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Historical Development of Polymer Science: A Review

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Introduction

The advancements in science and technology have indeed led to the development of innovative materials with remarkable properties. Polymers, in particular, have emerged as a promising class of materials due to their versatility and adaptability. Polymers can be synthesized with specific chemical, mechanical, and electrical properties to meet diverse requirements. For example, some polymers are strong and durable, while others are flexible and lightweight. Many polymers can withstand high temperatures without significant degradation, making them suitable for applications in extreme environments. Polymers often exhibit excellent durability and longevity, ensuring their performance over extended periods. Polymers can be processed into a wide range of products, from plastics and fibers to coatings and adhesives. The potential of polymers has driven extensive research and development efforts, leading to numerous advancements in various fields, including materials science, engineering, medicine, and electronics. The word *polymer* is derived from the classical Greek words *poly* meaning "many" and *meros meaning* "parts". To summarize, a polymer is a large molecule made up of many smaller, repeating units called monomers. These monomers are linked together by covalent bonds to form the long chains that characterize polymers. Polymers have high molecular weights due to their large size. The repeating units in a polymer are often derived from simple molecules. The covalent bonds between monomers give polymers their structural strength and stability.

Literature Review

P.N. Sudha *et.al*. investigated sorption studies of Cr (VI) from aqueous solution using nano-chitosan-carboxymethyl cellulose blend under different experimental conditions like initial chromium concentration, adsorbent dose and pH. The adsorption data have been explained on basis of Langmuir and Freundlich equations. The sorption kinetics was tested for the pseudo first order & pseudosecond order reaction. The result has shown that the adsorptions of Cr(VI) onto Nano-chitosan-carboxymethyl cellulose blend (Nc-CMC) was found to fit well with the Freundlich isotherm. The rate constant of sorption for kinetic models were calculated and good correlation coefficients reported for the pseudo second order kinetic model.

Veera M. Boddu *et. al.* investigated the removal of hexavalent chromium from waste water using a new composite chitosan bio-sorbent and reported that the batch isothermal equilibrium and continuous column adsorption experiments were conducted at 25oC to evaluate the bio-sorbent for the removal of hexavalent chromium from synthetic and field samples from chrome plating industries. The effect of pH, sulfate and chloride ion on adsorption was also investigated. Experimental equilibrium data was well fitted to Langmuir and Freundlich adsorption isotherms and respective isotherms constant were reported.

Gurnule *et. al.* prepared 8-HQAF terpolymer resin based on the condensation polymerization of 8-hydroxyquinoline and adipamide with formaldehyde in the presence of 2M HCl as catalyst. The newly synthesized terpolymer resin was found to be soluble in DMF, DMSO and aqueous NaOH and insoluble in common organic solvents. From the elemental analysis, UV-visible, IR and 1HNMR spectral studies, they have proposed the tentative structure for the 8-HQAF terpolymer.

Classification of Polymers

The field of polymers is vast and constantly expanding. The sheer variety of atoms and their arrangements within polymer molecules leads to an incredible diversity of materials with unique properties. There are hundreds of existing polymers, and many more are expected to be discovered or created in the future. Polymers contain a wide range of atoms, which contributes to their diverse structures and properties. Polymers can exhibit different chemical structures, physical properties, mechanical behavior, thermal characteristics, and more. Based on their properties, polymers can be classified into various categories.

Based on Origin

On the basis of their occurrence in nature, polymers have been classified in three types.

Natural polymers: -

Polymers isolated from natural materials such as plants and animals are called natural polymers. Example: Cellulose, Starch, Proteins, Nucleic acids, etc.

Synthetic polymers: -

Polymers are synthesized in the laboratories thus they are manmade polymers called synthetic polymers. Example: Polyethylene, PVC, Nylon, etc.

Semisynthetic polymers: -

These polymers are mostly derived from naturally occurring polymers by chemical modification. Example: Cellulose Diacetate, Cellulose Nitrate, Gun Cotton, etc.

Properties of polymers

The type of monomers that make up a polymer significantly influences its properties. The arrangement of monomers within a polymer chain affects its structure and behavior. These properties describe how a polymer behaves as a macroscopic material, such as its strength, flexibility, and thermal conductivity.

These properties relate to the interactions between polymer chains at the nanoscale, including forces like van der Waals forces and hydrogen bonding.

