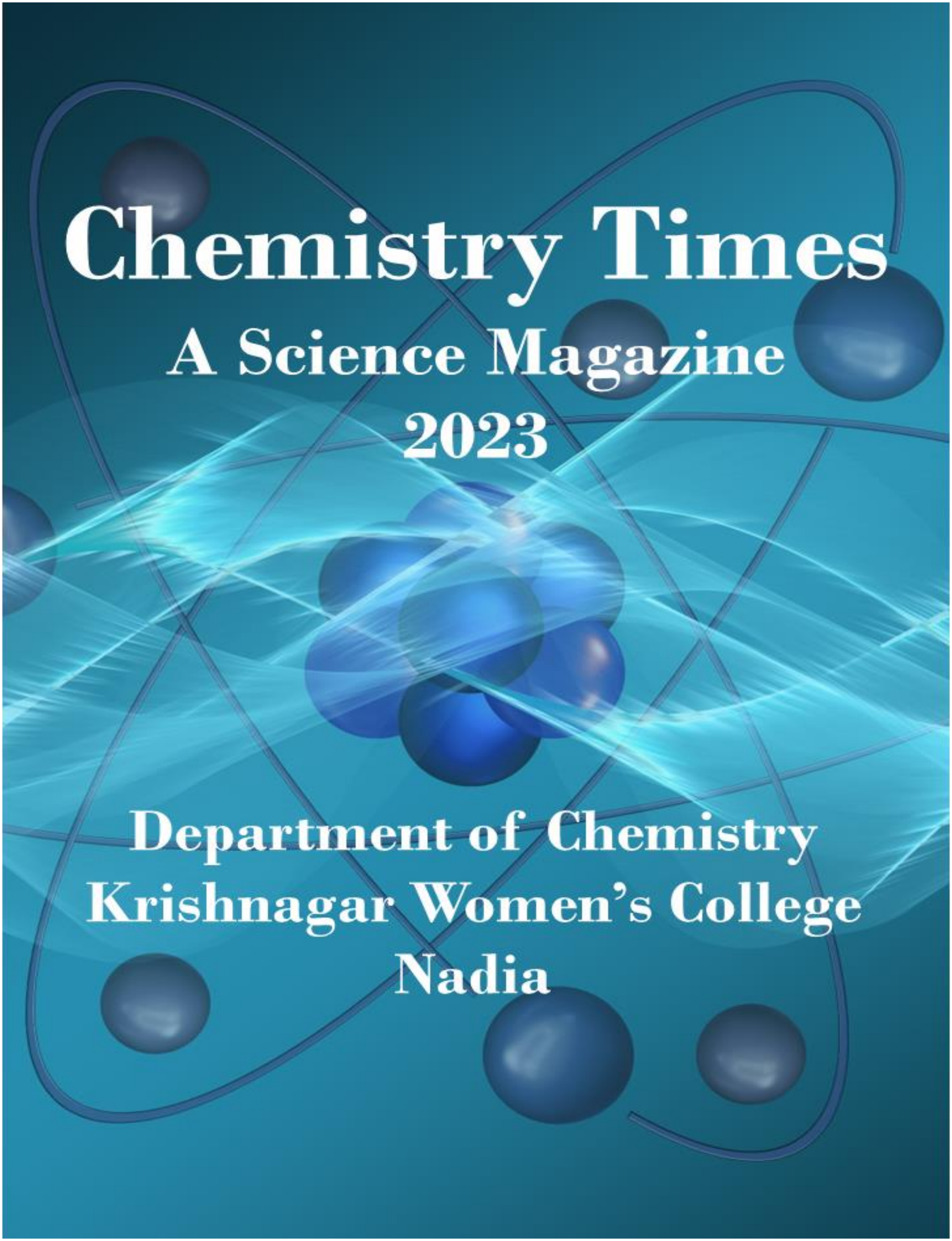


Chemistry Times

A Science Magazine

2023

Department of Chemistry
Krishnagar Women's College
Nadia

Message from the Principal

I am glad to know that the Department of Chemistry, Krishnagar Women's College is going to publish an e-magazine titled "Chemistry Time" in the year 2023. The magazine is a collection of academic articles written by the students of the department under the supervision of the departmental faculty. Our young scholars have studied the uses of the "Polymers" in various practical fields and shared their views on the findings.

The department has always supplemented its classroom teaching by arranging seminars, study tours and workshops regularly. Now this e-magazine will provide a platform to our budding scientists to expresses and exchange their thoughts and views on theoretical and practical aspects of the subject.

I extend my heartiest congratulation to the Faculty and the student of the Department and wish them all success in the new endeavor.

Dr. Natasa Dasgupta
Principal
Krishnagar Women's College

Message from the Head of the Department

It gives me immense pleasure to announce that Department of Chemistry, Krishnagar Women's College will be publishing "Chemistry Times" as its second electronic magazine in 2023-2024. This journal will comprise the research done by 6th semester students of the department on topics related to many specialized fields of chemical sciences. The B.Sc. (Hons.) programme involves students to do project work on a wide range of contemporary scientific topics/challenges. The department has taken initiative to encourage students to engage in project work related to their area of study that requires urgent attention for a solution. I believe that this effort would inspire and drive all students to pursue cutting-edge research in many disciplines of chemistry. If there are any mistakes, please accept my deepest apologies.

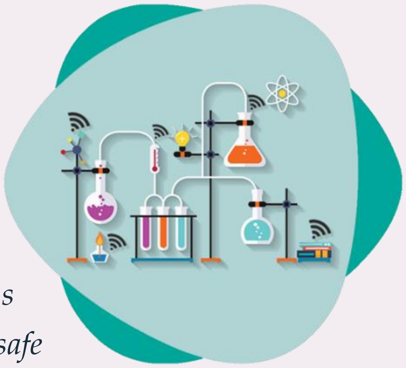
I also ask for everyone's help in improving the E-Magazine with recommendations and counsel. Last but not least, I want to express my profound thanks to Dr. Natasa Dasgupta, the college's principal, for her constant support and encouragement of the magazine's publication. I would also want to express my gratitude to our teachers and students for their tireless work and invaluable contributions to this project. My best wishes are with the department's magazine. My sincere wish is for the department's magazine to be a great success.

Dr. Md Moniruzzaman Sk
Department of Chemistry
Krishnagar Women's College

Contents

Carbon Material for Water Filtration

Aditi Sarkar, Dr. Md Moniruzzaman Sk and Dr. Maya Biswas (Sinha),
Department of Chemistry, Krishnagar Women's College



Water filtration process is necessary for purifying water. The bad quality of water and the worldwide demand of water has forced many people to focus on these matters. 1 in 9 people worldwide have been recorded to be using unsafe sources of water. As per Niti Aayog, overall, 70 percent of freshwater sources in the country were found to be contaminated. There are various types of pollutants that are present in water and the processes to remove them are some of serious challenges. The ability and performance and advancement of some main carbon-based materials (activated carbon, carbon nanotubes, graphene) for water filtration though, have come to the rescue.

Introduction

Water is one of the most important resources which is used by human beings all over the world. 71% of the earth's surface is covered by water accounting for about an estimated value of 1.386 billion cubic km of water. It is thus used in many fields like agriculture, industrial process. As all used water is in order from natural starting points, so a right filtration process is needed. This filtration process is used to remove impurities like natural organic material, wastages, pathogens from water. Due to extensive, human induced pollution of source waters the filtration and purification process is being emphasized upon.
There are various types of contaminants. However, it is a big challenge to remove all types of contaminants in a single process.

Nowadays, point of use (POU) water cleansing apparatus is used by many peoples for home use in a large number. There are some purification substrates which are used in POU devices, among them activated carbon (AC) is the most widely used example. It is a highly porous material which is used to take away high number of organic species from water. Recently advanced carbon-based nanomaterials (carbon nanotubes, graphene) are also under development for high operation water cleansing.

Classification of water contaminant species

There are two types of contaminant species that pollute the water-

Natural occurring water contaminants

Natural organic matter, microorganisms including bacteria, viruses are put in order as natural occurring water contaminants. They have bad effects on human health. Allochthonous pollution occurs due to the breakdown of earthly plants and animal matter. Autochthonous pollution occurs due to the breakdown of aquatic vegetation.

Artificial water contaminants

The advancement in agriculture and industrial fields plays a big role in the contribution of organic and inorganic pollutants to the water sources. Industrial contaminants species include dyes and plasticizers, agricultural contaminants include pesticides and fertilizers that are resulting in the release of phosphorus and nitrogen, and contaminants from pharmaceutical and cosmetic products are the artificial water contaminants.

Classification of carbon materials for water filtration

There are mainly three types of carbon materials which is used in water filtration–

- Activated Carbon (AC)
- Carbon Nanotubes (CNTs)
- Graphene

1. Activated carbon for water filtration

Activated carbon is extremely porous material which is used as an absorbent material in both Water treatment plants and POU water purification. It is derived from the pyrolysis and chemical treatment of sources including wood, coal, bamboo and other organic material. The activation process is performed at high temperature by chemical or steam treatment.

1.1 Properties of activated carbon relevant to water filtration

Based on the average particle size, activated carbon is classified as–

- Granulated activated carbon (GAC): The average size of GAC is in between 0.2 and 5 μm.
- Powdered activated carbon (PAC): The average size of PAC is in between 10 and 50 μm.

The other forms of activated carbon are extruded AC and block AC. Activated carbon has highly porous internal structure with a heterogeneous range of pore diameters in which macro (>50 nm), meso (2-50 nm) and micro (<2 nm) pores are present. For this high porous structure, it has a high surface area up to 2500 m^2/g. It is graphite like. The typical elemental composition of AC is around 80 % carbon, with oxygen and nitrogen.

1.2 Adsorption mechanism of activated carbon

Due to its graphite like structure, it is suitable for adsorbing organic compounds specially those containing aromatic functional groups. It has high adsorption capacity for small organic compounds like DBPs.

Adsorption generally occurs through π–π interactions between the adsorbate and the AC surface, and hydrogen bonding and Van der Waals interactions. The adsorption of species to AC is affected by factors as pH, ionic concentration, temperature, the concentration of other pollutants and the physical size of AC.

1.3 Chemical modification of activated Carbon for improved pollutants adsorption

Chemical modification of AC has been earned through acid or base chemical treatment methods which convey a more positive or negative charge.

For acid modification of AC HNO_3, H_2SO_4, HCl are usually used. This treatment is used to increase the acidic functional groups like alcohols, lactones on the AC surface. When acidic functional groups are exposed to aqueous media with $pH > pKa$, the surface carries a negative charge that enhances the adsorption of positively charged species.

For basic modification of AC NaOH, NH_3, KOH are used. This treatment is used to increase the basic functional groups such as amides, aromatic amines on the AC surfaces. Removal of oxygen species from the surface can be employed to provide higher degrees of basicity of AC. Such surface chemistry will enhance the adsorption of negatively charged compounds.

One of the other chemical modifications in AC is the impregnation of metal or metal oxide nanoparticles within porous structure. It is prepared by the reduction of metals in solutions, or by direct adsorption of pre-prepared nanoparticles. The microwave heating for the preparation and modification of AC is also a method which increases the adsorption capacity of AC to certain species. It is not only a direct chemical modification but also a physical modification.

1.4 Biologically activated carbon for water purification

Biologically activated carbon is used to remove DOM from water. BAC filters are consisted when specific bacteria are induced and entangled with in the AC porous matrix. Under good conditions and with adequate organic matter, bacteria can replenish on the surface of AC. When the BAC is in contact with water containing macromolecular organic compounds, it is absorbed by AC and the bacteria can biodegrade them into CO_2, water and simpler organic compounds. They are easily absorbed to the AC surface and removed from water. Thus, the BAC is used for water purification. In general, ozone and UV treatment is applied to the dissolve pollutants before BAC filtrations.

1.5 Application of activated carbon for water filtrations

It is used in drinking water purification, municipal water treatment. GAC is used to remove specific chemicals, organic matters from water. It also removes chemicals that give exceptionable odors or tastes from water such as H_2S, chlorine.

2. Carbon Nanotubes for water filtrations

Carbon nanotubes are cylindrical large molecules that consist hexagonal arrangement of hybridized carbon atoms. It is used in water purification.

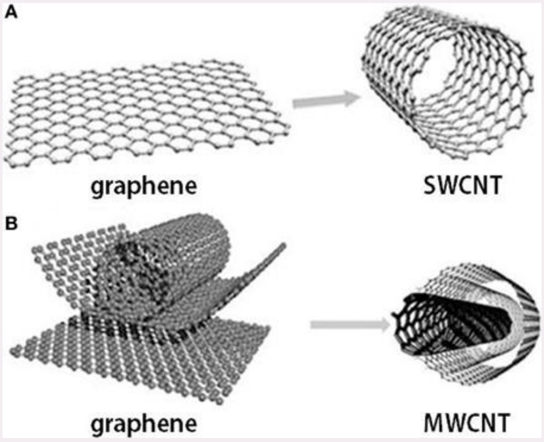


Figure 1: *Structural relation of SWCNs and MWCNs with graphene*

2.1 Adsorption Properties and Target Species of Carbon Nanotubes

CNTs is used as nano-membrane filters for water conduction. Nowadays, this method is used as an alternative of polymeric membrane for desalinating. CNTs and its composite materials are improved adsorbents for the separation of contaminants from water. It has shown good results in water purifications. It has some similarities with AC. Due to their nanoscale and high ratio of micropores, CNTs shows exalted surface area which help absorb the contaminants. There are mainly two types of carbon nanotubes-

- Single-wall carbon nanotubes (SWCNs).
- Multi-wall carbon nanotubes (MWCNs).

They granted more flexibility in water purification. Each of them has been exhibited as a useful adsorbent material. Its adsorption mechanism is same as AC. In CNTs internal diffusion is not necessary for the interaction of compounds with CNTs while in AC it is necessary. Adsorption on the CNTs surface, especially for big compounds, will be the primary site of interaction.

The main feature of CNTs for water purification is their strength which is used to dispel heavy metals from solution Compared to AC. Available surface area and surface functional groups are the main factors that impact the high adsorption capacity of CNTs.

