value of young's the less flexible the material.
- CNTs have Youngs modulus ranging from 1.28 to 1.80TPa. One terapascal is a pressure very close to 107 times of atmospheric pressure. The Youngs modulus of steel is 0.21TPa, which means that Youngs modulus of CNT is almost 5 to 10 times of steel. That is, CNTs are very stiff and hard to bend.

## 5.2.7 Chemical reactivity:

The large chemical reactivity of nanomaterials is attributed to their large surface area as well as to the presence of more edges, angles, and crystal defects.

This larger chemical reactivity makes nanomaterials ideal for application as catalysts. Due to increased surface area, nanomaterials possess greater surface energy and are thermodynamically less stable. The atoms or molecules that exist on the surface or the interface are somewhat different from atoms/molecules in the bulk/interior of the material.

Another advantage of the large chemical reactivity is, these nanomaterials can be used in sensors. For example, carbon nanotubes and metal nanoparticles can detect various gases such as hydrogen, acetone, ammonia and ethanol a result of a modification in their electrical conductivity or light absorption spectrum.

Nanomaterials can also be applied as antibacterial agents. Several metal oxides such as titanium dioxide, zinc oxide, magnesium oxide, and copper oxide also have a decontaminating action against toxic gases like mustard and pesticides.

Another category of chemical applications of nanomaterials is related to their barrier properties. Nanoporous membranes can be used for water filtration by nanofiltration and air filtration.

Nanomaterials also display some interesting physicochemical properties, namely, super hydrophobicity. Indeed, nanoscale surface features allow one to obtain a contact angle $>150^0$ that prevents water from sticking to the surface, leading to the so-called 'lotus effect'. Applications of nanomaterials with super hydrophobic properties include textiles with stain resistant, rapid drying, easy decontamination, fog-free and self-cleaning glasses, windows, screens etc.

## Magnetic properties

Nano particles of magnetic and even non magnetic solids exhibit a totally new class of magnetic properties.

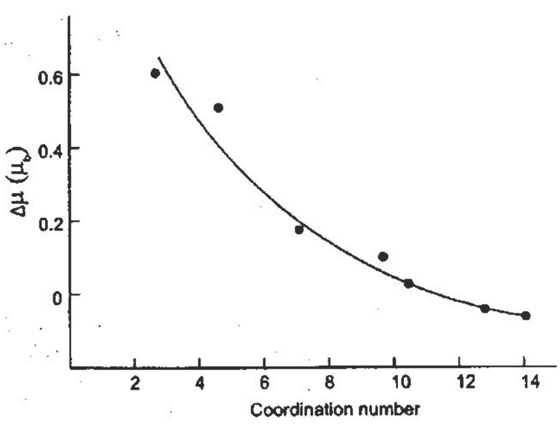
Table gives an account of magnetic behavior of very small particles of various metals.

Ferro magnetic and anti ferromagnetic multilayers have been found to exhibit *Giant Magneto Resistance (GMR).*

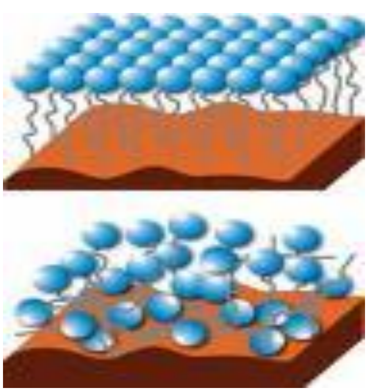
Small particles differ from the bulk in that these atoms will have lower co-ordination number.

From the below Fig, it is inferred that the small particles are more magnetic than the bulk material

| Metal | Bulk | Cluster |
|---|---|---|
| Na, K | Paramagnetic | Ferromagnetic |
| Fe, Co, Ni | Ferro magnetic | Super paramagnetic |
| Gd, Tb | Ferromagnetic | Super paramagnetic |
| Rh | Paramagnetic | Ferromagnetic |



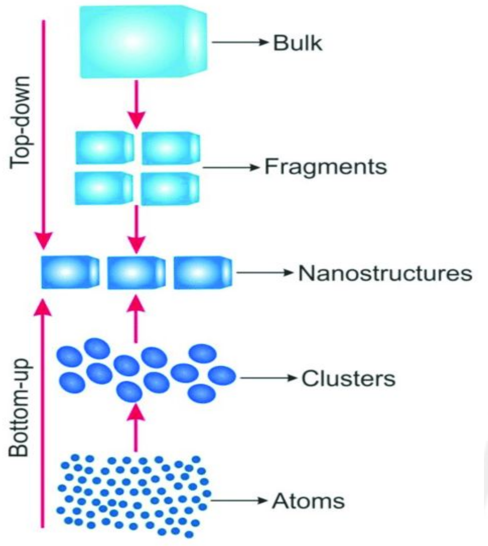

Change in bulk magnetic moment versus co- ordination number



## 5.3 General Methods of Synthesis

There are two approaches generally adopted for the synthesis of nanomaterials and structures. Top down approach refers to successive cutting of a bulk material to get nanoparticles. E.g. Attrition or milling

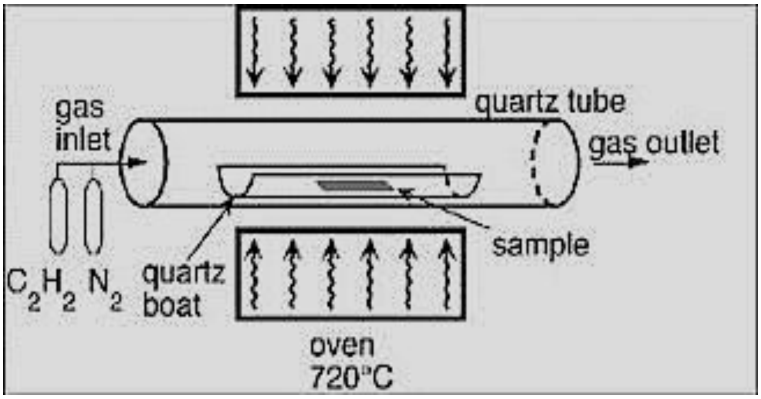
Bottom up approach is the building up of a material from the bottom, that is, atom by atom, molecule by molecule or cluster by cluster. E.g. colloidal dispersion.




Schematic representation of the building up of nanostructures.

### 5.3.1 Top down approach

**5.3.1.1 Chemical vapor deposition (CVD):** This technique involves decomposition of metal organic compounds at high temperature and reduced atmospheric pressure. Nanoparticles of different metal oxides, carbon, composites, etc., can be produced by this method.



The reactor consists of a quartz tube surrounded by an oven. The substrate like silica, mica or quartz coated with a layer of metal nanoparticle catalyst like Ni, Co is taken. The substrate is heated along with precursor carbon source (acetylene or ethylene or methane) and a process gas like nitrogen, to around 720°C in an oven. At high temperature, the hydrocarbons are broken and produce pure carbon atoms. The carbon diffuses towards the substrate and binds on the surface of catalyst. Carbon nanotubes are formed if the proper parameters are maintained.

Nanosized particles of metals and ceramics can also be obtained using this method in good amounts by adjusting the residence time of the precursor molecules; changing the gas flow rate, the pressure difference between the metal organic compound delivery system and the main chamber and the temperature of the reactor.