Polymers are very light in weight with great degrees of strength.

- Polymers can be processed in various ways.
- Polymers have many inherent properties that can be further enhanced.
- Polymers can be very resistant to chemicals and also to weather. They only react with particular solvent.
- Polymer can act as both thermal and electrical insulator.
- Polymers have excellent transport properties such as diffusivity.
- Mechanical properties of polymers have made polymers to great interesting materials. Polymers replaced many materials with their good physical properties.

Materials and Methods

Ultraviolet-Visible spectrometer uses light in the visible and adjacent (UV) and near infrared (IR) ranges. In this region of spectrum, molecules undergo electronic. UV-Vis spectrometer is routinely used in the quantitative determination of solutions of transition metal ions and highly conjugated organic. The basic parts of a are a light source (incandescent lamp for the visible and deuterium arc lamp for ultra violet wavelength), a holder for the sample, a diffraction grating or monochromator to separate the different wavelength of light and a detector. In a double-beam instrument, the light splits into two beams before it reaches the sample. One beam is used as the reference and the other beam passes through the sample. Some double beam instruments have two detectors. The sample and the reference beams are measured at the same time. In other instruments, the two beams pass through a beam chopper, which blocks one beam at a time. The detector alternates between easuring the sample beam and the reference beam. UV-Vis spectrophotometer has been used during the present investigation Electrically operated oil bath was used for refluxing the reaction mixture during synthesis of copolymers. The required temperature of the oil bath was controlled by digital pH meter with combined glass electrode was used for pH-measurement Rotary flask shaker (Fig.) having 25 conical flask capacity with 300 rpm manufactured by Tempo Instrument Pvt. Ltd., Mumbai was used for adsorption studies using batch equilibrium method. Here's a breakdown of the equipment used in the drying process Model:

Fig.: - Rotary Flask Shaker

Experimental Methods

The methods of Synthesis, Purification and Surface modification of new copolymers are given below. The reaction mixture was taken in 500 ml round bottom flask fitted with water condenser and heated in an electrically operated oil bath at 120 ± 20C for 6 with occasional shaking. The temperature of the oil bath was controlled with the help of The solid mass obtained was removed immediately as soon as the reaction period was over. The separated copolymer product was filtered and purified The solid copolymer product was repeatedly washed with hot distilled water followed by methanol to remove unreacted monomers. The resinous product was air dried and powdered. The powder was washed several times with petroleum ether in order to remove resorcinol formaldehyde copolymer which may be present with the desired copolymer. The product so obtained was further purified by reprecipitation technique. The copolymer was dissolved in 8% aqueous NaOH, filtered and reprecipitated by drop wise addition of 1:1(v/v) of conc. HCl / distilled water. The precipitated product was filtered off, washed with hot water until it was free from chloride ions, dried and powdered. The finely ground copolymer was passed through a 300 mesh size sieve. The purity of newly synthesized and purified copolymer sample has been tested and confirmed by TLC. **161** DMSO was used as a solvent for developing TLC chromatogram and was allowed to run for about 30 min. When the was exposed to iodine chamber single spot was observed.

Characterization of Newly Synthesized Materials

This chapter deals with characterization of newly synthesized copolymers/surface modified copolymers. The characterization specifically has as a goal to confirm the of the material. Many characterization techniques should ideally be linked to the desirable properties of the material such as strength, impermeability, thermal stability and optical properties. Characterization techniques are typically used to determine solubility, molecular weight, molecular structure, morphology, thermal properties and other important physical properties.

Solubility of new copolymers in different organic solvents

The solubility of copolymers in different solvents has shown in Table. All copolymers are found to be mainly soluble in N,N-Dimethylformamide (DMF), tetrahydrofuran (THF), Dimethyl and aqueous NaOH/KOH solutions, whereas the copolymers are insoluble in common organic solvents. I'd be glad to provide a response that incorporates the insights from the ratings and addresses the prompt effectively Elemental Analysis of Copolymers Elemental analysis was conducted to determine the composition of newly synthesized. The technique involves measuring the percentages of carbon, hydrogen, nitrogen, and oxygen in the samples.