2.2 Chemical modification and composite compounds of CNTs

Chemical modifications of CNTs have been introduced to improve their adsorption capacity and selectively to many contaminant species. As the chemical structure of CNTs is same as AC, the acid modification method is also same for CNTs. In this method HNO_3 or H_2SO_4 treated with CNTs for modifying surface functional groups and fulfills two purposes, that is shortening the tube length and addition of polar functional groups.

CNTs are easily included into composite materials by the introduction of certain functional groups. CNTs are assembled with different types of polymers such as polyacrylamide, polysulfone and polyaniline, to form water penetrable composite that has the capacity of filtering specific matters. It also combined with solid support materials including silica, aluminum and ceramic to filtrate water.

Another water filtrations method is use of the vertically aligned CNT (VA-CNT) array membranes. CNTs are not extensively used in water filtrations even if the cost is minimized nowadays.

2.3 Point-of-Use Water Purification Devices Based on Carbon Nanotubes

CNT increased the adsorption capacity of contaminant metal ions and made complex composite materials. For these properties along with electrical conductivity properties and antimicrobial properties it's composites could be incorporate into ACPOU devices so that it can remove the specifically water contaminant species. CNTs and its composites have a great role in water purification and POU devices.

2.4 Applications of Carbon nanotubes

One of the vital applications of CNTs in water purification is for the neutralizations or exclusion of bacteria and virus from water via nano-filtration. Its anti-fouling capacity helped to prevent the synthesis of bacteria and bio-film formation. CNTs-based composite membranes are used in sea water or brine desalination, oil-water separation, removal of heavy metal ions and membrane separation.

3. Graphene for water filtrations

Graphene is a two-dimensional sheet form of crystalline carbon.

3.1 Properties of grapheme and grapheme oxides

Graphene is a two-dimensional material and it exist as sheet of a single later of carbon atoms. It has fascinating conductivity and thermal resistance properties like CNTs. It has the high obtainable surface area in which the contaminant species can be absorbed. External chemical modification and composite fabrication properties of graphene makes it more suitable for water purification than AC and CNTs. Nano-perforated grapheme sheets are used as size exclusion filtration membranes in water purification.

Graphene is transformed into grapheme oxides by adding oxygen. By this, space is created in the structures for the water to flow through. These grapheme oxides are mainly used in water purification. It contains high number of hydrophilic oxygen functional groups such as epoxides, carboxylic acid, alcohols, etc. Laminar structures of grapheme act as an adsorbent material and anti bacterial agents. For these properties grapheme is suitable for water purification.

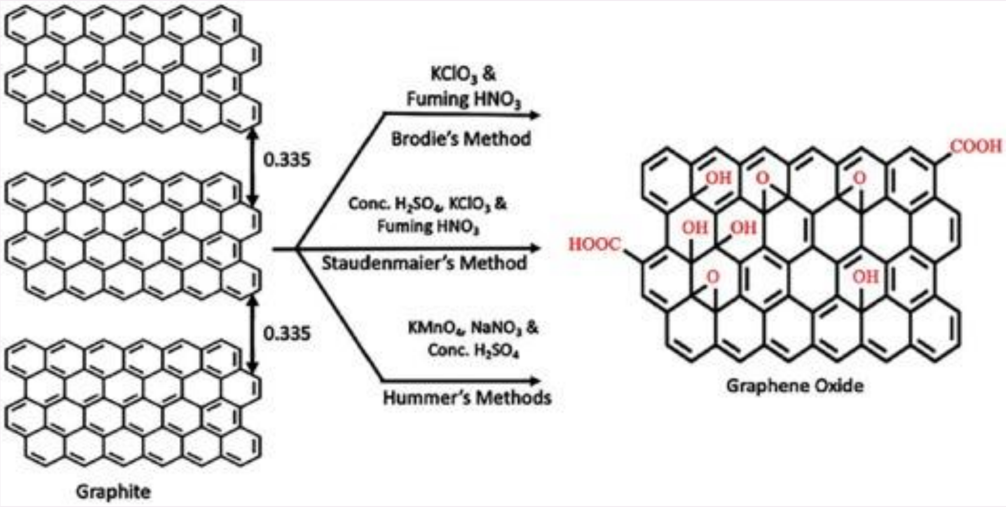


Figure 2: *Structural relation of graphite with graphene oxide*

3.2 Water purification mechanism using graphene

There are mainly two types of purification mechanism of grapheme and grapheme oxide composite materials.

Adsorbent graphene are materials that rely on the similar mechanism for absorbing contaminant species as AC and CNTs. The materials have fantastic absorbing capacity because of the hydrogen bonding and theπ–π interactions between contaminant species and the grapheme materials and the high specific surface area of this 2D material.

The nano filtration grapheme oxide membranes that rely on the elimination of the contaminants to give purified water include the laminar structures and nano-perforated membranes. Graphene materials and composites work through various mechanisms such as penetration and compromisation of the bacteria membrane, generation of reactive oxygen species (ROS) and envelopment of microorganisms to neutralize and to inactivate microorganisms.

3.3 Applications of graphene

Graphene and its oxides are used in the removal of heavy metals like uranium, arsenic and dyes and virus and bacteria from the water. Due to grapheme oxide's strong hydrophilicity, it is also used in desalination. They remove water from a gas mixture to an extraordinary level.

Conclusion and Perspective

On the basis of the research on water health, there is now worldwide confession that the health of water ways is in decay. So, nowadays it is more important to maintain the utility of water treatment facilities with large effort. Currently, Carbon based materials are highly used in water filtrations research field. However, people will still be in touch with water pollutants that are not dispelled from water on the treatment process. For this reason, we should increase the number of POU water purification devices. There are some types of composite material mentioned in this total review that we can use in small range filtration in home POU devices.

For the high cost of activated carbon production, it becomes the most eminent carbon-based material which is used in water filtration. As the cost of CNTs and graphene is decreased, these nanomaterials will be manifested as additional components in water filtration devices to catch certain contaminants. The reproduction ability of CNTs and graphene over AC will affected the next generations of water filtrations devices. The concourse of carbon materials (ACs) with other, developing nanomaterials will be highly related in developing the next generation of water filtration and purification materials and devices.

Nuclear Chemistry – Application and Effects on Biosphere

Amrita Das and Dr. Amit Kumar Guria, Department of Chemistry, Krishnagar Women's College

Worldwide, over eight countries generate more than half of their power from nuclear sources. In order to generate power from nuclear sources, you must have an extensive knowledge of nuclear chemistry. Therefore, the aim of this paper is to provide an overview on nuclear chemistry. Nuclear chemistry is a branch of chemistry that deals with radioactivity and all radioactive processes. Radioactivity is the major aspect of nuclear chemistry. However, different articles on nuclear chemistry have failed to give an extensive overview on how nuclear chemistry is dependent on radioactivity. To address this issue this paper would cover the reasons, main areas, and different applications and hazards of nuclear chemistry.

Introduction

The branch of chemistry concerned with the properties and changes in nucleus of atom, that is the subatomic particles, is called nuclear chemistry. This also deals with radioactivity and can lead to the generation of a large amount of energy if properly used, and also in the medical fields. This branch of study has an aptitude for chemistry, biochemistry and statistics. They also need keen interest in understanding radioactive substances and nuclear processes.

In the new outlook for global nuclear capacity for electricity generation by 2050, the IAEA has increased its high case scenario by 10% compared with last year's report. In 2021, the Agency revised its up annual projections for the first time since Japan's Fukushima Daiichi nuclear accident in 2011.In its high case scenario, the Agency now sees world nuclear generating capacity more than doubling to 873 gigawatts net electrical energy [GW(e)] by 2050, compared to current levels of around 390 GW(e) only. That is an additional 81 GW(e) on top of last year's projection. In the low case scenario, generating capacity remains essentially flat. "We are at a defining moment in the world's transition to a more secure, stable and affordable energy future", IEAE Director General Rafael Mariano Grossi said.

Why study nuclear chemistry

The reasons are a lot. A few maybe listed below –

- To study the natural phenomenon of 'radioactivity', nuclear chemistry is a must.

- This deals with processes like fission and fusion which are important to know in order to study fields as cosmology, other than chemistry.
- Learning this is the only way to learn and implement proper disposal and storage of fatal nuclear wastes.
- They help us detect and measure exposure to radiation due to natural or man-made causes and help minimize the risk of contamination of the environment.
- This can be used in diagnosing and treating diseases. Nuclear medicine is used for scanning the heart, lungs, kidneys, glands, brain disorders, etc.
- Nuclear chemistry is essential to avoid and deal with accidents as the Chernobyl disaster.
- Enhancing knowledge and application in this field would lead to better understanding of the process of as well as the generation of power source itself.

According to Our World in Data, nuclear energy is the second safest energy source after solar energy.

- This is the key to understanding how nuclear weapons work. Without advancement in the field of nuclear chemistry, creation, maintenance, and advancement in the nuclear weapon would be impossible.

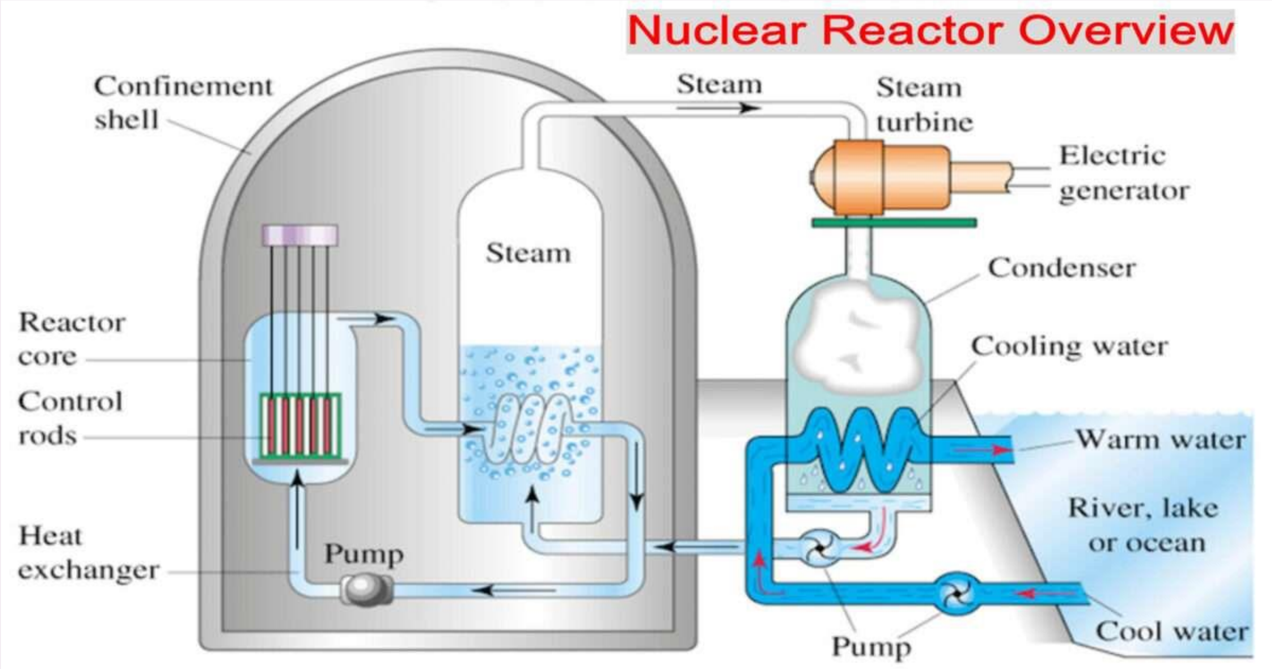


Figure 1: *Nuclear reactor overview*

Materials used in Nuclear Reactors

Industrial use of nuclear chemistry requires substances called NUCLEAR FUEL. These are the substances that will sustain the process of fission chain reaction so that it can be used as a source of energy. Basically, these are heavy elements as Uranium ($_{92}U^{235}$), Plutonium ($_{94}Pu^{244}$), etc.

Besides it also has other parts as –

Coolant – In order to transfer the heat from the fuel to the turbine. Water, heavy water, liquid sodium, etc. are being used.

Moderator – It is the material in the core which slows down the neutrons released from fission so that they cause more fission. It is usually water, but may also be heavy water and graphite.

Control rods or blades – These are neutron absorbing materials such as cadmium, hafnium or boron and are inserted or withdrawn from the core to control the rate of reaction or to halt it.

Pressure vessel or tubes – Usually a robust steel vessel containing the reactor core and moderator/coolant, but it may be a series of tubes holding the fuel and conveying the coolant through the surrounding moderator.

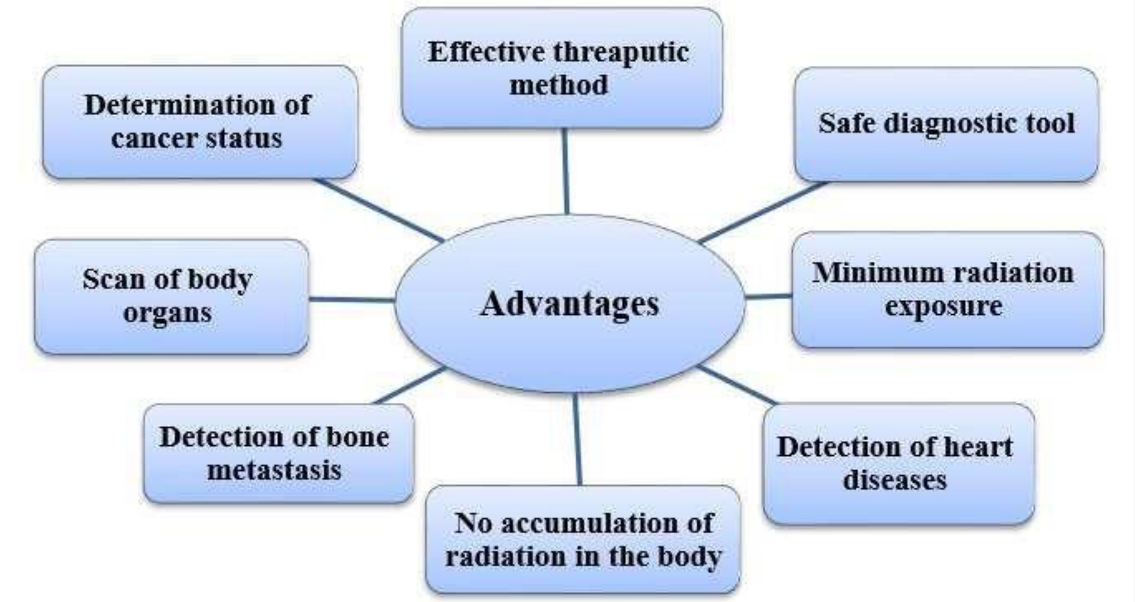
Steam generator – Part of the cooling system of pressurized water reactors where the high-pressure primary coolant bringing heat from the reactor is used to make steam for turbine, in a secondary circuit.