**Types of CVD**

CVD can be classified into different types based on the method by means of which chemical decomposition is initiated.

**1. Thermal CVD**

It is the oldest method. The chemical reaction is activated by high temperature from 800 to 2000°C.

Based on the source of heat provided the thermal CVD is classified as following:

1. High temperature thermal CVD and low temperature thermal CVD
2. Atmospheric pressure CVD and low pressure thermal CVD
3. Cold wall CVD and hot wall thermal CVD
4. Closed thermal CVD and open thermal CVD

**2. Plasma CVD**

In this process the chemical reaction is activated by plasma at the temperature between 300 °C – 700 °C.

**3. Laser CVD**

In this process the reaction is activated as a result of thermal energy from laser which heats the absorbing substrate. It is also called as pyrolysis.

**4. Photo-CVD**

In this process the chemical reaction is activated by the action of photons from UV radiations which break the chemical bonds in the reacting substance. It occurs at room temperature.

**Advantages**

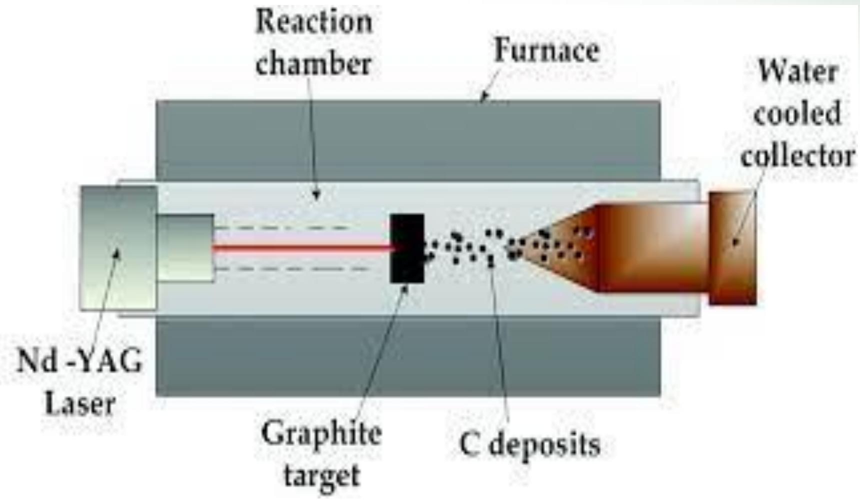
- Lower temperature range.
- Relatively high purity
- This method can produce both MWNTs and SWNTs depending on the temperature.
- Mass production can be done in industry.

## 5.3.1.2 Laser ablation:

It is a method in which high power laser pulse hits the target and evaporates the matter which condenses and becomes a nanoparticle such that the stoichiometry of the materials is preserved in the interaction.

High-quality CNTs can be produced from carbon plasma by using a laser beam, typically a YAG (yttrium aluminum garnet) or $CO_2$ laser, where intense laser pulses ablate graphite as a source of carbon. The reaction chamber made of quartz tube is maintained at 1200°C under inert atmosphere. High-power pulsed laser is used to vaporize a graphite target. Intense laser pulse ablates the carbon target. During the process some inert gases like helium or argon flows through the chamber, which sweeps carbon atoms towards the copper collector. The carbon atoms cool and condense as nanotubes. The laser ablation method yields around 70% CNTs.

The result of the product depends on the catalyst. In absence of catalyst, the product will be SWNTs, whereas MWNTs will be formed in presence of catalyst. This method was first discovered by Guo et al., at Rive University in 1995. The tubes produced by this method are in the form of a mat of ropes 10–20 nm in diameter and up to 100 microns or more in length. The advantage of this method is high-quality SWNT, diameter control, the investigation of growth dynamics, and the production of new materials.




**Advantages**

- This method is capable of high rate of production of 2–3 g/min.
- It is suitable for highly toxic and radioactive materials often in trace amounts.
- Very easy to operate ,Eco friendly method.

**Applications**

- It is used to produce high melting point elements and transition metals.
- Elements of gold, palladium and compounds of sulphides are produced by this method.

## 5.3.2 Bottom up approach

### 5.3.2.1 Liquid solid reactions (precipitation):

In this method, ultrafine particles of the desired material are produced by precipitation from a solution in the presence of a water-soluble inorganic stabilizing agent. The presence of desired nuclei in the solution is a necessary condition to initiate the process. For example, $TiO_2$ powders with particle sizes in the range 70–300 nm have been prepared from titanium tetraisopropoxide by this method. Similarly, ZnS powders may be produced by reaction of aqueous zinc salt solutions with thioacetamide.

**Example**

**Formation of $BaSO_4$ nanopowder:** An inorganic metal salt such as barium nitrate is added with sodium sulphate solution in the presence of the stabilizing agent sodium hexa meta phosphate. The solution is stirred for more than one hour. Precipitation occurs slowly.

$$Ba(NO_3)_2 + Na_2SO_4 \xrightarrow{\text{Stabilizing agent}} BaSO_4 \downarrow + 2NaNO_3$$

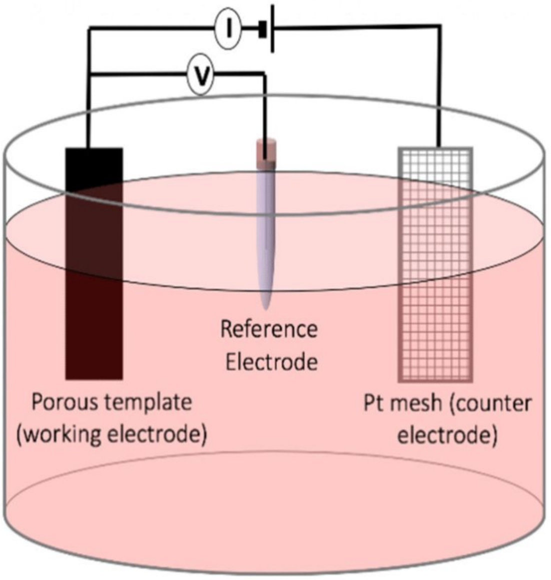
The resulting precipitate was filtered and washed several times with distilled water until free of nitrate ions and finally dried in air. The obtained materials were calcined for 3 hours at different temperatures and thus nanopowder products are obtained.

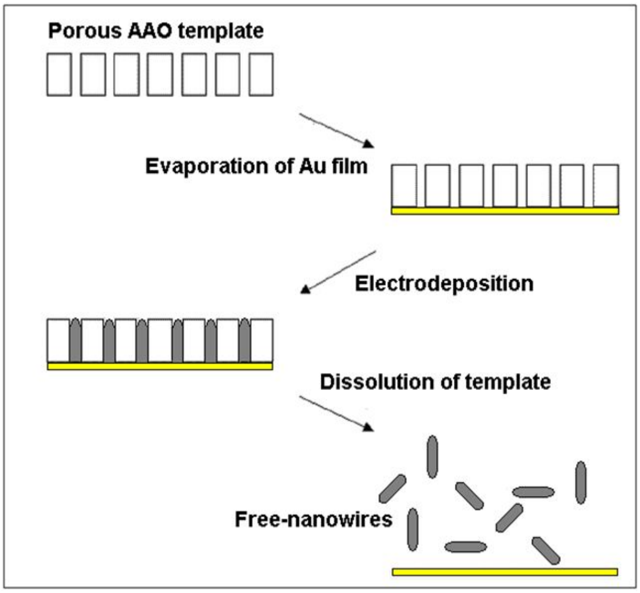
### 5.3.2.2 Electrodeposition:

This technique involves creation of solid materials from electrochemical reactions in liquids. A conducting substrate is placed in liquid containing electrolytes. When a potential is applied, redox reaction takes place and the material is deposited as thin film at the cathode.