Table: The solubility of copolymers in different organic solvent

Solvent	Copolymers			
	RPHF-I	RPHF-II	RSF-I	RSF-II
Methanol	⊗	⊗	⊗	⊗
Ethanol	⊗	⊗	⊗	⊗
Acetone	⊗	⊗	⊗	⊗
CCl_4	⊗	⊗	⊗	⊗
$CHCl_3$	⊗	⊗	⊗	⊗
Benzene	⊗	⊗	⊗	⊗
DMSO	√	√	√	√
HCl(1:1)	⊗	⊗	⊗	⊗
DMF	√	√	√	√
THF	√	√	√	√
Aqueous NaOH	√	√	√	√
aqueous KOH	√	√	√	√

Adsorption Studies and Experimental Techniques

pH is one of the very most important factor which influences almost all biological as well as chemical reactions. Therefore, it is one of most important factors to be considered for optimization. The experiment was carried out as per the procedure mentioned bellow Experiment Setup Adsorbing Cr(VI) from Solution Experiment Overview This experiment

aims to study the adsorption of hexavalent chromium (Cr(VI)) from aqueous solutions using various newly synthesized adsorbents. Experimental Procedure Flask Preparation: A series of 250 mL conical flasks were prepared. Cr(VI) Solution: 100 mL of a Cr(VI) solution with an initial concentration (Co) of 25 mg/L was added to each flask Temperature Control: A constant temperature of 300 K (27 °C) was maintained throughout the experiment.

Results and Discussion

The percentage adsorption with different As(III) concentration was studied by varying As(III) ion concentration from 10 to 100 mg/lit keeping other parameters such as adsorbent dosage, pH of solution, contact time optimum. The result is shown in Fig.5.44. From the figure, it is observed that the percentage of As(III) removal was decreased from 95.13% to 59.12% as initial concentration of As(III) increased from 10 to 100 mg/lit for RPHF-II. Similarly, for CCRPHF-II same trend was observed that is the percentage of removal was decreased from 99.23 to 65.66%. Thus in the both cases, the decreased is justified by the fact that RPHF-II and CCRPHF-II have limited number of active sites which is saturated beyond certain concentration. This means that at fixed RPHF-II and CCRPHF-II dose, the number of active adsorption sites to accommodate the As(III) ions remained unchanged while with higher adsorbate concentration, As(III) ion to be accommodated increased. But the actual amount of As(III) adsorbed per unit mass of copolymers increased with the increase of As(III) ion concentration in the solution for the both the adsorbents. It means that the adsorption is highly dependent on initial concentration of As(III). At lower concentration, the ratio of the initial number of As(III) ions to the available surface area is low. However at higher concentration of As(III).the available sites for adsorption becomes fewer and hence the percentage of the removal of As(III) depend on the initial concentration.

Summary and Conclusion

The chapter opens with a brief discussion of polymers, historical development of polymers, properties of polymers, synthesis of copolymers, surface modification of copolymers, various applications of copolymers and their surface modified copolymers, applications of copolymers for environmental/water pollution control and toxicity due to heavy metals with special reference to hexavalent chromium and trivalent Arsenic. Causes, effect and control of pollution have also been discussed in brief. This chapter covers preamble and the detailed exhaustive literature survey concerned with the present research work. The origin of the research problem, aims and objectives (goals to be attained) have also been presented at the end of this chapter.

The present research work is to devoted to synthesize new copolymers and their surface modified forms which worked as potential adsorbents for removal of Cr(VI) and As(III). The characterizations of these potential adsorbents have been done with respect to modern techniques like elemental analysis, FTIR, NMR, XRD, SEM and TGA etc. The practical applicability has been evaluated to prove these copolymers/surface modified copolymers as potential adsorbents for uptake of Cr(VI)

and As(III) from the contaminated water employing batch equilibrium method. In batch equilibrium method the parameters such as pH, contact time, adsorbents dose and initial metal concentration etc. were studied and from the characteristic data and equilibrium data following conclusions have been drawn from the present research investigation.

- Four copolymers could be successfully synthesized in the laboratory and they were abbreviated as RPHF-I, RPHF-II, RSF-I and RSF-II.
- Chitosan coating was successfully done on the surface of RPHF-I, RPHF-II, RSFI and RSF-II to get surface modified copolymers and they were abbreviated as CCRPHF-I, CCRPHF-II, CCRSF-I and CCRSF-II.

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