Other than these there are also some other components used as turbine (to convert the heat energy bore by the coolants into other forms of energy as wind energy), fuel assembly (that is the structured collection of fuel rods in a nuclear reactor), core (the core reactor comprises all the nuclear fuel that produces all heat), etc.

Applications of Nuclear Chemistry

- This helps in deeper studying and revealing of atomic structure and sub atomic particles as positron, meson, etc.
- This can lead to the development of a whole new source of energy that might be economical and vast to support the growing population as well as be comparatively much more environments friendly and that comes with lesser hazard.
- Radiation therapy or radiotherapy is a therapy using ionization radiation, generally provided as a part of cancer treatment in which a strong beam of energy is focused on to control or kill malignant cells.
- Radioactive dating of rocks, minerals, fossils, etc. using radioactive isotopes. Here the age of geological materials is calculated in years by measuring the presence of a short life radioactive element as Carbon-14 or a long life one plus its decay products as Potassium-14.

- Radioactive tracers are used in imaging tests that help find problems inside the body as well as it is used industrially for trouble shooting and measuring hydrodynamic parameters and process visualization in industrial systems. These find application as these can be used to access and picturize spots that are hard to access. This uses the radioactive species whose radiations are obtained on a photographic plate and the abnormality is observed.



Scheme 1: *The advantages of nuclear medicine*

- An atomic or nuclear battery is a device which uses energy from the decay of radioactive isotope to generate electricity. They are extremely costly and have a long life and high energy density hence is used in space crafts, pacemakers, etc.
- Application in forensic science called nuclear forensics. This is the examination of nuclear and other radioactive materials using analytical techniques to determine the origin and history of this material in the context of law enforcement investigations or the assessment of nuclear security vulnerabilities.
- Sterilization with ionizing radiation inactivates microorganisms very efficiently and when used for product wrapping, ensures the health care products are safe and can be relied upon. Thus, radiation is also used for killing germs that can cause disease and neutralize other harmful organisms.
- Mutations induced by radiation. If the plants and seeds are irradiated by radioactive source, the rate of mutation is greatly increased and development of stains is achieved in a fraction of time taken otherwise.
- Radio-pharmaceuticals, drugs containing a radionuclide are used in the nuclear medicine department for the diagnosis and treatment of certain diseases. This thus

involves a fusion of the nuclear chemistry with the coordination chemistry for the human welfare.

- The catalyst activation by preliminary or simultaneous irradiation, and the energy transfer between the different phases of the heterogeneous irradiated systems are now experimentally tangible. It appears that the radiation catalysis will contribute in an important manner to a better insight of the catalytic process.
- Radio-luminescence is the phenomenon by which light is produced in a material by bombardment with ionizing radiation such as alpha or beta particles and gamma radiation. These are used to make the pointer or dials of watches visible during night time.
- The discovery of transuranic elements has been achieved by artificial radioactivity. Moreover, radioactive isotopes of other stable elements have been discovered by the artificial transmutation of elements.
- Application in agriculture. Recently tremendous amount of work has been done to study rates and mechanisms of absorption of essential elements by the plants from various compounds. These have resulted in the improvement of crops and efficient use of fertilizers. Potassium-32 has extensively been used in such studies. Tritium has been used as a tracer to measure the rate of movement and distribution of water absorbed by the roots of the plants. Carbon-14 labelled carbon dioxide has been used in the investigation of respiration by plants.
- Applications in industry. Using tracer technique, the movement of mud and sand in river and harbors has been investigated. Iodine-131 has been used to trace the direction and velocity of underground water. Sodium-24 can be used to locate leaks in underground water pipes. Cracks are inspected by putting them in radioactive salt-baths and the finding out with Geiger Muller counter whether any penetration has taken place in the metal, etc.

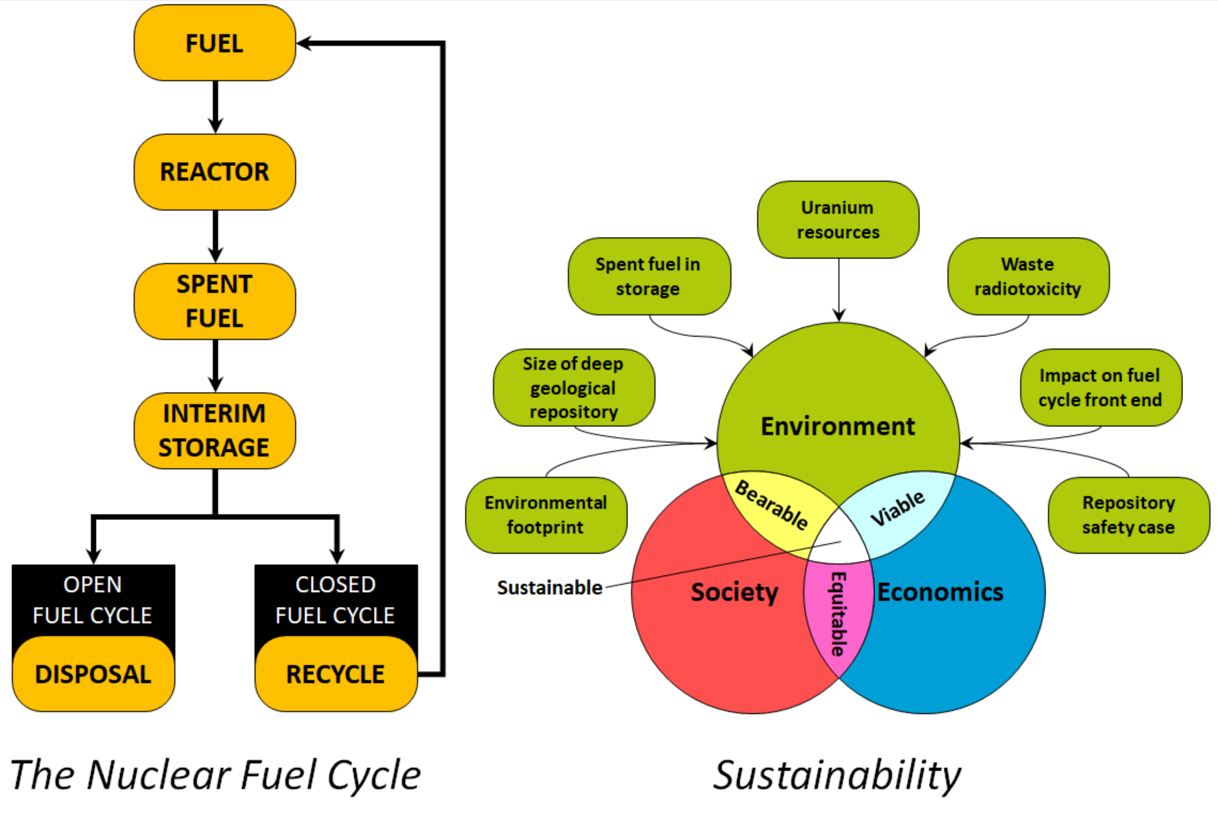
Negative Impacts of Nuclear Science

Accidents in Nuclear Power Plants – International Atomic Energy Agency (IAEA) has defined this as "an event that has led to significant consequences to people, the environment or the facility. Examples include lethal effects to individuals, large radioactivity release to the environment, reactor core melt".

Some notable disasters have been the Chernobyl disaster in 1986 and the Fukushima nuclear disaster in 2011 that had a large number of casualties that have still been growing in number due to the constant exposure to radiation till date.

Unethical use of power – Although nuclear power is useful on many fronts, its misuse is very harrowing for mankind. Since the discovery of nuclear power, the unethical and destructive utilization of this form of energy has been evident and feared by all. A worthy mention would be that of atomic bomb dropping on the cities of Hiroshima and Nagasaki, that has claimed thousands of lives over years whose effects are still predominant after so many generations and feared by all. This technology thus can easily be misused by nuclear equipped countries to manufacture lethal weapons that can cause a great loss to humanity and nature.

Disposal and management of nuclear wastes – Nuclear waste is toxic, poisonous and radioactive in nature. Despite being the cleanest of all the methods of generating energy, this has its cons. The major demerit is the nature of the waste generated by a nuclear plant. This might cause fatal conditions as the induction of cancer and other high-risk diseases. It consists of materials like Plutonium that is highly poisonous and only lose it over time that is it stays in the biosphere. Also, the disposal of waste involves a lot of costly procedures and is yet an issue of great concern.



Scheme 2: *The nuclear fuel cycle and sustainability*

Thermal pollution– The generation of energy via nuclear power plants is highly dependent on heat and thermal energy that has its own demerits. For instance, the dumping of thermal waste is generally done into the water bodies which causes adverse effects for the aquatic plants and animals. Thus, it increases water pollution.

Installation and Safety cost and Laws – The nuclear reactors are required to build with utmost perfection and advanced technology. The raw materials and construction costs are high. Maintenance needs labor and price too. Also, the security of nuclear energy is of prime concern as it may lead to severe side effects or accidents otherwise. All these involve a huge amount of fund. Besides, it also needs and involved the criteria of receiving license from the government which can only be obtained if it fulfils all the necessary conditions (like the minimum distance it should maintain from a locality) exactly and appropriately that makes its installation tougher.

Fuel availability and handling – Extraction of uranium from its ore is a very time exhausting process and needs to be handled skillfully in order to minimize exposure to radiation. Moreover, the availability of uranium is limited or scarce. Due to the limited availability, it is often referred to as a non-renewable resource.

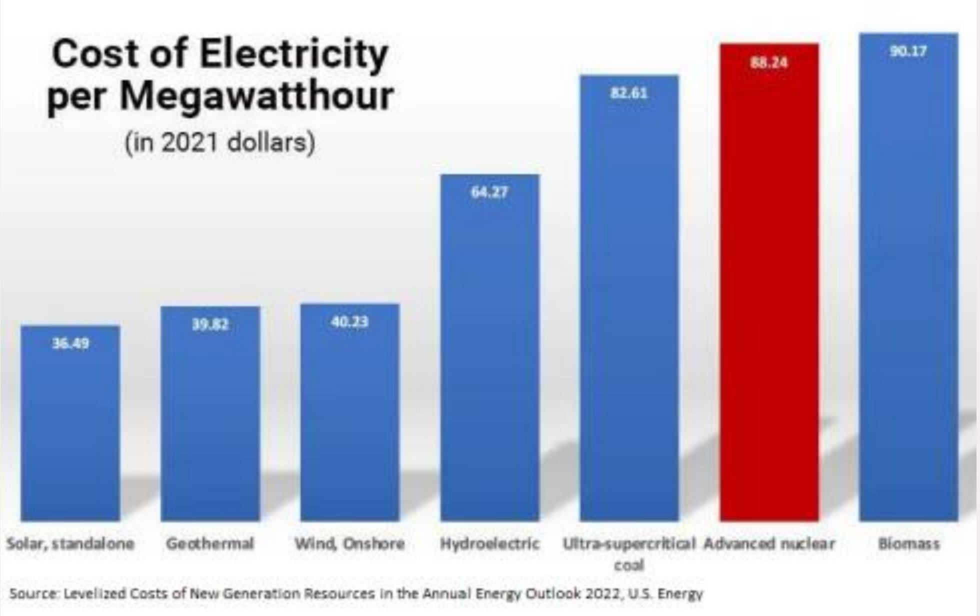
Impact on human life – Even the minimum exposure to the harmful radiations may cause serious health effects that might include painful death or giving birth to children with physical and neurological defects. Though the government puts strict conditions and takes measures to minimize its effects on mankind, workers that constantly work inside the radiation have been found to be exposed to a radiation that is much beyond the acceptable and healthy level.

Why use Nuclear Science and Reactors (Why is it gaining attention)

Clean – Traditional energy generation techniques make use of fossil fuels such as coal, wood, petroleum, etc. these fossil fuels release toxic gases in the air upon combustion and are also responsible for leaving waste residue after burning. This causes a number of breathing problems and other health hazards. On the other hand, the waste produced by nuclear energy plants is dumped deep inside the earth’s surface. If toxic waste dumping is compared with toxic waste being openly released in the air, the former seems much more logical, while the latter is a silent killer.

Less Carbon Content - Nuclear energy is most popular for its nature of releasing a negligible amount of carbon into the air. The process of nuclear fission, which is responsible for nuclear energy generation, releases thermal energy or steam as a by-product. Therefore, no carbon-rich toxic gas is liberated during or after the completion of the energy generation process. The steam generated is nothing but water converted from liquid to the gaseous form. Hence, it is not harmful at all.

Job Opportunities & Growth of a Nation - Nuclear energy, being one of the latest technologies, creates more job opportunities for the youth. The technology is already under research and promises a great future to humanity. Technology advancement is also necessary for the development of a country; therefore, nuclear power enables the rank improvement of a nation in terms of growth.



Source: Levelized Costs of New Generation Resources in the Annual Energy Outlook 2022, U.S. Energy

National Security - Nuclear power primarily earned recognition while being developed and used as a destructive weapon. It was decades after which ethical usage of nuclear energy came into consideration. This portrayed nuclear power as a matter of national security. In terms of safety, nuclear power plays an important role because a nuclear energy-equipped nation is less likely to be challenged for war because the consequences of using nuclear power are very well known to all humanity.

Resists Climate Change - Nuclear fuel is not combustible and does not release any carbon-rich gases into the environment. Therefore, nuclear energy keeps the environment safe by avoiding any sort of pollutant generation. Take an example of a thorium reactor. Thorium is abundantly available, it is tough enough to make weapons, and it generates two orders of magnitude less of nuclear waste. One ton of thorium generates power equal to the power generated by 200 tons of uranium, which is equivalent to 3.5 million tons of coal burnt in order to generate the same power. This is one of the prime advantages of using nuclear energy because climate change is a serious issue and needs to be taken care of immediately.