**Process**

The template assisted-electrodeposition system consists of a working electrode, a reference and counter electrode. Reference electrode is an electrode which has known and stable potential whereas counter electrode is usually a Pt wire. The working electrode consists of template which has the required size of the nanowire. This template electrode and counter electrode are immersed in the electrolyte. Usually the electrolyte is a precursor solution with suitable additives. When suitable potential is applied between the electrodes, the metal ions from the precursor solution moves towards the cathode and fills the pores of template and generates desired nanowires.



**Example:**

Nanostructured gold can be prepared by electrodeposition technique using gold plate as cathode. An array of aluminium template is used for this process. When current is passed through the electrolyte of $AuCl_3$ solution, $Au^{3+}$ diffuses into pores of alumina templates and gets reduced at cathode resulting in the growth of gold nanowires.

Electroless deposition can also be obtained by using complex chemical solutions wherein deposition occurs spontaneously (without applied electric potential) on surfaces. Nanorods and nanoparticles can be fabricated by both the methods using templates. Semiconductor ZnO nanotube arrays can also be synthesized by direct electrochemical deposition from aqueous solutions into the pore channels of anodically-formed alumina.

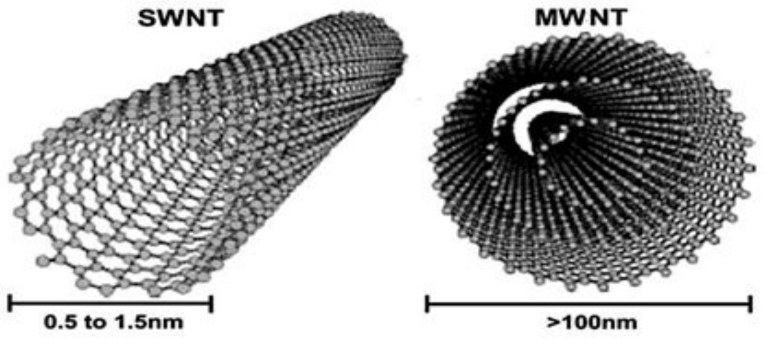
## 5.4 Types of Nanomaterials

### 5.4.1 Carbon Nanotubes

Carbon nanotubes (CNTs; also known as bucky tubes) are allotropes of carbon with a cylindrical nanostructure. Nanotubes have been synthesized with length-to-diameter ratio of up to 132,000,000:1. They possess extraordinary strength and electrical and thermal properties. These novel properties make them useful in nanoelectronics, optics and other areas of materials science.

### Types of Carbon Nanotubes

**1. Single-walled nanotubes (SWNTs)** have a diameter of ~1 nm, with a tube length many million times longer. The structure of a SWNT can be imagined to be a wrapping of a one-atom-thick layer of graphite (graphene) into a seamless cylinder.



**Based on the carbon atom arrangement SWNTs can be classified as (a) armchair (b) zigzag (c) chiral**

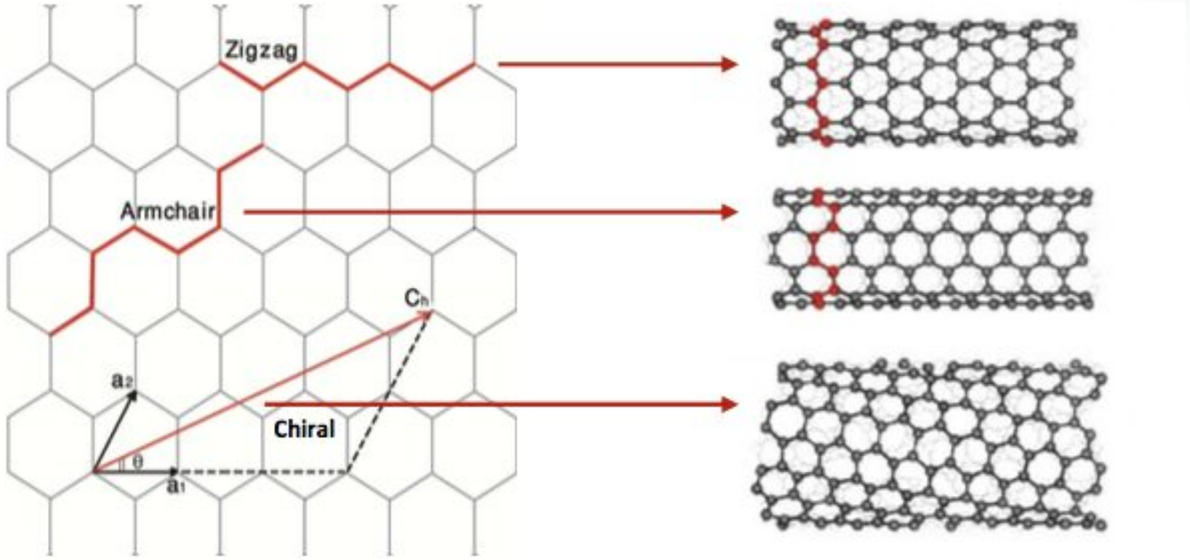
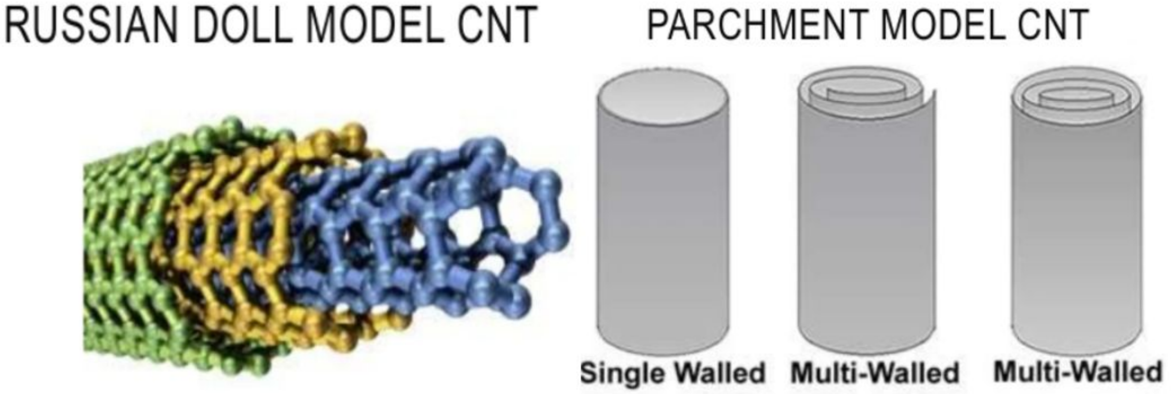



**Figure 1.** Schematic diagram showing zigzag, armchair and chiral carbon nanotubes.

**2. Multiwalled nanotubes (MWNTs)** consist of multiple rolled layers or otherwise concentric tubes of graphite. There are two models that describe the structures of multiwalled nanotubes. In the Russian Doll model, sheets of graphite are arranged in concentric cylinders, that is, single-walled nanotube within a larger single-walled nanotube. In the Parchment model, a single sheet of graphite is rolled in around itself, resembling a rolled newspaper.