Long Life - Uranium is a stable chemical element and stays steady for a long period of time. Therefore, the raw material having a long life adds a plus point to technology. The technology or the energy station, therefore, lasts longer than the conventional and traditional energy generating plants. Once properly set up and maintained, a nuclear energy generating station guarantees energy generation for ages.

Low Fuel Cost - The fuel used for power generation by nuclear power plants is the radioactive element uranium that is found mostly in rocks. Compared to the other fuels the mining and extraction process of uranium is somewhat more feasible, thereby reducing both the efforts and the cost involved. Also, the nuclear fission process runs as a chain reaction. Hence, a large amount of energy can be generated by introducing even a small amount of the element.

Summary and Outlook

Since nuclear science has so many pros over its cons and nuclear plants can produce so much energy, far fewer are needed in order to meet demands than coal or gas plants. Thus, the more nuclear power plants in the country, the lesser the need for coal or gas plants. Thus, lesser will be the overall pollution and more efficiently will it serve the alarmingly rising population. Nuclear energy produces only about 10 grams of CO2 per kilowatt hour compared to that of 500 grams and 1000 grams for fossil gas and coal respectively. It is hence one of the minimal polluting sources of energy that also produces much more energy than the other such sources as the wind or solar energy. Also, according the economic statistics, the rate of business in uranium has increased folds in the 21st century as compared to that in the 20th century.

Thus, the nuclear science would soon be the leading branch of science and source of energy in the world and would also substitute several sources of energy with advancements in its fields, for the greater good, and the nuclear scientists and chemists would obviously be looking forward to it.

Synthesis of Different Types of Polymers

Dipanwita Biswas and Smt. Nabanita De, Department of Chemistry, Krishnagar Women's College

Materials are all around us and they have most effects on many things, benefits, contribution with very large amount of each matter in this world and also have different properties. If looked anywhere, the materials can be felt in there. The biological macromolecular aggregation, the DNA, the cellulose in flora and most of the wastes dumped on the ground like plastics, are all nothing but polymers, Polymers these days even hold a large market size for individual nations, globally. Since, most of the materials that can be seen are constituted of the polymers and it's important to understand how they made or joined together.

Introduction

Polymer synthesis is tailored according to the need to develop chemically diverse hydrogels for specific applications. Depending on the application, the synthesized polymers may require biocompatibility, mechanical strength, or analyte specificity in addition to sensitivity to stimuli. Polymer synthesis involves several aspects of synthetic chemistry. In order to develop polymers of desired characteristics, control of process and parameters are very especially when the product is meant for health care and food industries. Material science division undertakes projects for the synthesis of novel materials for various applications or develops alternative materials for different applications.

What is synthesis of polymer

The word (polymer) is derived from the Greek word poly and mer. Poly means many and mer means parts respectively. And synthesis is the production of chemical compounds by reaction from simpler materials. Polymer synthesis also called polymerization is the process by which monomers (small molecules) are covalently bonded to from a usually long polymer chain.

Classification of polymer

Origin based polymer

It depends upon polymers sources.

- Natural polymer: Natural rubber is one type of natural polymer. Natural rubber consists mainly of cis-1,4 polyisoprene, of which the constituent monomer isopentenyl pyrophosphate (IPP) is synthesized from the mevalonate (MVA) pathways and possibly also from the 2-C-methyl-d-erythritol-4-phosphate (MEP) pathway in plants.
- Synthetic polymer: Nylon 6,6 is a synthetic polymer. It is prepared by condensation polymerization of hexamethylenediamine with adipic acid at high temperature and pressure.
- Semi synthetic polymers: Semi synthetic polymers are derived from natural sources, but they undergo chemical treatment to enhance their usability. Vulcanized rubber is a semi synthetic polymer. It is obtained by poly isoprene and sulfur which is attach crossed link or chain reaction.

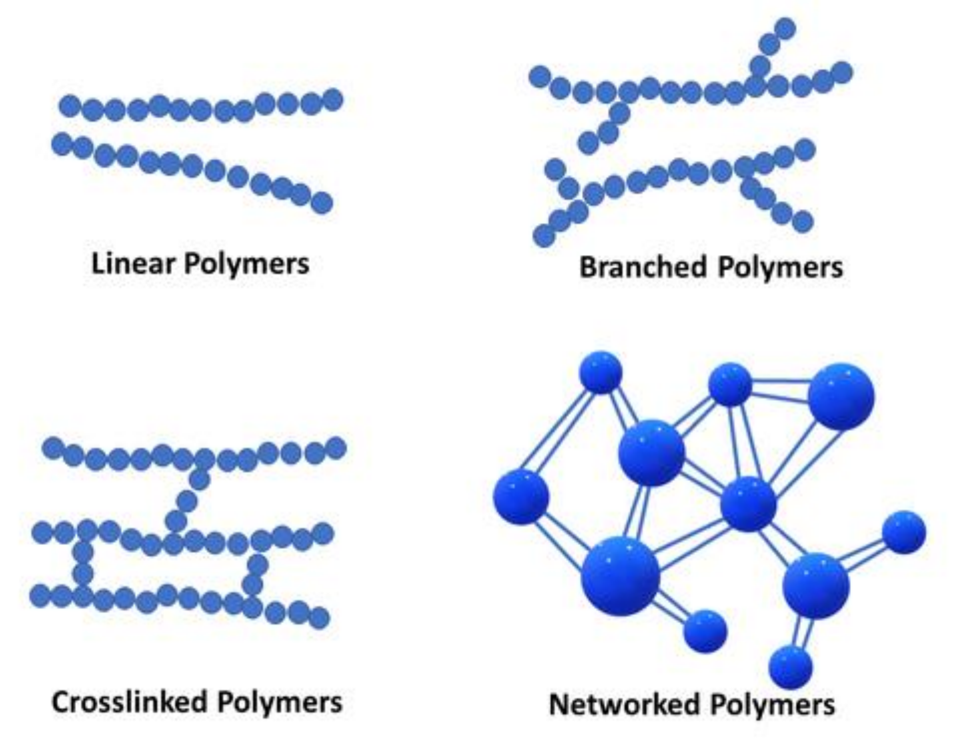


Figure 1: *Different structures of polymers*

Based on structure

It depends upon carbon-carbon bonds cleavage or linkage of monomers.

- Linear chain polymers: Polyamides are example of linear. Polyamides are conventionally synthesized by condensation between amides and carboxylic acids or their derivatives.

- Branched chain polymer: Low density polyethylene is one type of branched chain Polymerization. Polyethylene is made from the Polymerization of ethylene (or ethene) monomer. The chains are produced by addition or radical Polymerization.
- Cross linked or 3D network polymers: Bakelite is one type of cross-linked polymer. Bakelite is formed from the reaction of phenol and formaldehyde. Basically, it is formed in two steps. In the first step formaldehyde reacts with phenol and produces o- hydroxymethyl phenol. Then o-hydroxymethyl phenol and phenol came together and form Bakelite.

Based on molecular forces

It depends on intermolecular interaction, molecular mass and size.

- Elastomers: The polymer having weak intermolecular forces and viscoelasticity is known as elastomers. Neoprene is example of elastomers. It is prepared by free radical Polymerization of chloroprene.
- Fibers: These have strongest intermolecular forces in the form H-bonds or dipole-dipole interactions due to presence of strong forces. These polymers are thin and thread like structure. Nylon-6,6 is an example of fibers. This polymerization reaction proceeds by a condensation mechanism.

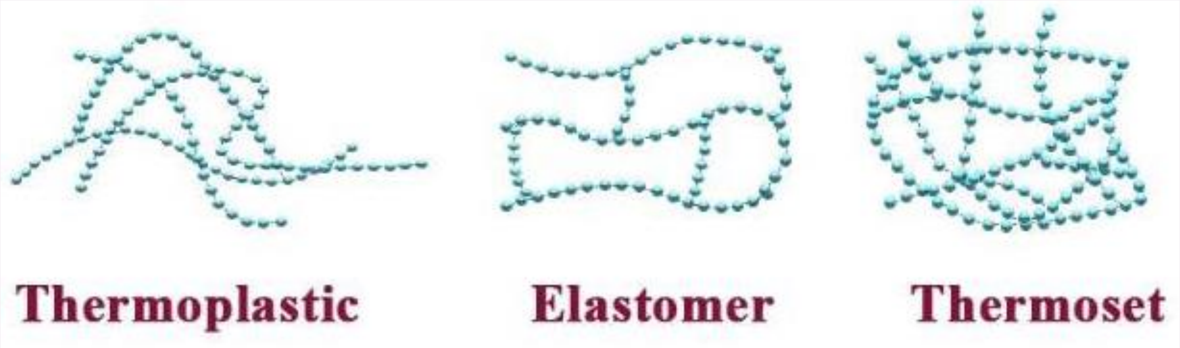


Figure 2: *The structure of thermoplastic, elastomer and thermosetting polymers*

- Thermoplastics: Thermoplastics are formed by addition polymerization and they are soft and less brittle. They are soluble in organic solvents. Teflon is a one type of thermoplastics polymer. It is synthesized by polymerizing tetrafluoroethylene. It follows free radical mechanism.
- Plasticizers: Plasticizers are most widely used additives in plastics. Nitrile butadiene rubber is an example of plasticizers. It follows copolymerization reaction. It is a copolymer of acrylonitrile and butadiene.
- Thermosetting polymer: Polyester is one type of thermosetting polymer. Polyesters are prepared by the condensation Polymerization of a dicarboxylic acid with a dihydric alcohol with the elimination of water.

Based on the stereo chemistry of monomer

It depends on stereo or 3D animation, steric factor etc.

- Isotactic: Greek meaning "same order”. In this polymer the solid chains/groups are oriented on the same side of the main polymer chain having regular and definite order. Polypropylene is one type of isotactic polymer. It is produced via chain growth polymerization from the monomer propylene.
- Syndiotactic: A syndiotactic polymer is one in which the pedant groups have a regular, alternating pattern along the hydrocarbon backbone chain. Polyisoprene is an example of syndiotactic polymer. It follows addition Polymerization. It is obtained by polymerizing isoprene.
- Atactic: An atactic polymer is defined as a linear polymer containing symmetrically substituted carbon atoms in the repeating unit in the main chain. Polystyrene is one type of atactic polymer. The synthesis of polystyrene is carried out using a reaction known as free radical polymerization is obtained by polymerizing styrene.

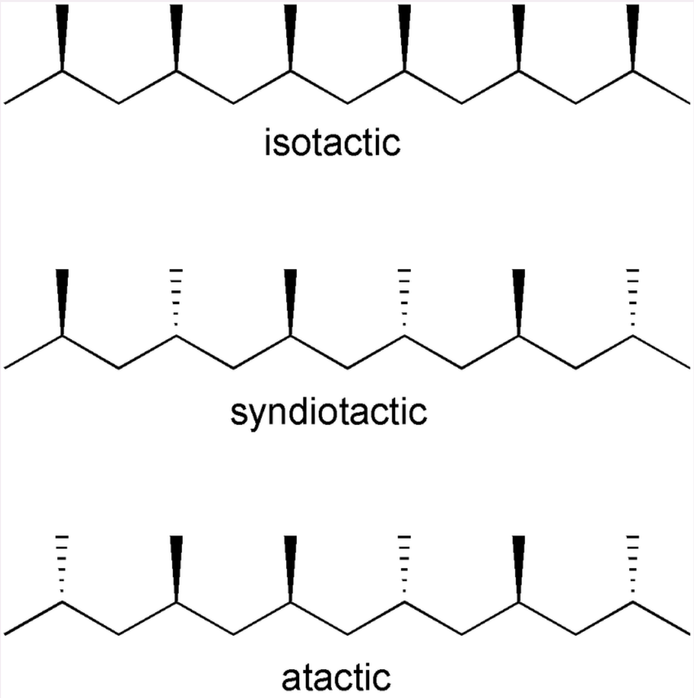


Figure 3: *The structure of isotactic, syndiotactic and atactic polypropene*

Synthesis based polymer

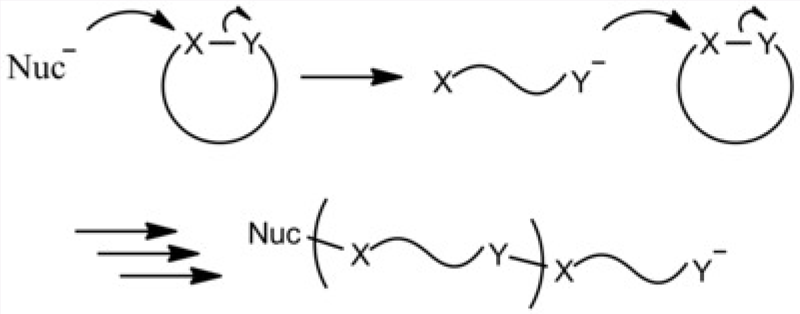
It depends upon carbon –carbon bonds cleavage or linkage of monomers.

- Addition polymer: The process by which monomer unit joined together by simple linkage to form giant molecule without elimination of small molecules such as water, alcohol, ammonia is called addition polymerization. Such polymer is called addition polymer. e.g., polyethylene, polyvinyl chloride, polystyrene etc.

- Condensation polymer: The polymers which are formed by the combination of monomers with the elimination of small molecules such as water, alcohol, hydrogen chloride etc., are known as condensation polymers. E.g., nylon 6,6 is formed by the condensation of hexamethylene diamine with adipic acid.
- Ring-opening polymer: A polymerization in which a cyclic monomer yields a monomeric unit which is acyclic or contains fewer cycles than the monomer. If the monomer is polycyclic, the opening of a single ring is sufficient to classify the reaction as ring opening Polymerization.

Ring -opening polymerization (ROP) is a form of chain growth polymerization, in which the terminal end of a polymer chain acts as a reactive center where further cyclic monomers can react by opening its ring system and form a longer polymer chain.

The propagating center can be radical, anionic or cationic. ROP continues to be the most versatile method of synthesis of major groups of biopolymers, particularly when they are required in quantity. Cyclic monomers that are polymerized using ROP include a variety of structures, such as alkenes, alkanes etc.



Scheme 1: *Ring opening polymerization proceed via anion*

Ring opening Polymerization can proceed via -

- Radical polymerization: free-radical polymerization (FRP) is a method of polymerization by which a polymer forms by the successive addition of free radical building blocks (repeat units). Free radicals can be formed by a number of different mechanisms, usually involving separate initiator molecules. Following its generation, the initiating free radical adds (non radical) monomer units, there by growing the polymer chain.
- Anionic Polymerization: Anionic polymerization is a form of chain-growth polymerization that encompasses the polymerization of vinyl monomers with strong electronegative groups. This type of polymerization is often employed to produce synthetic polydiene rubbers solution, styrene-butadiene rubbers (SBR), and thermoplastic styrene elastomers.

- Cationic polymerization: cationic polymerization is a type of chain growth polymerization in which a cationic initiator transfers charge to a monomer which then becomes reactive. This reactive monomer goes on to react similarly with other monomers to form a polymer.

Summary and Outlook

Polymers are defined as high molecular mass macromolecules, which consist of repeating structural units derived from the corresponding monomers. These polymers may be of natural or synthetic origin and are classified in a number of ways. In the presence of an organic peroxide initiator, the alkenes and their derivatives undergo addition polymerization or chain growth polymerization through a free radical mechanism. Condensation Polymerization reactions are shown by the interaction of bi or poly functional monomers containing ammine, hydroxyl, carboxylic groups. This type of polymerization proceeds through the elimination of certain with phenol and melamine to form the corresponding condensation polymer products. The condensation Polymerization progress through step by step and is also called as step growth polymerization. Nylon, Bakelite and Dacron are some of the important examples of condensation polymers. However, a mixture two unsaturated monomers exhibit copolymerization and forms a co- polymer containing multiple units of each monomer. Natural rubber is a cis 1,4 polyisoprene and can be made more tough by the process of vulcanization with Sulphur. Synthetic rubbers are usually obtained by copolymerization of alkene and 1,3 butadiene derivatives. In view of environmental hazards of synthetic polymeric wastes, certain biodegradable polymers such as PHBV and nylon 2-nylon - 6 are developed as alternatives.

Metal Complexes and Chelating Ligands in Medicine

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Metal complexes and chelating ligands have been extensively studied in medicine for their potential therapeutic applications. These compounds can target specific biological pathways, alter enzymatic activity, and act as diagnostic agents. Many of the compounds we see around us are all complexes, be it the hemoglobin of our blood or the chlorophyll in plant leaves. They, thus evidently play a very significant role in the existence and proceedings of life on earth. Moreover, drugs are of a whole different level and obviously demand special attention – the way they need to be administered and their mechanism of working inside our bodies, thus, need to be studied and explored separately.

Introduction

The use of metal complexes and chelating ligands in medicine can be traced back to the early 20th century. In 1913, Alfred Werner proposed his theory of coordination compounds, which revolutionized the understanding of metal-ligand interactions. Werner's theory was based on the concept of the coordination number, which referred to the number of ligands that could bind to a metal ion. In the 1950s, the discovery of the antibiotic properties of some metal complexes, such as penicillin, spurred interest in the development of metal-based drugs. One of the earliest metal-based drugs was cisplatin, which was discovered in the late 1960s. Cisplatin is a platinum-containing complex that is used to treat various types of cancer, including ovarian, testicular, and bladder cancer.

Chelating ligands, which are organic molecules that can form stable ring containing complexes with metal ions, have also played an important role in the development of metal-based drugs. One example of a chelating ligand is ethylene diamine tetraacetic acid (EDTA), which has been used as a chelating agent to treat heavy metal poisoning. In addition to their use in medicine, metal complexes and chelating ligands have also found applications in other areas, such as imaging and diagnosis. For example, gadolinium-based contrast agents are used in magnetic resonance imaging (MRI) to enhance contrast between different tissues. Overall, the development of metal complexes and chelating ligands in medicine has been a significant area of research in the past century, leading to the development of many important drugs and diagnostic tools.

Scope of Work

Looking ahead, the field of metal complexes and chelating ligands in medicine holds promising prospects. There are several areas of research that could be explored to further advance their therapeutic potential:

Development of novel metal complexes and chelating ligands

Researchers can continue to design and synthesize new metal complexes and chelating ligands with improved properties, such as higher stability, increased selectivity, and reduced side effects. This could be achieved through advanced ligand design strategies and the utilization of computational tools for rational drug design.

Mechanistic studies and understanding of biological pathways

Further studies on the mechanisms of action of metal complexes and chelating ligands at the molecular level can provide valuable insights into their therapeutic effects. Understanding the biological pathways and interactions of these complexes can help optimize their design and enhance their efficacy.

Combination therapies

Metal complexes and chelating ligands can be used in combination with other therapeutic agents, such as conventional chemotherapy drugs or immune-therapies, to improve treatment outcomes. Synergistic effects of combined therapies can potentially enhance the efficacy of metal complexes and chelating ligands in treating various diseases.

Clinical trials and translation to clinical practice

Continued research on metal complexes and chelating ligands should be accompanied by rigorous clinical trials to evaluate their safety and efficacy in human patients. Successful translation of these compounds into clinical practice can provide new treatment options for patients suffering from various diseases.

Literature Review

The use of metal complexes and chelating ligands in medicine has been extensively studied in recent years. Various metal complexes, such as gold, silver, and copper, have been investigated for their potential as antimicrobial agents. The use of chelating ligands has also been explored to enhance the bioavailability and stability of metal complexes. For example, the chelating ligand diethylene triamine pentaacetic acid (DTPA) is used to chelate gadolinium for use in MRI contrast agents. Other chelating ligands, such as polyamines and polyamides, have been explored for the development of metal-based drugs for the treatment of cancer and other diseases.

The use of metal complexes and chelating ligands in medicine has enormous potential, and the field is rapidly evolving with new discoveries and innovations. This presentation will provide an overview of the current state of research in the field and highlight some of the recent advances in the design and development of metal-based therapeutics.

Metal Complexes and Chelating Ligands

Metal complexes: Metal complexes are compounds that contain a central metal ion coordinated with surrounding ligands. Metal complexes have been widely used in medicinal chemistry for the development of drugs with diverse therapeutic applications.

A metal complex refers to a compound in which a central metal atom or ion is surrounded by a coordinated group of ligands. These ligands are typically molecules or ions that possess one or more lone pairs of electrons, allowing them to form coordinate bonds with the metal atom or ion. Metal complexes are widely studied in the field of inorganic chemistry and have a variety of important applications in areas such as catalysis, materials science, medicine, and more. Here are some key points about metal complexes -

- Coordination Number: The coordination number of a metal complex refers to the number of ligands attached to the central metal atom or ion. It indicates the number of bonds formed between the metal and the ligands.
- Ligands: Ligands are the molecules or ions that bind to the central metal atom or ion in a coordination compound. They can be classified as monodentate (forming a single bond) or polydentate (forming multiple bonds) ligands.
- Coordination Sphere: The coordination sphere of a metal complex consists of the central metal atom or ion and all the ligands attached to it. It represents the immediate environment around the metal and determines the chemical and physical properties of the complex.
- Coordination Geometry: The arrangement of ligands around the central metal atom or ion in a metal complex is referred to as coordination geometry. Common coordination geometries include octahedral, square planar, tetrahedral, and trigonal bipyramidal.

- Chelation: Chelation occurs when a polydentate ligand forms multiple bonds with a metal ion, creating a ring-like structure known as a chelate. Chelating ligands are often more stable and exhibit different properties compared to monodentate ligands.
- Metal Complex Stability: The stability of a metal complex depends on various factors, such as the nature of the metal ion, the ligands, and the coordination geometry. Thermodynamic and kinetic factors influence the formation, stability, and reactivity of metal complexes.
- Transition Metal Complexes: Transition metals, such as iron, copper, and platinum, are commonly involved in the formation of metal complexes due to their ability to exhibit multiple oxidation states and form different coordination geometries.

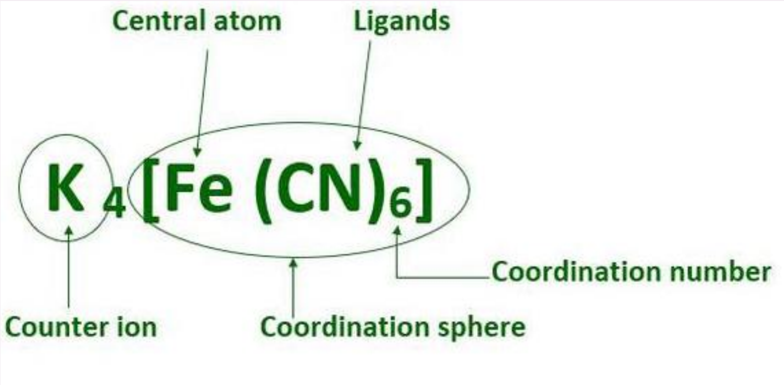

Figure 1: *Different terms of metal complexes*

Chelating ligands: Chelating ligands are molecules or ions capable of forming coordinate bonds with a central metal atom or ion. These ligands possess multiple donor atoms, allowing them to bond to the metal at multiple points simultaneously. The term "chelate" is derived from the Greek word for "claw," reflecting the ligand's ability to tightly bind to the metal ion. Here are some key points about chelating ligands -

- Multiple bonding sites: Chelating ligands possess two or more donor atoms, typically nitrogen, oxygen, or sulfur, arranged in a specific spatial arrangement. These donor atoms are capable of coordinating to the metal atom or ion.
- Coordination number: Chelating ligands increase the coordination number of the metal complex compared to monodentate ligands, which only bind through a single atom. For example, a chelating ligand with two donor atoms increases the coordination number by two.
- Stability and rigidity: Chelation enhances the stability of metal complexes by forming a cyclic structure known as a chelate ring. The chelate ring restricts the movement of the ligand and metal ion, increasing the complex's overall stability.

- Selectivity: Chelating ligands can exhibit high selectivity for specific metal ions due to the complementary size, charge, and coordination preferences of the metal ion and ligand. This selectivity can be useful in various applications such as metal ion extraction or catalysis.

Examples: Common chelating ligands include ethylene diamine tetraacetic acid (EDTA), 1,10-phenanthroline, dimethylglyoxime, porphyrins, and crown ethers. These ligands exhibit different chelation properties and are widely utilized in diverse fields.

Why Metal Complexes?

- Unique chemical and physical properties.
- Wide range of biological activities.
- High affinity for biological targets.
- Easy to modify for specific therapeutic applications.
- Potential for multimodal therapy.

Applications of Metal Complexes: 1. Cancer therapy, 2. Anti-inflammatory agents, 3. Antimicrobial agents, 4. Imaging agents, 5. Drug delivery agents

Metal Complexes as Drugs

Metal complexes, including those containing platinum (Pt), silver (Ag), and rhodium (Rh), have been extensively studied and developed as drugs for various medical applications.

- Platinum complexes: Pt-based complexes, such as cisplatin and carboplatin, are widely used as chemotherapy drugs for the treatment of various types of cancer, including ovarian, testicular, and lung cancer. These complexes work by binding to DNA and interfering with cell division, leading to inhibition of cancer cell growth. They are considered highly effective against many types of cancer, but they can also have significant side effects.
- Silver complexes: Ag-based complexes, such as silver sulfadiazine, are commonly used as topical antimicrobial agents for the treatment of burns and other skin wounds. These complexes release silver ions, which have antimicrobial properties and can help prevent infection and promote wound healing. Silver complexes are also being studied for potential use in other medical applications, such as anti-inflammatory and anti-cancer therapies.
- Rhodium complexes: Rh-based complexes, such as rhodium (II) citrate, have been studied for their potential anti-cancer properties. Rhodium complexes have shown promising results in preclinical studies as potential chemotherapeutic agents due to their ability to inhibit cancer cell growth and induce cell death. However, further

research is needed to better understand their mechanisms of action and potential clinical applications.

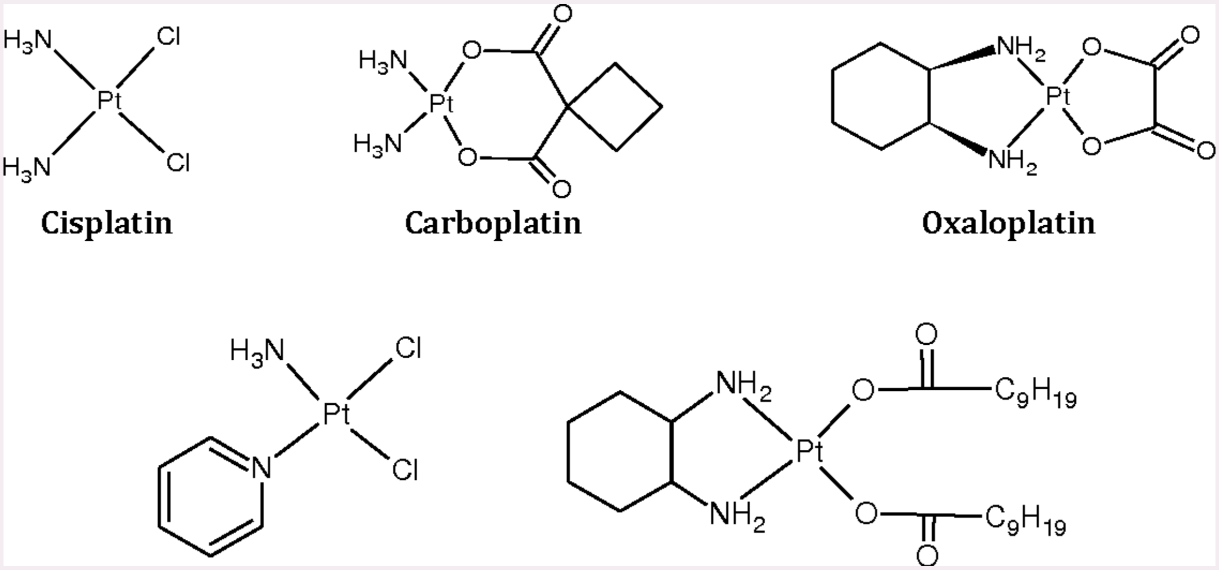

Figure 2: *Structures of platinum complexes used as drugs*

Other examples of metal complexes as drugs -

- Cisplatin: Cisplatin is a well-known anticancer drug that contains a platinum metal center coordinated with two chloride ions and two ammine ligands. Cisplatin is used in the treatment of various types of cancers, including testicular, ovarian, and lung cancers.
- Ferrous sulfate: Ferrous sulfate is a commonly used iron supplement in the treatment of iron-deficiency anemia. It contains a ferrous (Fe^{2+}) ion coordinated with sulfate ligands.
- Gadolinium-based contrast agents: These complexes contain gadolinium ions coordinated with ligands such as diethylene triamine pentaacetic acid (DTPA) or 1,4,7,10-tetraaza cyclododecane-1,4,7,10-tetraacetic acid (DOTA). Gadolinium-based contrast agents are used to improve the visualization of organs, blood vessels, and tumors in MRI scans.
- Ruthenium complexes: Ruthenium complexes have shown promising against cancer activity in preclinical and clinical studies. They exhibit a wide range of mechanisms of action, including DNA binding, enzyme inhibition, and modulation of signaling pathways.