## Synthesis/Preparation of Carbon Nanotubes:

Carbon nanotubes can be synthesized by any one of the following methods.

1. Pyrolysis of hydrocarbons.

2. Laser evaporation.

3. Carbon arc method.

4. Chemical vapour deposition

### 1. Pyrolysis

CNTs can be synthesized by the pyrolysis of hydrocarbons such as acetylene at 700 °C in the presence of Fe-silica or Fe-graphite catalyst under inert conditions.

### 2.Laser evaporation:

**Write from page number 26 briefly. (5.3.1.2)**

### 3. Carbon arc Method:

It is carried out by applying DC arc (60–100 A and 20–25 V) between graphite electrodes of 10 – 20 μm diameter.

### 4. Chemical Vapour deposition:

**Write from page number 24 briefly. (5.3.1.1)**

## Properties of CNTs:

1. CNTs are very strong, withstand extreme strain in tension and possess elastic flexibility.

2. The atoms in a nano-tube are continuously vibrating back and forth.

3. It is highly conducting and behaves like metallic or semiconducting materials.

4. It has very high thermal conductivity and kinetic properties.

## Applications of CNTs:

1. Carbon nanotubes find application in nanoelectronics. The nanotube integrated memory circuit was first made in 2004. CNT-based transistors can operate at room temperature and are capable of digital switching using a single electron.

2. A paper battery is made up of a paper-thin sheet of cellulose infused with aligned carbon nanotubes. The nanotubes act as electrodes to conduct electricity. These batteries provide a long and steady power output comparable to a conventional battery (lithium battery), as well as quick release of high energy (as a supercapacitor).

3. The solar cells have been developed at the New Jersey Institute of Technology using a carbon nanotube complex, formed by a mixture of carbon nanotubes and carbon buckyballs (fullerenes) to form snake-like structures.

4. CNTs find applications in composite polymer materials where they are used to further add to the strength of the polymers.

5. As CNTs have high mechanical strength, they are being explored for fabricating clothes' stab-proof and bullet-proof properties.

5. Due to their similarity in physical dimensions to those of biologically active macromolecules such as proteins and DNA, carbon nanotubes find increasing utility in biologically inspired design.

6. Ultra-short SWNTs have been used as in vivo nanoscale capsules. In cancer research, SWNTs inserted around cancerous cells and excited with radio waves results in killing the cancerous cells.

## 5.4.2 Nanocomposites

• A nanocomposite is a matrix reinforced by added nanoparticles. Nanocomposite is a multiphase solid material with one of the phases having dimensions <100nm.

•The reinforcing material can be particles, sheets or fibres (e.g., carbon nanotubes).

• Due to the exceptionally high surface area to volume ratio of the reinforcing phase and/or its high aspect ratio, the area of the interface between the matrix and reinforcement phase(s) in nanocomposites is typically an order of magnitude greater than for conventional composite materials.

• The properties of the nanocomposite materials such as electrical, thermal, optical, mechanical, electrochemical and catalytic significantly differ from that of the component materials. The size of the nanoparticle affects the property of the nanocomposites.

## Nanocomposites can be of following types:

1. **Ceramic-matrix nanocomposites:** The main part of the volume is a ceramic and the second component is a metal.

2. **Metal-matrix nanocomposites:** The metals form the matrix in which carbon nanotubes or other nanoparticles are dispersed.

3. **Polymer-matrix nanocomposites:** A polymer or copolymer is the matrix with nanoparticles or nanofillers is dispersed in the polymer matrix.

## 5.5 General Applications of Nanomaterials

### 5.5.1 Electronics

- Nanowires find potential use in electronic applications such as junctions with good rectifying characteristics. Junction diodes, memory cells and switches, transistors, LEDs and inverter etc., have already been fabricated using nanowire junctions.
- The main application of nanorods is in the area of display technologies because their reflectivity changes on change of orientation with an applied electrical field. They are also used in microelectromechanical (MEMS) systems.
- Nanorods fabricated using semiconducting materials are used in energy harvesting systems and light emitting diodes. ZnO nanorods are also extensively used to fabricate nanoscale electronic devices.
- The integrated memory circuits have been found to be effective devices using nanomaterials.
- Nanowires are used to build transistors without p-n junctions.
- Nanoradios (also called carbon nanotube radio) is a nanotechnical device that acts as a radio transmitter and receiver by using carbon nanotubes.
- MOSFET (Metal oxide semiconductor FET) performs both as switches and as amplifier

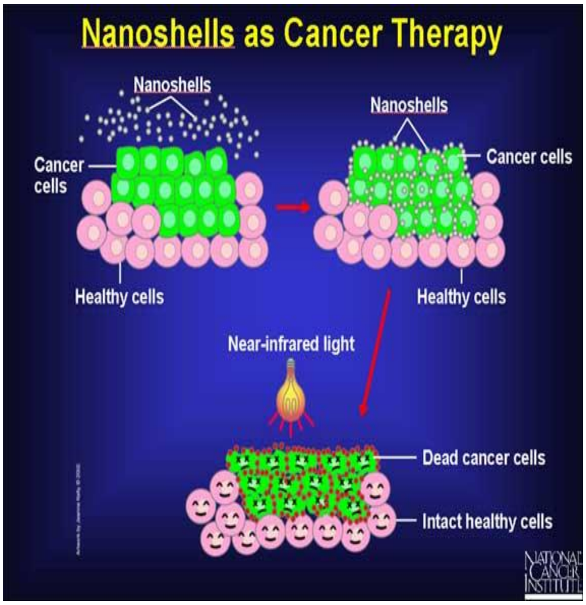
### 5.5.2 Information technology

• Using magnetic random access memory (MRAM), computers will be able to 'boot' almost instantly. MRAM is enabled by nanometer-scale magnetic tunnel junctions and can quickly and effectively save data during a system shutdown or enable resume-play features.

### 5.5.3 Medical and healthcare

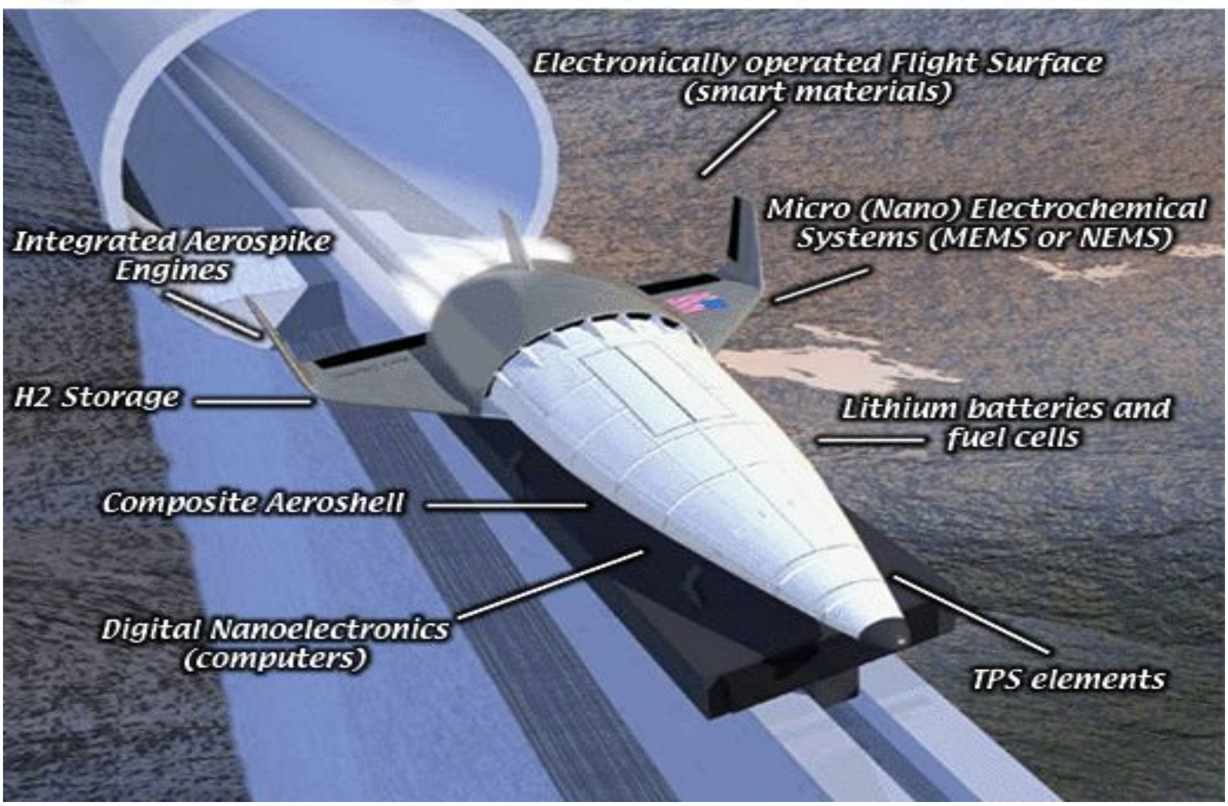
The size of nanomaterials is very similar to that of biological molecules and structures; therefore, these find extensive use in both in vivo and in vitro biomedical applications.

- **Drug delivery:** Drug consumption and side-effects can be reduced considerably by depositing the active agent in the diseased regions and in appropriate dose. Nanoporous materials can be used to hold small drug molecules and to transport them to the desired location. Applications include cancer treatment with iron nanoparticles or gold shells.





## Faster, Better, Cheaper Space Transportation with Nanotubes



- **Transdermal drug delivery:** It involves nanosized protrusions on the underside of patches that would be fixed to the skin like a plaster. The protrusions carrying doses of the drug act as tiny needles, discharging the drug, which can then reach the other parts of the body through tissue fluids.
- **Tissue repair:** Nanotechnology can help to regenerate or to repair damaged tissues and the technique is called tissue engineering. This uses artificially stimulated cell proliferation through suitable nanomaterial-based scaffolds and growth factors. Tissue engineering might replace today's conventional treatments like organ transplants or artificial implants surgeries.
- **Laboratories on a chip:** Nanotechnology has enabled the production of "laboratories on a chip", that can perform multiple medical tests. It is a device that integrates one or several laboratory functions on a single integrated circuit (commonly called a "chip") of only millimeters to a few square centimeters to achieve automation.
- **Nanomedibots:** Nanobots are small "robots" ranging from 1 to 100 nanometers in size. Scientists are exploring different applications of nanobots in medicine and healthcare, to fight cancer as well as to unblock blood vessels.

## 5.5.4 Energy

- Nanotechnology can be incorporated into solar panels to convert sunlight to electricity more efficiently, promising inexpensive solar power in the future. Nanostructured solar cells could be cheaper to manufacture and easier to install, since they can use print-like manufacturing processes and can be made in flexible rolls rather than discrete panels. Newer research suggests that future solar converters might even be "paintable."
- Nanotechnology is already being used to develop many new kinds of batteries that are quicker-charging, more efficient, lighter weight, have a higher power density, and hold electrical charge longer.
- An epoxy containing carbon nanotubes is being used to make windmill blades that are longer, stronger, and lighter-weight than other blades to increase the amount of electricity that windmills can generate.

In the area of energy harvesting, researchers are developing thin-film solar electric panels that can be fitted onto computer cases and flexible piezoelectric nanowires woven into clothing to generate usable energy on the go from light, friction, and/or body heat to power mobile electronic devices. Similarly, various nanoscience-based options are being pursued to convert waste heat in computers, automobiles, homes, power plants, etc., to usable electrical power.

### 5.5.5 Environmental remediation

- Nanomaterials show a better performance in environmental remediation than other conventional techniques because of their high surface area (surface-to-volume ratio) and their associated high reactivity.
- They are used for the treatment of drinking water and industrial waste water contaminated by toxic metal ions, radionuclides, organic and inorganic solutes, bacteria and viruses and the treatment of air
- Dissolved solids and colour producing organic compounds can be filtered very easily from water.
- Magnetic nanoparticles are effective in removing heavy metal contamination from waste water.

### Nanofiltration (NF)

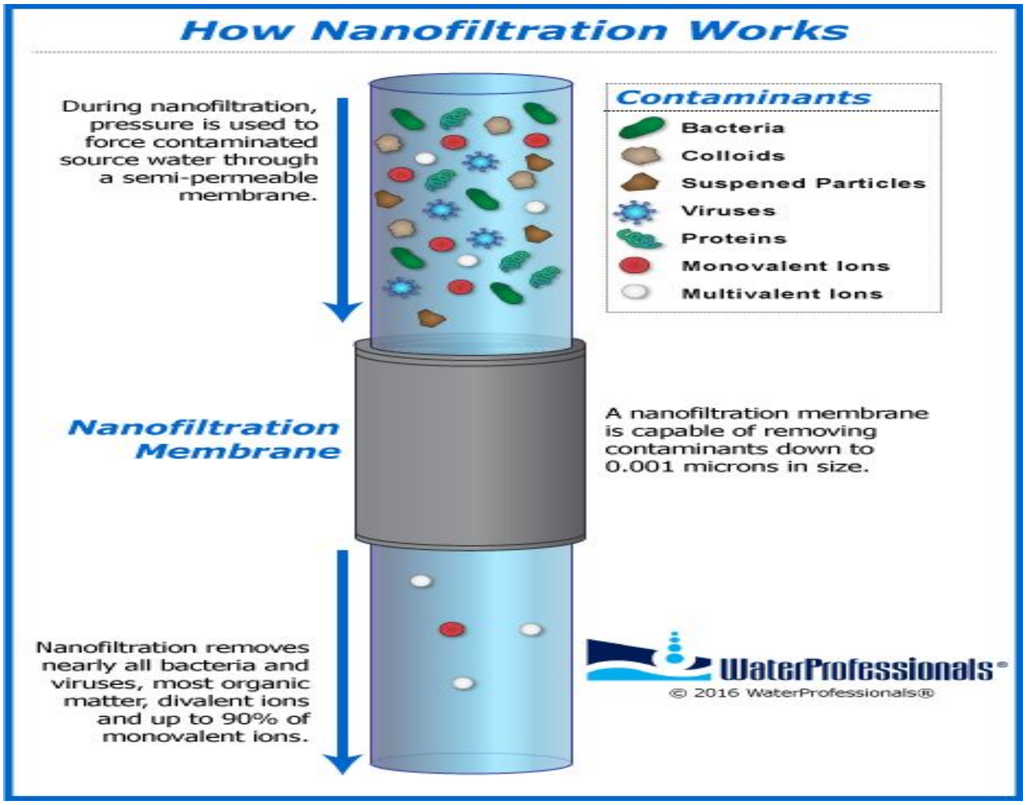
Nanofiltration is a pressure-driven membrane process that lies between ultrafiltration and reverse osmosis in terms of its ability to reject molecular or ionic species. Nanofiltration membranes, organic membranes, or ceramic membranes can be either dense or porous.