Application of metal complexes

- Chelation therapy: Metal complexes can be used in chelation therapy, which involves the administration of a chelating agent that binds to metal ions in the body. This can be used to treat heavy metal poisoning, such as lead or mercury poisoning.
- Anticancer drugs: Platinum-based complexes such as cisplatin and carboplatin are widely used in chemotherapy for the treatment of various cancers, including ovarian, lung, and testicular cancers. These complexes form covalent bonds with DNA, disrupting the DNA structure and inhibiting cancer cell proliferation.
- Imaging agents: Gadolinium-based complexes are commonly used as contrast agents in MRI due to their high magnetic properties, which enhance the contrast of images and help in the diagnosis of various diseases.
- Anti-inflammatory drugs: Metal complexes can act as scavengers of reactive oxygen species (ROS) and reactive nitrogen species (RNS), which are involved in inflammation processes. Metal complexes can also inhibit enzymes involved in inflammation, such as cyclooxygenases (COX), lipoxygenases (LOX), and nitric oxide synthase (NOS), leading to anti-inflammatory effects.
- Antimicrobial drugs: Silver-based complexes have antimicrobial properties and are used in wound dressings and medical devices to prevent infection. Other metal complexes, such as copper and zinc complexes, also exhibit antimicrobial activity and can be used in the treatment of infections caused by drug-resistant micro-organisms.
- Nutritional supplements: Iron complexes can be used to treat iron-deficiency anemia, while zinc and copper complexes can be used to supplement the diet of individuals with deficiencies in these trace elements.

Metal complexes and their unique properties and functions make them versatile and promising candidates for pharmaceutical and medical applications. However, it's important to note that the development and use of metal complexes as drugs require thorough research, testing, and regulatory approval to ensure their safety and efficacy in clinical settings.

Chelating Ligands as Drugs

Chelating ligands are molecules that can form stable complexes with metal ions by donating multiple coordinating atoms to the metal ion. These complexes are typically formed through a process known as chelation, and the resulting chelates can have various applications in medicine, including as drugs. Some common examples of chelating ligands used as drugs include -

- EDTA (ethylene diamine tetraacetic acid): It is used in medicine for its ability to chelate and remove excess metal ions from the body, and is often used in the treatment of heavy metal poisoning, such as lead poisoning.
- DETA (diethylene triamine pentaacetic acid): DETA is another chelating agent that can form stable complexes with metal ions. It is used in medicine as a chelator for radioactive metals, such as technetium and gallium, which are used in medical imaging and cancer treatment.
- DFO (deferoxamine): DFO is a chelating agent that specifically binds to iron ions, forming stable complexes. It is used in the treatment of iron overload conditions, such as thalassemia and hemochromatosis, where excess iron accumulates in the body.
- Ferrous salts: Ferrous salts, such as ferrous sulfate and ferrous gluconate, are chelating agents that can be used as oral iron supplements to treat iron deficiency anemia. They work by chelating with iron ions in the gastrointestinal tract, making them more readily absorbed by the body.
- Deferiprone (DFP): DFP is a chelating agent that is used to treat iron overload conditions such as thalassemia and sickle cell disease. It binds to excess iron in the body and helps remove it from the bloodstream.
- Ferumoxytol: Ferumoxytol is a chelating agent that contains iron and is used as an intravenous treatment for iron deficiency anemia. It binds to hemoglobin in the bloodstream and helps transport oxygen to the body's tissues.

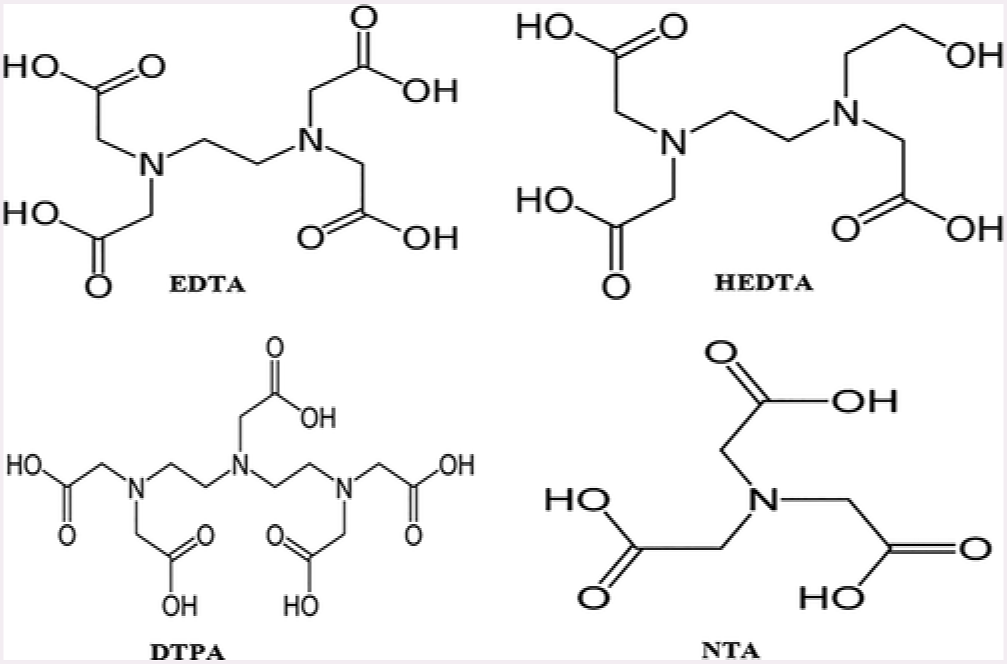

Figure 3: *Structures of chelating ligands used as drugs*

Applications of chelating ligands

- Metal chelation therapy: Chelating ligands can be used as drugs themselves in metal chelation therapy, which involves the administration of chelating agents to treat heavy metal poisoning. Chelating agents such as dimercaprol and deferoxamine are commonly used to form stable complexes with toxic metal ions, such as lead, mercury, and iron, and help to remove them from the body through excretion.
- Enhancing therapeutic efficacy: Chelating ligands can be used to enhance the therapeutic efficacy of certain drugs by forming stable complexes with metal ions that can modulate the drug's properties. For example, chelation of metal ions can improve the stability of certain drugs, protect them from degradation, and increase their half-life in the body, resulting in improved drug efficacy.
- Targeted drug delivery: Chelating ligands can be used to specifically target drugs to certain tissues or organs in the body. By attaching chelating ligands to drug molecules, the resulting complexes can selectively bind to metal ions that are present in specific tissues or organs. This allows for targeted drug delivery, reducing off-target effects and improving drug localization at the desired site of action.
- Imaging agents: Chelating ligands can also be used as imaging agents in diagnostic applications. By chelating metal ions, these ligands can be used to create contrast agents for imaging techniques such as magnetic resonance imaging (MRI) and positron emission tomography (PET). These chelating ligand-based imaging agents can help visualize specific tissues or organs in the body, aiding in the diagnosis and monitoring of various diseases.
- Radiotherapy: Chelating ligands can be used in combination with radioactive metal ions to create radiopharmaceuticals for targeted radiotherapy. The chelating ligands can help to stabilize the radioactive metal ions and facilitate their delivery to specific tissues or tumor sites, allowing for precise radiation therapy to cancer cells while minimizing damage to healthy tissues.

Summary and Outlook

Metal complexes and chelating ligands have a wide range of applications in medicine.

The use of metal complexes and chelating ligands in medicine is a rapidly growing field, and there is still much to be explored and discovered. Researchers are continually developing new types of metal complexes and chelating ligands with improved properties and capabilities. As our understanding of the complex interactions between metal complexes, chelating ligands, and biological systems improves, we will likely see new and exciting applications in medicine.

Scheme 1: *Chelation theory*

One area of particular interest is the development of metal complexes and chelating ligands for targeted drug delivery. By selectively targeting specific cells or tissues, these complexes could potentially reduce side effects and improve the efficacy of drugs. There is also increasing interest in the use of metal complexes and chelating ligands in immunotherapy, which could help to harness the power of the immune system to fight cancer and other diseases.

Overall, the use of metal complexes and chelating ligands in medicine is a promising area of research with many potential applications. Continued research and development in this field will likely lead to new and innovative approaches to diagnosing and treating a wide range of diseases.

Self-healing polymers hydrogel: A highly functional material for biomedical applications

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Self-healing hydrogels (SHH) are a specialized type of polymer hydrogel. A hydrogel is chemically or physically cross-linked hydrophilic three-dimensional (3D) polymer network. Generally, Hydrogels are synthesized from hydrophilic monomers by either chain or step growth along with a functional cross linker to promote network function. A net-like structure along with void imperfections enhance the hydrogel's ability to absorb large amounts of water via hydrogen bonding. As a result, hydrogels, self-healing alike, develop characteristic firm yet elastic mechanical properties. Self-healing hydrogels have the capability of automatically repairing any damage surface either completely or partially after the damage. Therefore, self-healing hydrogels (SHH) are of great interest in tissue engineering, wound healing, and drug delivery. Moreover, SHH has a huge application in biomedical field.

Introduction

Hydrogels are chemically or physically cross-linked hydrophilic three-dimensional (3D) polymer networks that retain substantial amount of water, and may be synthesized either in a one-step procedure with polymerization in the presence of multifunctional cross-linking monomers or through synthesis of polymer molecules that passes reactive groups allowing subsequent network formation. Hydrogels exhibited excellent Properties such as ultra-high mechanical strength, stimuli, responsiveness, biocompatibility and biometric. The self-healing hydrogels (SHH) are hydrogels that show special healing ability. The self-healing property of hydrogel comes from the reversible physical and chemical bonds. However, the classic hydrogels with irreversibly cross-linked polymer networks are unable to heal after rupture leading to degradation and deterioration in their functions over time and shortened lifetime. In contrast, self-healing hydrogels have emerged as a novel type of hydrogels whose mechanical integrity and functions could be autonomously restored after physical damage, which could extend the longevity and increase the durability of the hydrogels. The formation of self-healing hydrogels relies on reversible interactions, which refers to spontaneous formation of nee interactions when old cross links are broken within a hydrogel network endowing self-healing capacity.

After mechanical damage, self-healing hydrogels (SHH) spontaneously regenerate through dynamic covalent cross linkages, covalent and non-covalent interactions. Self-healing hydrogels had the ability to repair itself. It exhibits a prolonged life span even after being exposed to external forces. As a result, self-healing hydrogel is always accompanied by injectability which reduces comport and pain while maintaining the wound in its natural state. These self-healing hydrogels called "smart hydrogels" have the capability of automatically repairing themselves either completely or partially after damage. Therefore, SHH are of great interest in biomedical field like tissue engineering, wound healing, drug delivery etc. Moreover, self-healing hydrogels has huge applications in biomedical field.

Self-Healing Mechanism in Hydrogels

Self-healing hydrogel (SHH) is an intrinsic polymer and this special healing ability of hydrogel either comes from the reversible physical or chemical bonds or combination of those bonds. Some other properties of SHH are conductivity, fast adhesion and stimuli responsiveness. More importantly SHH should possess enough mechanical toughness.

The hydrogel self-healing mechanism possesses similarities with biological systems. The healing process progresses through five consecutive individual steps. Those are -

1. Surface Rearrangement
2. Surface approach
3. Wetting
4. Diffusion
5. Randomization

All those steps are facilitated through the molecular interactions of two fractured surfaces of the damage bonding to ensure the healing process.

There are several interactions have been followed to obtain self-healing hydrogel. The healing interactions are broadly classified as covalent and non-covalent bonding. Dynamic covalent bonding includes imine bonds, Boronated ester bonds, Diels -Alder reaction, arylhydrazone bonds, oxime bonds and disulfide bond whereas non covalent interactions include hydrogen bonds, ionic interaction, host guest interaction and hydrophobic interaction. The hydrogels basically obtained from non-covalent interactions. They are generally highly flexible and self-heal because of their ability to easily break and reconstruct cross links whereas those obtained from covalent bonding are highly stable.

Hydrogen bond

The cross linked hydrogels based on hydrogen bonds are obtained through reversible cross-linking of polymeric networks where hydrogen atoms interact with highly electronegative atoms such as nitrogen, oxygen, and fluorine. These hydrogels exhibit improved bond strength and self-healing ability. The self-healed hydrogels fabricated via the hydrogen bonding mechanism are relatively-less stable, compared to self-healing hydrogel prepared utilizing ionic and covalent interactions. Hydrogen bonds also play a critical role in many Biological self-assembled systems such as DNA base-pairing and Protein folding. Several examples where hydrogen bonding has been utilized in hydrogel design.