It is **one of the widely used membrane processes for water and wastewater treatment** in addition to other applications such as desalination. NF has replaced reverse osmosis (RO) membranes in many applications due to lower energy consumption and higher flux rates.

#### How Nanofiltration works?

Nanofiltration membranes are not a complete barrier to dissolved salts. Depending on the type of salt and the type of membrane, the salt permeability may be low or high. If the salt permeability is low, the osmotic pressure difference between the two compartments may become almost as high in reverse osmosis.

However, a high salt permeability of the membrane would not allow the salt concentrations in the two compartments to remain very different. Thus, osmotic pressure plays a minor role if the salt permeability is high. In practice, reverse osmosis and nanofiltration are applied as a crossflow filtration process. The simplified process is shown in the figure below.




- **Nanofiltration** is sometimes used to recycle wastewater, as it offers higher flux rates and uses less energy than a reverse osmosis system.
- The design and operation of nanofiltration is very similar to that of **nanofiltration** is very similar to that of reverse osmosis, with some differences.
- The major difference is that the nano membrane is not as "tight" as the reverse osmosis membrane.
- It operates at a lower feed water pressure and it does not remove monovalent (i.e., those with a single charge or valence of one) ions from the water as effectively as the RO membrane.

- While a RO membrane will typically remove 98-99% of monovalent ions, such as chlorides or sodium, a nanofiltration membrane typically removes 50% to 90%, depending on the material and manufacture of the membrane.
- Because of its ability to effectively remove di and trivalent ions, nanofiltration is frequently used to remove hardness from water while leaving the total dissolved solids content much less affected than would RO.
- For this reason, it has been called the "softening membrane". Nanofiltration is often used to filter water with low amounts of total dissolved solids, to remove organic matter and soften water.
- Nanofiltration membranes are less likely to foul or scale and require less pretreatment than reverse osmosis systems.
- Sometimes it is even used as pretreatment for reverse osmosis.
- **Nanofiltration** can be employed in a variety of water and wastewater treatment industries for the cost-effective removal of ions and organic substances.
- Besides water treatment, nanofiltration is often employed in the manufacturing process for pharmaceuticals, dairy products, textiles and bakeries.

The nano filtration technique is mainly used for the removal of two valued ions and the larger mono valued ions such as heavy metals. This technique can be seen as a coarse RO (reversed osmosis) membrane.

Because nano filtration uses less fine membranes, the feed pressure of the NF system is generally lower compared to RO systems. Also the fouling rate is lower compared to RO systems.

Applications for NF systems are:

- softening
- specific removal of heavy metals from process streams for reuse of water
- Reduction of salt contents of slightly brackish water

There are two types of membranes:

- Spiral membranes, cheapest but more sensitive for pollution
- Tubular/ straw membranes, the most used membranes seen the costs and effect, shall not easily be polluted

The surfaces from the filter determine the capacity from the filter. Spiral membranes have the biggest surface area in general and are therefore the most cheapest in use. The pre purifying of the feeding water has a influence on the performance of the installation.

### 5.5.6 Construction industry

- Nanoparticles of $TiO_2$, $Al_2O_3$ or ZnO are applied as a final coating on construction ceramics to bring specific characteristics to the surfaces.
- $TiO_2$ is being used for its ability to break down dirt or pollution when exposed to UV light and then allow it to be washed off by rainwater on surfaces like tiles, glass and sanitary ware.
- ZnO is used to have UV resistance in both coatings and paints.
- Nanosized $Al_2O_3$ particles are used to make surfaces scratch resistant. These surfaces also prevent / decelerate formation of bad smells, fungus and mould.

### 5.5.7 Transportation

- Nano-engineered materials in automotive products include high-power rechargeable battery systems; thermoelectric materials for temperature control; tyres with lower rolling resistance; high-efficiency/low-cost sensors and electronics; thin-film smart solar panels; and fuel additives for cleaner exhaust and extended range.
- Nanotechnology-enabled lubricants and engine oils also significantly reduce wear and tear, which can significantly extend the lifetimes of moving parts in everything

### 5.5.8 Textile industry

- Nano-textiles is an emerging and interesting application of nanotechnology.
- It involves dealing with nano fibers at the atomic and molecular levels in order to tweak their properties. This novel technology can give rise to incredible clothing such as water-resistant and dirt-free clothes, odor-less socks, and intelligent clothes that can perform climate control for you.

- Nanofibers in clothes make waterproof and stain-repellant or wrinkle-free and can be washed less frequently.
- Nanotechnology in textiles may offer protection from electrostatic charges for the wearer.
- Socks embedded with silver nanoparticles kills all the bacteria and makes it odour free.

### 5.5.9 cosmetics industry

- Nano zinc oxide and titanium oxide are used in sunscreen creams, lotions and other cosmetics. These nanoparticles become transparent and retain their ability to absorb UV radiation.

### 5.5.10 Food industry

- Nanotechnology finds applications in the production, processing, safety and packaging of food stuffs.
- The inclusion of nanoparticles in food contact materials can be used to generate novel type of packing materials and containers which can protect food from drying and spoilage.

### 5.5.11 As catalysts

- It depends on the surface area of the material. As nanoparticles have huge surface area and enhanced reactivity, its catalytic activity is excellent.
- Example: Bulk gold is chemically inert; whereas gold nanoparticles have excellent catalytic property.

## 5.5.12 Automobiles

- Nanotechnology can be incorporated in various automobile parts such as paint, batteries, fuel cells, tyres, mirrors, and windows.
- Incorporation of small amount of nanoparticles in car bumpers can make them stronger than steel.
- Specially designed nanoparticles are used as fuel additive to lower consumption in vehicles.

Nanotechnology in Tyres

- Tyres are one of the early applications of nanostructured materials in automobiles. Carbon black was the first nanomaterial to be used by the automotive industry in tyres as a pigment and reinforcing agent.
- The key to tire performance is the mixture of the rubber – but its optimization requirements can be contradictory (highly complex chemical and physical interactions between the rubber and the filler material): While the tire needs good grip its rolling resistance has to be low as well.

### 5.5.13 Sports

- Sports equipment such as tennis balls and rockets are produced by nanotechnology.
- This equipment have extraordinary strength and they are long lasting in nature.

### 5.5.14 Biomaterials in biology

- Nanomaterials are used as bone cement and bone plates in medical fields and as a material for joint replacements.
- Nanotechnology is being used to develop miniature video camera attached to a blind person's glasses.
- Nanomaterials are also used in the manufacture of some components like heart valves and contact lenses.
- Nanomaterials are used in dental implants.
- CNTs are used as light weight shielding materials for protecting electronic equipment's against electromagnetic radiation

## Practice Quiz

Unit V:

- https://docs.google.com/forms/d/e/1FAIpQLScHjzs_PwAxaEcVQRipyiwheGfEBCfDyLR-bZ8GxtnZ5Im0BQ/viewform?usp=sf_link

# Assignment

# Unit V

| S.No. | Questions | K level |
|---|---|---|
| 1. | Write the benefits of using carbon nanotubes in fuel cells. | K2 |
| 2. | Write a note on: Evolution of nanotechnology in Sports Equipment / Medical field | K3 |

# Part-A Question and Answer

| S.No. | PART-A<br>Q & A | K level | CO |
|---|---|---|---|
| 1 | **Define nanoscience and Nanochemistry.**<br>The study of the nanomaterials is known as nanoscience. Nanochemistry involves the study of synthesis and characterization of nanomaterials. | K1 | CO5 |
| 2 | **How does nanotechnology work?**<br>Nanotechnology is the understanding and control of matter at the nanometer scale, where unique phenomena enable novel applications. | K1 | CO5 |
| 3 | **What are nanomaterials?**<br>A nanomaterial is an object that has at least one dimension in the nanometre scale (approximately 1-100 nm). | K1 | CO5 |
| 4 | **Give examples for the different Dimensional structures.**<br>0D-Spheres, Clusters<br>1D-nanofibers, nanotubes, nanowires, nanorods<br>2D-thin films, nanocoatings, nanoplates<br>3D-nanocomposites | K2 | CO5 |
| 5 | **Illustrate the size dependent properties of nanoparticles?**<br>Nanomaterials have a relatively larger surface area when compared to the same mass of material produced in a larger form. Nano particles affects many properties such as melting point, band gap, optical properties, electrical properties and magnetic properties. | K3 | CO5 |

| S.No. | PART-A<br>Q & A | K level | CO |
|---|---|---|---|
| 6 | **What are nanocomposites?**<br>A nanocomposite is a matrix reinforced by added nanoparticles. Nanocomposite is a multiphase solid material with one of the phases having dimensions <100nm. The reinforcing material can be particles, sheets or fibres (e.g., carbon nanotubes). | K1 | CO5 |
| 7 | **What are carbon nanotubes?**<br>Carbon nanotubes are allotropes of carbon with a cylindrical nanostructure. Nanotubes have been synthesized with length-to-diameter ratio of up to 132,000,000:1.<br>Two Types of nanotubes are there based on structure. They are Single walled nanotubes (SWNTs) and Multi walled nanotubes (MWNTs). | K1 | CO5 |
| 8 | **Write any four uses of CNT.**<br>1.CNT is used in battery technology and in industries as catalyst<br>2.It is used as light weight shielding material for protecting electronic equipment<br>3.CNTs are used effectively inside the body for drug delivery<br>4.It acts as a very good biosensors | K2 | CO5 |

| S.No. | PART-A<br>Q & A | K level | CO |
|---|---|---|---|
| 9 | **Explain the typical electrical properties of nanomaterials.**<br>The electrical conductivity of nanomaterials is complex. Electrical conductivity decrease due to increase in band gap. However electrical conductivity of nanomaterial can be increased by formation of ordered microstructure. It is also observed that conductivity changes when some shear force is given to nanomaterial.<br>E.g. bulk silicon is an insulator but becomes a conductor at nanoscale. | K2 | CO5 |
| 10 | **Explain the effect of size reduction on mechanical properties of nanomaterials.**<br>The mechanical properties of nanomaterials increase with decrease in size, because smaller the size, lesser is the probability of finding imperfections such as dislocations, vacancies, grain boundaries. Mechanical applications of nanocomposites include sport equipment, household items, windmill blades, and construction materials like concrete and asphalt. | K2 | CO5 |
| 11 | **What are the advantages of chemical vapour deposition?**<br>•Lower temperature range.<br>•Relatively high purity.<br>•This method can produce both MWNTs and SWNTs depending on the temperature.<br>•Mass production can be done in industry. | K2 | CO5 |

| S.No. | PART-A<br>Q & A | K level | CO |
|---|---|---|---|
| 12 | **List out some of the applications of Nanotechnology in electronics**<br>i. Quantum wires are found to have high electrical conductivity.<br>ii. The integrated memory circuits have been found to be effective devices.<br>iii. A transistor, called NOMFET, (Nanoparticle organic memory field effect transistor) is created by combining gold nanoparticles with organic molecules. | K2 | CO5 |
| 13 | **Define top down and bottom up approach?**<br>Top down approach refers to successive cutting of a bulk material to get nanoparticles. E.g. Attrition or milling<br>Bottom up approach is the building up of a material from the bottom, that is, atom by atom, molecule by molecule or cluster by cluster. E.g. colloidal dispersion | K2 | CO5 |
| 14 | **Why is nanotechnology an important tool for cancer research?**<br>Nanoporous materials can be used to hold small drug molecules and to transport them to the desired location. Applications include cancer treatment with iron nanoparticles or gold shells. | K2 | CO5 |
| 15 | **Write environmental applications of nanotechnology.**<br>Nanomaterials are used for the treatment of drinking water and industrial waste water contaminated by toxic metal ions, radionuclides, organic and inorganic solutes, bacteria and viruses and the treatment of air.<br>Magnetic nanoparticles are effective in removing heavy metal contamination from waste water. | K2 | CO5 |

| S.No. | PART-A<br>Q & A | K level | CO |
|---|---|---|---|
| 16 | **How does size change affect the optical properties of Nanoparticles?**<br>Nanomaterials, have peculiar optical properties as a result of the way light interacts with their nanostructure. At the nanoscale, matter may change color.<br>For e.g., gold nanospheres turn blue or red depending on their diameter and wall thickness.<br>Opaque substances such as titanium dioxide, zinc oxide, and copper may also become transparent. | K2 | CO5 |
| 17 | **Mention the uses of nanotechnology in food industry.**<br>Nanotechnology finds applications in the production, processing, safety and packaging of foodstuffs.<br>The inclusion of nanoparticles in food contact materials can be used to generate novel type of packing materials and containers which can protect food from drying and spoilage. | K2 | CO5 |
| 18 | **Write notes on the applications of nanoparticles in Biomaterials.**<br>Nanomaterials are used as bone cement and bone plates and as a material for joint replacements.<br>Nanomaterials are also used in the manufacture of some components like heart valves and contact lenses.<br>Nanomaterials are used in dental implants. | K2 | CO5 |

| S.No. | PART-A<br>Q & A | K level | CO |
|---|---|---|---|
| 19 | **Write the difference between SWNT and MWNT.**<br>A one-atom-thick layer of graphite (graphene) is wrapped into a seamless cylinder to form SWNT.<br>MWNT consist of multiple rolled layers or otherwise concentric tubes of graphite. | K2 | CO5 |
| 20 | **What is the difference between the Russian doll model and the Parchment model of CNT?**<br>In the Russian Doll model, sheets of graphite are arranged in concentric cylinders, that is, single-walled nanotube within a larger single-walled nanotube. In the Parchment model, a single sheet of graphite is rolled in around itself, resembling a rolled newspaper. | K2 | CO5 |
| 21 | **Mention the types of nanocomposite materials.**<br>**1. Ceramic-matrix nanocomposites:** The main part of the volume is a ceramic and the second component is a metal.<br>**2. Metal-matrix nanocomposites:** The metals form the matrix in which carbon nanotubes or other nanoparticles are dispersed.<br>**3. Polymer-matrix nanocomposites:** A polymer or copolymer is the matrix with nanoparticles or nanofillers is dispersed in the polymer matrix. | K1 | CO5 |