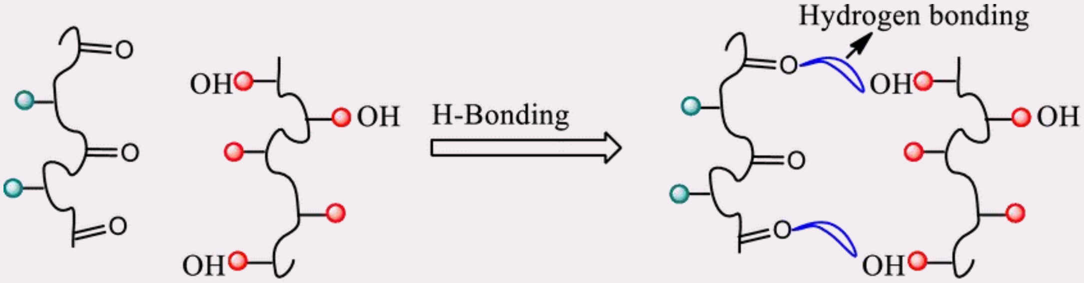

***Figure 1:** Hydrogen bonding*

Ionic Interactions

The interaction between oppositely charged polymers promotes crosslinking in polymeric solutions during the synthesis of hydrogels. The migration of free ions to the non-crosslinked or broken region of the polymeric chain causes self-healing, resulting in a reversible reaction caused by ionic bonding between free ions and polymers. For example, using Fe ions in the production of hydrogels to generate self-healing hydrogels based on ionic bonding. For example, an ionic bond achieved by interaction of carboxylic group present in polyacrylic acid (PAA) with Fe3+ ions lead to the self-healing ability of the hydrogel. This hydrogel exhibited self-healing ability because of the existence of ionic interaction and an improved mechanical strength due to the formation of covalent bonds by the carboxylic acid ions present in PAA. PAA-Fe3+ hydrogel thus obtained underwent healing for 24hrs at room temperature and on cyclic stretching relaxation test, it exhibited good stability that could withstand up to 200% stretch of its original length even after 1000 cycles. Fe3+ also acted as a cross linker in a nano-composite hydrogel that has self-healing ability and enhanced mechanical strength. It revealed tensile strength of 860 kPa for prepared hydrogel and 560 kPa for self-healed hydrogel. The properties such as self-repair, toughness, stretchability makes these hydrogels unique for tissue engineering applications.

Likewise, catechol has also been used for making ionic bond-based hydrogels. These self-healing and load-bearing hydrogels were created by electrostatic crosslinking Fe3+ ions and catechol-grafted chitosan, which re-established their full strength within 100 s in cyclic time sweep experiments. Similarly, dopamine and catechol groups grafted on the surface of montmorillonite hydrogel were prepared, which showed 70% recovery of its original storage moduli even after applying 100% amplitude oscillatory force. Ionic interaction of catechol and ferric ions is responsible for the self-healing property. In addition, a carboxybetaineacrylamide self-healing hydrogel containing zwitterionic material that was repaired via ionic bonds recovered 90% of its compressive capabilities following repair and showed time-independent healing behavior.

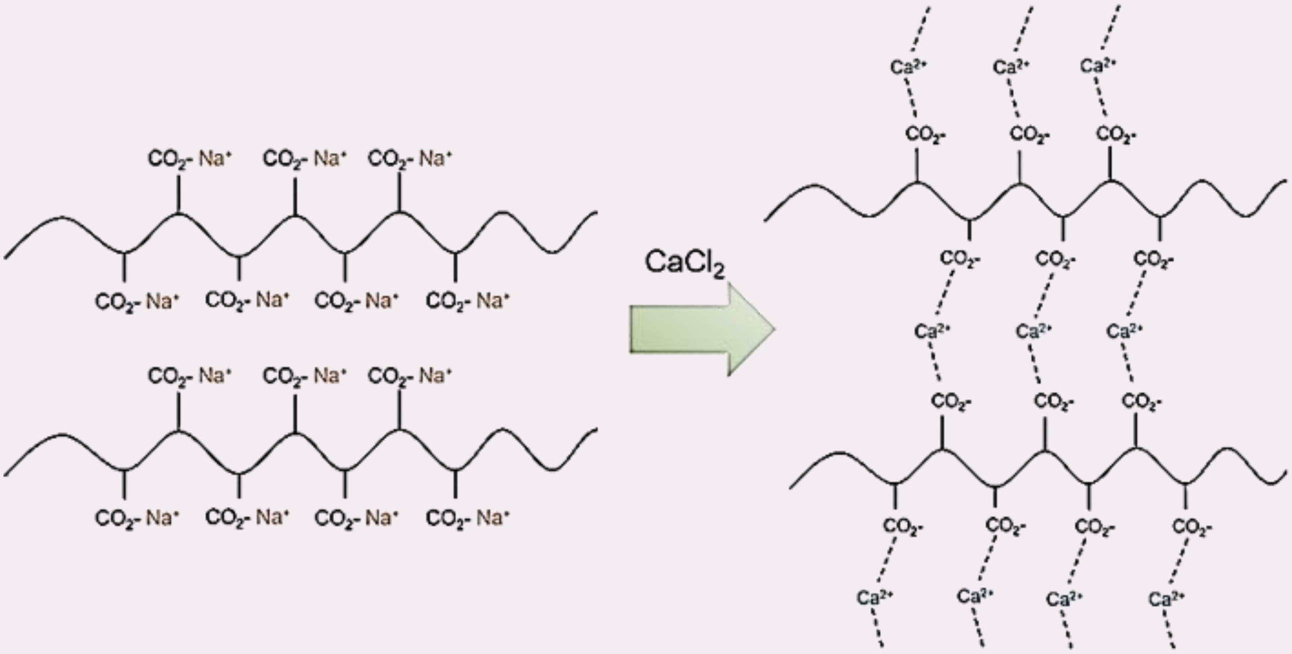

Figure 2: Ionic interaction

Host-Guest Interactions

The host–guest interaction enabled the hydrogel to rapidly self-heal. When it was cut, fresh surfaces were formed with dangling host and guest molecules (due to the breaking of host–guest recognition), which rapidly recognized each other again to heal the hydrogel by recombination of the cut surfaces. These bonds are based on the transient association and formation of inclusion complexes between molecules containing a cavity (i.e., host) with suitable molecular Guests. The family of cavitands includes both naturally-derived (e.g., cyclodextrin) and synthetic (e.g., cucurbit[n]urils, calix[n]Ares, and pillar[n]ares) macrocycles. The criteria for a guest–host Pair involve complementary size of the host cavity and guest Molecule and interactions through hydrophobicity. Based on These broad criteria, macrocycles can be paired with many different potential guests, which may be inert, or stimuli-responsive molecules, pharmaceuticals, biomolecules, or polymers.

Hydrophobic Interactions

Hydrophobic interactions are another strategy for synthesizing Self-healing hydrogels. Hydrophobic interactions are generated by the incorporation of hydrophobic monomers within the hydrophilic polymer network in aqueous media with the help of Surfactants such as sodium dodecyl sulfate (SDS). This takes place thorough cyclic dissociation and re-association of the micelles.

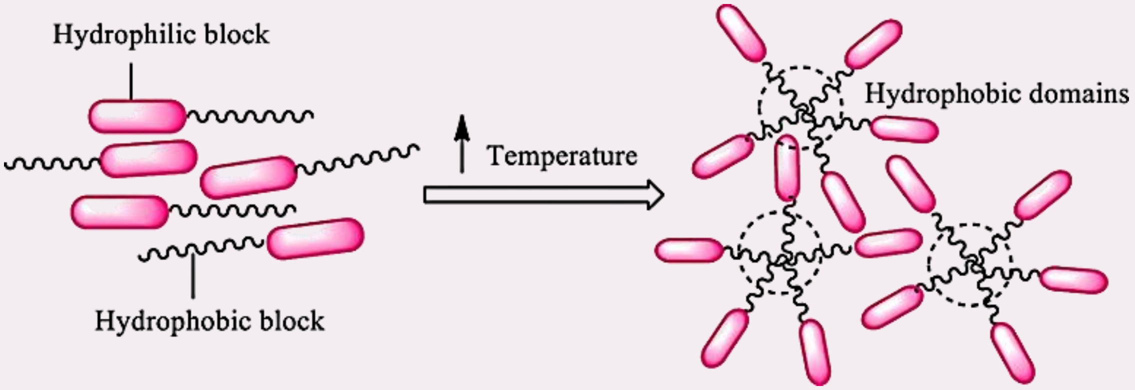

Figure 3: *Hydrophobic interaction*

Imino Bonds

Imine bonds (i.e., Schiff base) are a promising class of dynamic covalent interaction that develops self-healing hydrogels by the formation of cross linking among amine groups and aldehyde or ketone groups of polymers under physiological conditions. The formation of Schiff base has greater reaction speed under mild conditions. Ready gelation and heal ability taking it forward for tissue engineering applications.

Biomedical applications of Self-healing polymer hydrogels

In recent years, the use of self-healing hydrogels (SHH) becomes more attractive. The synthesized hydrogel has significant Properties such as mechanical strength, biocompatibility, biodegradability, stimuli responsiveness etc. These Properties are substantial for biomedical applications. In this section, various applications of Self-healing hydrogels in biomedical fields such as wound healing, Bone regeneration, cardiac regeneration, tissue engineering and drug delivery.

Wound healing

Self-healing hydrogels can be prepared through dynamic covalent bonds and non-covalent interactions. The dynamic equilibrium between dissociation and recombination of various interactions leads the hydrogel to heal damages and reform shapes. They can be applied as a permanent or temporary dressing for different wounds to support the regeneration and healing of the injured epidermis, dermis, or both.

The hydrogel provides moisture which enables painless debridement of necrotic and infected tissue, promotes granulation and encourages complete healing. Since they have a high-water content, they are not completely absorbent, which makes them appropriate for wounds with light to moderate exudation. In other situations, the accumulation of water can result in skin maceration and multiplication of microbes, leading to a foul-smelling infected wound.

Hydrogels may also cool the wound which is helpful in alleviating pain. The gel flattens out the wound surface contours to prevent dead space from becoming infected, besides providing support for surface healing. Burn wounds are particularly complicated because they can cause damage to the tissue beneath the skin. In such cases, a standard wound dressing must be replaced after it absorbs the exudates, which can lead to complications such as wound exudates, wear and tear on the neo tissue formed in the wounded area. In all such cases, the so-called “smart hydrogel” serves as a boon where the dissolvable capacity of the hydrogel overcomes the above-mentioned drawbacks of wear and tear making the procedure easy and painless.

Tissue Engineering and Regeneration

Hydrogels are created from cross linked polymers that are water-insoluble. Polymer hydrogels absorb significant amounts of aqueous solutions, and therefore have high “water content. This high-water content makes hydrogel more similar to living body tissues than any other material for tissue regeneration. Additionally, polymer scaffolds using self-healing hydrogels are structurally similar to the extracellular matrices of many of the tissues. Scaffolds act as three-dimensional artificial templates in which the tissue targeted for reconstruction is cultured to grow onto. The high porosity of hydrogels allows for the diffusion of cells during migration, as well as the transfer of nutrients and waste products away from cellular membranes. Scaffolds are subject to harsh processing conditions during tissue culturing. These include mechanical stimulation to promote cellular growth, a process which places stress on the scaffold structure. This stress may lead to localized rupturing of the scaffold which is detrimental to the reconstruction process. In a self-healing hydrogel scaffold, ruptured scaffolds have the ability for localized self-repair of their damaged three-dimensional structure.

Current research is exploring the effectiveness of using various types of hydrogel scaffolds for tissue engineering and regeneration including synthetic hydrogels, biological hydrogels, and biohybrid hydrogels. In 2019, researchers Biplab Sarkar and Vivek Kumar of the New Jersey Institute of Technology developed a self-assembling peptide hydrogel that has proven successful in increasing blood vessel regrowth and neuron survival in rats affected by Traumatic Brain Injuries (TBI). By adapting the hydrogel to closely resemble brain tissue and injecting it into the injured areas of the brain, the researchers' studies have shown improved mobility and cognition after only a week of treatment. If trials continued to prove successful, this peptide hydrogel may be approved for human trials and eventual widespread use in the medical community as a treatment for TBIs. This hydrogel also has the potential to be adapted to other forms of tissue in the human body, and promote regeneration and recovery from other injuries.

Drug Delivery

The swelling and bio adhesion of hydrogels can be controlled based on the fluid environment they are introduced to in the body. These properties make them excellent for use as controlled drug delivery devices. Where the hydrogel adheres in the body will be determined by its chemistry and reactions with the surrounding tissues. If introduced by mouth, the hydrogel could adhere to anywhere in the gastrointestinal tract including the mouth, the stomach, the small intestine, or the colon. Adhesion in a specifically targeted region will cause for a localized drug delivery and an increased concentration of the drug taken up by the tissues.

Smart hydrogels in drug delivery

Smart hydrogels are sensitive to stimuli such as changes in temperature or pH. Changes in the environment alter the swelling properties of the hydrogels and can cause them to increase or decrease the release of the drug impregnated into the fibers. An example of this would be hydrogels that release insulin in the presence of high glucose levels in the blood stream. These glucose sensitive hydrogels are modified with the enzyme glucose oxidase. In the presence of glucose, the glucose oxidase will catalyze a reaction that ends in increased levels of H+. These H+ ions raise the pH of the surrounding environment and could therefore cause a change in a smart hydrogel that would initiate the release of insulin.

Conclusion and future perspectives

Among the conventional hydrogel materials, self-healing hydrogels (SHH) are showing their promise in biomedical applications in tissue engineering, wound healing, and drug delivery. Additionally, their responses can be controlled via external stimuli (e.g., pH, temperature, pressure, or radiation). Identifying a suitable combination of viscous and elastic materials, lipophilicity and biocompatibility are crucial challenges in the development of SHH, for the drug release and wound healing applications, in addition to concern about the biocompatibility of ILs, we should also pay enough attention to Preparing more intelligent ionogel systems, for example, stimuli-responsive drug release systems. The biodegradability of ionogels should also be concerned.

Structure and Properties of Different Types of Polymers

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Polymer is a thing which is used in our daily life. Polymers are all around us not just in plastic products, clothes etc. but in substances we eat like protein, lipid, polysaccharide, and also in our bodies like proteins, nucleic acid etc. So, knowledge about the structure and properties of different types of polymer is important. Polymers can be found from different sources and synthetic procedure; properties of polymers are based on factors like origin, monomer, structure, molecular forces, crystallinity, stereochemistry of monomer i.e., tacticity, hydrophobicity, etc.

Introduction

The word polymer comes from two Greek words 'Poly' means many and 'Meros' means unit or part. A polymer always consists of a large no of repeating monomer units. In some cases, the repetition is linear and sometimes the chains are branched or interconnected with three dimensional networks. Examples includes polyethylene, polyvinyl chloride etc.