# Part-B Questions

| S.No. | PART-B QUESTIONS | K level | CO |
|---|---|---|---|
| 1 | **Discuss the size dependent properties of nanomaterials** | K2 | CO5 |
| 2 | **Explain in detail electrical, optical, thermal, and mechanical properties of nanomaterials** | K2 | CO5 |
| 3 | **Write note on top–down and bottom–up approach for nanomaterial preparation with examples.** | K1 | CO5 |
| 4 | **Compare bottom-up & top-down approach in nanomaterial synthesis.** | K2 | CO5 |
| 5 | **Explain Electrodeposition method for the synthesis of nanomaterials.** | K2 | CO5 |
| 6 | **Explain laser ablation method of preparing nanoparticles.** | K2 | CO5 |
| 7 | **Explain Chemical Vapor Deposition of Carbon Nanotubes.** | K2 | CO5 |
| 8 | **Discuss Bottom up approach synthesis of Nanomaterial** | K2 | CO5 |
| 9 | **Explain about the applications of nanomaterials in medical and health care in detail.** | K2 | CO5 |
| 10 | **Illustrate various applications of carbon nanotubes.** | K3 | CO5 |
| 11 | **Examine applications of Nanomaterials and explain them** | K3 | CO5 |

# Supportive online certification courses

https://www.coursera.org/learn/nanotechnology1

Nanotechnology and Nanosensors, Part 1

Coursera 5-week course

https://onlinecourses.nptel.ac.in/noc19_mm21/preview

Nanotechnology, Science and Applications

Swayam 8-week course

# Nano chemistry - Real-time application

| Various Fields | Applications |
|---|---|
| **Automobile Industry** | • Carbon black was the first nanomaterial to be used by the automotive industry in tires as a pigment and reinforcing agent.<br>• The latest nanomaterials made of extrmely thin and strong carbon fibre replace the car's steel body panels and can be used in the car's roof, doors, bonnet and floor.<br>• CNT based polymer composites are finding applications to make various components of an automobile car including but not limited to: headlight mirror coatings, side trims, door inners, body panels, engine cover, inverter cover, timing belt cover and tyres. Carbon nanotubes based composites are finding use in high performance tyres with less weight and better fuel efficiency, better durability and having higher grip to the road than traditional carbon black based tyres. |

| Various Fields | Applications |
|---|---|
| |  |
| **Cosmeceuticals** | • Nanocosmeceuticals used for skin, hair, nail, and lip care, for conditions like wrinkles, photo aging, hyper pigmentation, dandruff, and hair damage, have come into widespread use. Novel nanocarriers like liposomes, niosomes, nanoemulsions, microemulsion, solid lipid nanoparticles, nanostructured lipid carrier, and nanospheres have replaced the usage of conventional delivery system. These novel nanocarriers have advantages of enhanced skin penetration, controlled and sustained drug release, higher stability, site specific targeting, and high entrapment efficiency.<br>https://www.hindawi.com/journals/jphar/2018/3420204/<br>• The most popular nanomatrials used in sunscreens are nanoparticulate Zinc oxide (ZnO) and Titanium dioxide ($TiO_2$).<br>• L'Oreal has used polymer nanocapsules to deliver active ingredients, e.g. retinol or Vitamin A, into the deeper layers of skin. |

| | |
|---|---|
| **In Medicine** | • It promises to revolutionize drug delivery, gene therapy, diagnostics, and many areas of research, development and clinical application.<br>https://visual.ly/community/Infographics/technology/15-usages-nanotechnology-medicine<br>• Silver nanoparticles have longer-lasting antibacterial properties than bigger particles of silver. That's why they can be used in socks, to kill bacteria and prevent bad smells. |

# Content beyond the syllabus

## 1. Nanotechnology in water purification

| S.No. | Type of Nanoparticle | Type of pollutants removed |
|---|---|---|
| 1 | Carbon nanotubes | Organic contaminant |
| 2 | Nano scale metal oxide | Heavy metals Radionucleides |
| 3 | Nano catalyst PCB | Azo dyes, pesticides |
| 4 | Bioactive nanoparticle | Removal of bacteria, fungi |
| 5 | Biomimetic mambranes | Removing salts |

## 2. Nanotechnology in agriculture

| | |
|---|---|
| **Soil improvement** | Zeolites and Nanoclays for agrochemical, water retention and their slow release in soil. |
| **Crop production** | Nanofertilizers for enhancing nutrient absorption by plants. |
| | Nanofungicides, nanoherbicides, nanopesticides, nanocapsules and nanoemulsions. |
| **Precision Farming** | Nanosensors for plant pathogen and pesticide detection. |
| | Nanosensors for monitoring soil conditions |
| **Crop improvement** | Nanomaterial assisted plant genetic modifications. |

# PRESCRIBED TEXT BOOKS & REFERENCE BOOKS


**Textbooks**

- P. C. Jain and Monika Jain, "Engineering Chemistry", 17th edition, Dhanpat Rai Publishing Company Pvt. Ltd., New Delhi, 2018.
- Prasanta Rath, "Engineering Chemistry", Cengage Learning India Pvt. Ltd., Delhi, 2015.

**References**

- S. S. Dara and S. S. Umare, "A Textbook of Engineering Chemistry", S. Chand & Company, New Delhi, 2015.
- J.C. Kuriacose and J. Rajaram, "Chemistry in Engineering and Technology", Volume-1& Volume -2, Tata McGraw-Hill Education Pvt. Ltd., 2001.
- Geoffrey A Ozin, Andre C Arsenault "Nanochemistry: A Chemical Approach to Nanomaterials", 2nd edition, RSC publishers, 2005.
- Prasanna Chandrasekhar, "Conducting polymers, fundamentals and applications A Practical Approach", 1st edition, Springer Science Business Media New York, 1999.

https://www.pdfdrive.com/engineering-chemistry-fundamentals-and-applications-2nd-edition-d191456798.html

Engineering Chemistry Fundamentals and Applications - Shikha Agarwal

# Mini project suggestions

# UNIT-V

1. **Preparation of simple nanoparticles – ZnO, CuO**

2. **Preparation of activated carbon from coconut shell - water purification**

3. **Application of nano particles in cosmetology**

4. **Nanoparticle role in medical diagnosis**

Mini project suggestions

https://nanoyou.eu/en/virtual-lab/hands-on-activities6bf8.html?view=alphacontent

# Thank you