Classification of Polymers

Based on monomer

- Homopolymer: A polymer is obtained from identical monomer units is called homopolymer. These types of polymers are formed by addition polymerization to form a linear or simple chain.

Properties of homopolymer:
i. High crystalline level.
ii. Excellent creep resistance.
iii. Water resistance.
iv. Good oxidation strength.

- Copolymer: A polymer is obtained from polymerization of two or more than two types of monomers to form a complex chain. Basically these types of polymers are formed by condensation polymerization. Generally, copolymers are two types -

- Linear copolymer: These types of polymers are combined together to form a single linear chain. Basically, linear copolymers are three types-
    - Alternating copolymers: In this polymer, monomer units are arranged in alternating way with the single main chain. Example: Nylon 6,6
    - Block copolymers: In this polymer more than one homopolymer unit is combined together by covalent bond to form a single main chain. Example: SBS (styrene butadiene styrene) rubber.
    - Statistical copolymers: In this polymer two or more than two monomer units are arranged in an order which obeys some statistical rule. These types of polymers are formed by free radical polymerization. Random polymers are the special type of statistical polymers. Example: Styrene butadiene rubber (SBR)
- Branched copolymers: Generally branched copolymers are two types-
    - Grafted copolymers: In this polymer one or more than one homopolymer units are grafted together to form a branch with the main chain. Example: Polystyrene.
    - Star copolymers: In this polymer at least three polymer chains are expanded along the center. When the polymer chains are same is known as homostar and the polymer chains are different is known as heterostar. Example: Polyethylene oxide (PEO)

Properties of copolymer:

i. Low crystalline level.

ii. Best tensile strength.

iii. Exceptional dimensional stability.

iv. Impact resistance.

Based on origin

- Natural polymers: These are the complex compounds of high molecular mass obtained from natural sources. Example: Proteins, polysaccharides, gum, rubber are some important examples of natural polymers.

Properties of natural polymers:

i. Biodegradable.

ii. Proteins are generally strong or rigid in nature.

iii. Carbohydrates are flexible in nature.

- Synthetic polymers: There is an endless variety of man-made commercial polymer products which have specified properties e.g., synthetic rubber can be made to have such property which cannot be achieved with natural rubber. Example: polyvinyl chloride, Bakelite, Teflon etc.

Properties of synthetic polymer:

i. High strength.
ii. Chemical resistance.
iii. Flexibility.

- Semi-synthetic polymers: These polymers are obtained from chemically treated natural polymers. Example: Nitrocellulose is obtained by adding nitric acid to cellulose. Cellulose acetate is obtained by adding acetic acid to cellulose.

Based on structure of polymers

- Linear chain polymers: In these polymers' monomer units are linked together to form linear chains. The various polymeric chains are then stacked over one another to give a well packed structure. Due to this well packed structure, linear polymers have high tensile strength and high melting point. Example: Polyvinyl chloride, Nylon etc.

Properties of linear chain polymer:

i. High tensile strength due to well packed structure.
ii. High melting point.
iii. High density.

- Branched polymers: In these polymers' monomer units are combined to form side chains or branches of different lengths along with the linear chain (main chain). They don't have well packed structures like linear polymer. As a result, they have lower density, lower melting point and less tensile strength compare to linear chain polymer. Example: Low density polyethylene, glycogen etc.

Properties of branched polymer:

i. Low density.
ii. Low tensile strength.
iii. Low boiling point and melting point.

- Crosslinked or network polymers: In these polymers, the initially formed linear chains get cross-linked perpolymer chains are required to join together all the long chain molecules to form a giant molecule due to presence of cross-linked between different polymer chains. Example: Bakelite, vulcanized rubber etc.
- Properties of cross-linked polymer:
- Due to network structure the polymers are-
- i. Hard.
- ii. Rigid.

- iii. Brittle.

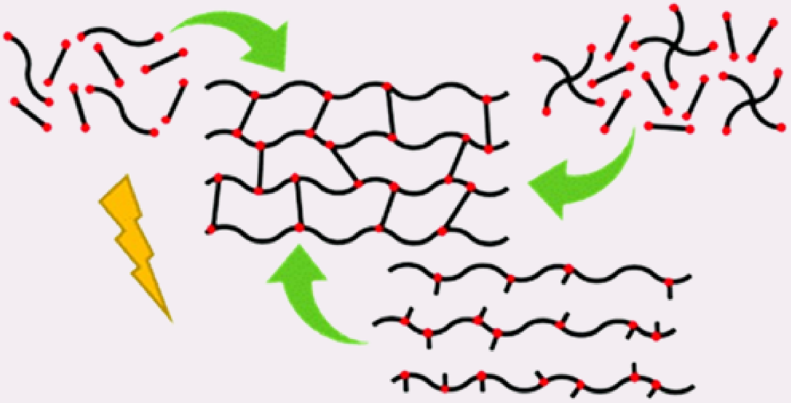

Figure 1: *Formation of cross-linked polymer*

Based on synthesis

- Addition polymers or chain growth polymers: When the molecules of same monomer or different monomers simply added together without loss of simple molecule like H_2O, NH_3 etc., the process is called addition polymerization and the polymer is called addition polymers. The monomers used here are unsaturated compounds such as alkenes, alkadienes and their derivatives. This type of polymerization can take place through the formation of either radical or ionic species such as carbocations or carbanions' process is called chain growth polymerization and the polymer is called chain growth polymer. Example: polystyrene, polyvinyl chloride, polyethylene etc.

Properties of addition polymers:

i. High density because monomers are added together without loose of simple molecule i.e., the molecular weight of the polymer is a multiples of monomer molecular weight.

ii. There is no side product is obtained with polymer in this type of polymerization.

iii. High melting point.

iv. Hard and crystalline.

- Condensation polymers or Step Growth polymers: These process of polymerization by which poly functional monomer combines to form a giant molecule by elimination of simple molecule such as H_2O, alcohol is called condensation polymerization and the polymer is called condensation polymer. This reaction occurs in a controlled step wise manner and the product formed in each step is a distinct functionalized species and not a reactive intermediate. Hence the process is called step growth polymerization and the polymer is called step growth polymer. Example: Nylon-6,6, poly amide

Properties of condensation polymer:

i. Low density because monomers are combined together with loses of simple molecule i.e., the average molecular weight of the polymer decreases.

ii. Side products are obtained mainly water, alcohol, ammonia etc. with polymer in this type of polymerization.

iii. Monomers are bifunctional or polyfunctional.

iv. In each step unreactive intermediate is formed.

- Co-ordination polymers: Co-ordination polymers are basically organo metallic polymer which contain metal cations center are linked by ligand. Example: High density polyethylene is produced using Ziegler-Natta catalyst.

Properties of coordination polymer:

i. Good electrical property i.e., electrical conductivity due to metallic bond.

ii. Magnetism shows especially paramagnetic property.

iii. Sensor capability i.e., the coordination polymers act as a solvent sensor because it can change color in different types of solvent.

Based on molecular forces

- Elastomer: In this type of polymers, the intermolecular forces are very weak. Due to the presence of very weak intermolecular forces, the polymer chains can be stress and they return to their original position on the removal of applied force. Example: Natural rubber, neoprene etc.

Properties of elastomer:

i. High viscosity due to presence of weak intermolecular forces.

ii. Good electrical property which makes them stronger to break and crake.

iii. Flexible in low temperature.

iv. Low Young’s modulus shows due to presence of weak intermolecular forces.

- Fibers: These have strongest intermolecular forces in the form of H-bonds or dipole-dipole interaction. Due to presence of strong forces, these are high tensile strength, lower elasticity and sharp melting point. These polymers are thin and thread like structure. Example: Terylene, Nylon-6,6 etc.

Properties of fibers:

i. Generally hydrophilic i.e., likes water.

ii. Fibers are mainly linear in structure.

iii. Generally fibers are long length.

iv. High melting point.

v. Heat resistance.

- Thermoplastic polymer: In this type of polymers, intermolecular forces of attraction are in between those of elastomers and fibers. Thermoplastics have linear polymer chains with a few chemical bonds acting as crossed-linked. These are hard at room temperature. Such polymers when heated it assumes any desired shape for flexible nature in high temperature. Example: polyethylene, nylonetc.

Properties of thermoplastic polymer:
i. High molecular weight.
ii. Flexible in high temperature. iii. Hard at room temperature.
iv. Recyclable.
v. Nonflammable.

- Thermosetting polymer: These polymers are generally made from semi fluid substances having low molecular weight. On heating in a mold, they become infusible and form an insoluble hard mass due to cross-linking between polymer chains forming 3D network of bonds. Example: Bakelite, Terylene etc.

Properties of thermosetting polymer:
i. Heat resistance i.e., when heated the polymer the polymer becomes decomposed before the melting temperature.
ii. When heated the polymer loss its elasticity so the polymer becomes brittle in nature.
iii. When heating the polymer becomes molded but not recyclable.
iv. Chemical resistance.

Based on the stereochemistry of monomer (tacticity)

- Isotactic polymer: In this polymer the side chains or groups are oriented on the same side of the main polymer chain having regular and definite order i.e., same order. Example: Isotactic polypropylene.

Properties of isotactic polymer:
i. Hard i.e., high density.
ii. Strongly crystalline.
iii. High melting point.

- Syndiotactic polymer: In this polymer the side chains or groups are oriented alternating on the both side of main chain i.e., alternating order. Example: Syndiotactic polypropylene.

Properties of syndiotactic polymer:
i. Crystalline in nature.
ii. High melting temperature.
iii. Heat resistance.

iv. Good chemical resistance.

- Atactic polymer: In this polymer these are irregular, random orientation of the side chain i.e.no order or random order. Example: atactic polypropylene.

Properties of atactic polymer:
i. Soft.
ii. Elastic in nature.

Based on crystallinity

- Crystalline polymer: In crystalline polymer the molecular chains are arranged in a definite direction. Example: polypropylene, syndiotactic polystyrene, nylon.

Properties of crystalline polymer:
i. Rigid.
ii. High melting point.
iii. Low affected by solvent penetration.

- Amorphous polymer: In amorphous polymer the molecular chains are random oriented. Example: Polyisoprene, atactic polystyrene.

Properties of amorphous polymer:
i. Soft.
ii. Low chemical resistance.
iii. No definite melting point.
iv. Low strength.

- Semi crystalline polymer: A special type of polymer which have a highly ordered molecular structure. Example: Polypropylene

Properties of semi crystalline polymer:
i. Intense melting point.
ii. Generally solid but when heated after a specific temperature it becomes brakedown.
iii. Anisotropic in nature.

Based on hydrophobicity

- Hydrophobic polymer: Water molecule made a contact angle more than 90 ^{O}C on the polymer surface is called hydrophobic polymer. Example: Polyethylene, polystyrene etc.

Properties of hydrophobic polymer:
i. Water resistance.
ii. Insoluble in water.

- Hydrophilic polymer: Water molecule made a contact angle is less than 90 °C on the polymer surface is called hydrophilic polymer. Example: Polyvinyl alcohol, cellulose.

Properties of hydrophilic polymer:

i. Flexible in nature.

ii. Water loving i.e., can absorb water.

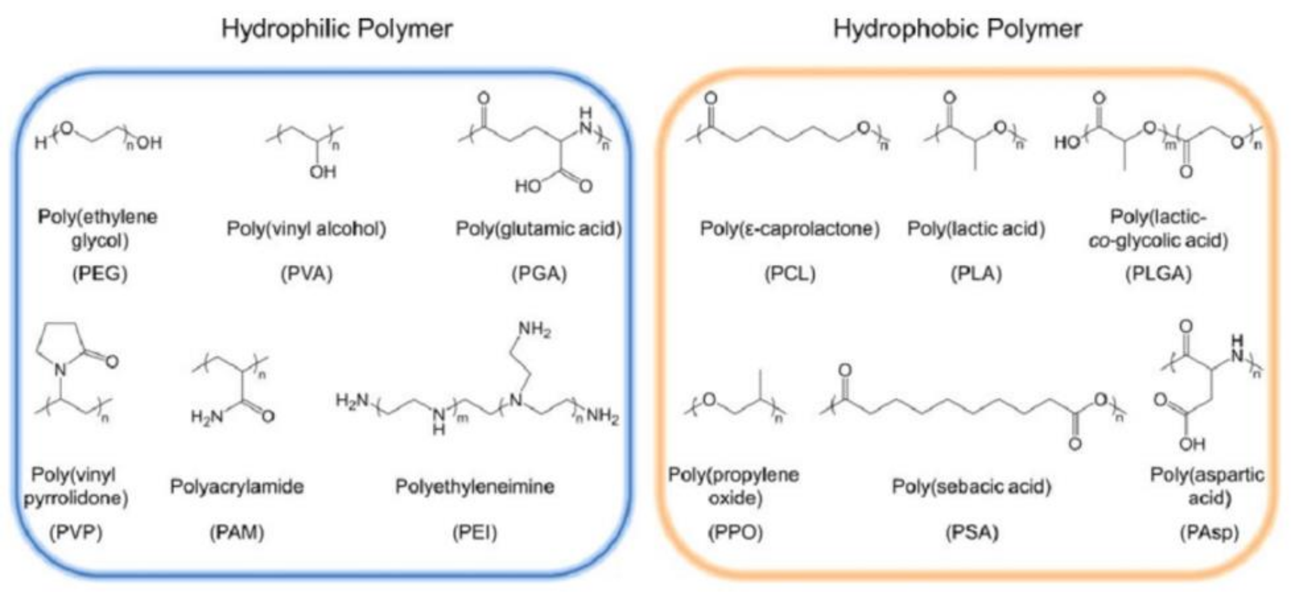

Figure 2: *Examples of hydrophilic and hydrophobic polymers*

Summary and Outlook

Polymers are defined as high molecular mass which consists of repeating structural units from the corresponding monomer. The polymers are classified in various numbers of ways. Generally, in presence of organic peroxide the alkenes and their derivatives undergo addition polymerization or chain growth polymerization by free radical mechanism.

In condensation polymerization the polyfunctional monomer combines to form a giant molecule with elimination of simple molecule like NH_3, H_2O etc. The condensation polymerization process is proceeded through step by step, due to this reason this polymerization is called step growth polymerization.