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SYNTHESIS OF POLYSTYRENE BY FREE RADICAL POLYMERIZATION AND ITS CHARACTERISATION

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Abstract: Polystyrene is a synthetic aromatic thermoplastic polymer made from the styrene monomer. Polystyrene can be clear, hard and rather brittle. In this study, polystyrene is prepared by free radical polymerisation from styrene monomer with 200 mg of Bezoyl peroxide initiator. In the polymerisation process, the carbon-carbon Pi-bond of vinyl group is broken and a chain of polymer is formed. The polymer was characterized by FTIR, XRD and Gel permeation chromatography (GPC) for the determination of Molecular weight. The polydispersity of polystyrene was found to be 2.274.

Index Terms- Polystyrene, Free radicals, Gel permeation chromatography, Polydispersity

I. INTRODUCTION

Plastics are widely used in modern society because of its low cost, strength, durability and versatile properties. One such plastic material, polystyrene finds many applications from thermal insulator to food packaging materials. It has been estimated that approximately 20 million tonnes of polystyrene are produced annually (Schellenberg and Leder, 2006). The polystyrene was obtained by distillation of Storax obtained from Turkish sweet gum trees and was manufactured industrially from the year 1869 (Ignazio Blanco et al. 2020).

Polymers are generally classified into thermoplastics, elastomers and thermosetting based on their properties at different temperature. (Awad and Khalaf, 2019, Job Momanyi, 2019). Thermoplastics are preferred over thermosetting polymers because of its low processing cost. Polystyrene is an aromatic polymer and there are two groups. General purpose polystyrene (GPPS) and high impact polystyrene (HIPS). The environmental degradation and impact caused by polymers can lowered by using recycled polymers (Kalargaris et al. 2017).

Polystyrene is a polymer obtained from monomer styrene, which is a hydrocarbon obtained from petroleum. Polystyrene is used in solid form and it is naturally transparent material, however it can be coloured by adding colourants. Being thermoplastic polymer, polystyrene is in solid form at room temperature but flows if heated above 100ºC (its glass transition temperature). It gets solidified again when it is cooled (Gowarikar et al. 2018).

There are many methods available for the preparation of polymers by radical means (Matyjaszewski, K. 1998, 1996). Polystyrene can undergo copolymerisation easily with monomers such as, vinyl chloride, butadiene, acrylonitrile, acrylates among others giving products with unique properties. The thermal and mechanical properties of modified polystryene finds many applications in industries which improves the elasticity and performance of materials. Ignazio et al (2019) have reported the synthesis of polystyrene nanocomposites with polyhedral oligomeric silsequioxanes which have better resistance to thermal degradation. The effect of quenching induces a ductility to the polymeric materials. Rouabah et al (2012) have reported the effect of quenching method on the mechanical and thermal properties of polystyrene and reported the improvement of the impact strength of the material after quenching carried out at 40°C.

Preparation of composite membrane made of styrene acrylonitrile (SAN) has been reported for the separation of chromic acid from water (Sonny Sachdeva and Anil Kumar, 2008). Arvanitoyannis and Biliaderis 1999 have reported the physical interaction between Polystyrene and starch by mixing these two materials at different ratios.

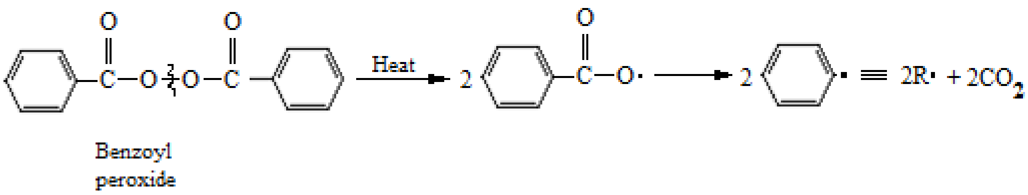
II. MATERIALS AND METHODS

Styrene monomer was purchased from and Benzol peroxide initiator was purchased from . The boiling point of the styrene monomer is around 145°C. Benzoyl peroxide decomposes with the cleavage of its oxygen-oxygen bond at a temperature between 80 and 90°C. First 200mg of benzoyl peroxide initiator was weighed accurately and transferred to a 100ml glass beaker. Then 15 ml of styrene was poured into beaker and stirred using magnetic stirrer until all the benzoyl peroxide get dissolved. The beaker was placed on heating mantle and heated between 80°C to 90°C. The beaker was continuously stirred till the polymerisation process gets over.

After few minutes, the beaker started bubbling with emanation of white smoke. Also volume in the beaker decreased overtime with the increase in the viscosity of solution. To determine completeness of the polymerisation process, a small amount of the solution was extracted using a glassrod and a fibrous string was observed. Then the polymer was poured into a petridish to cool down and solidify. Polystyrene solidifies in the beaker itself while pouring and was difficult to remove. The solidified polystyrene was broken into pieces and used for characterization.

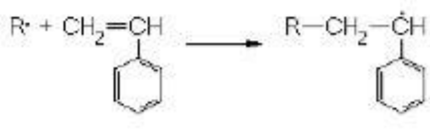
2.1. Mechanism:

Styrene is polymerized by a free-radical polymerisation mechanism. In this polymerization process the initiator benzoyl peroxide decomposes at 80-90°C with the cleavage Oxygen-Oxygen bond to give two benzoyloxy radicals, which then losses carbondioxide to form two benzyl radicals;

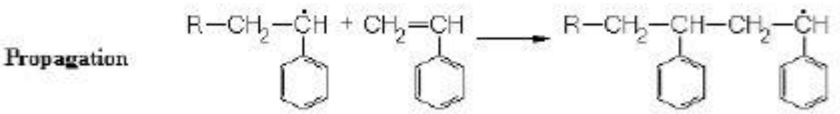


The initiator radicals (R^*) add to the C=C bond of styrene to produce a new, benzyl-type free-radical, as shown below.

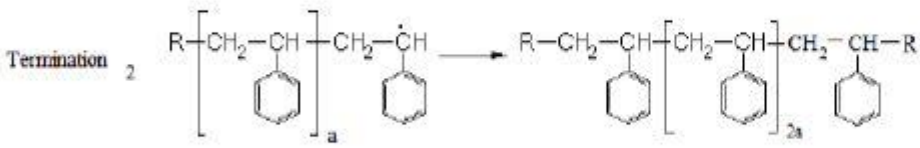
Initiation



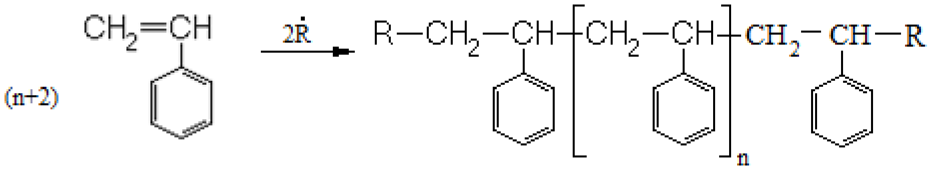
This radical then adds to another molecule of styrene, and the process continuous during which the polymer chain starts to grow:



There is a possibility of addition of 5000 monomer units before the chain is terminated. The contribution to the molecular weight by radical is negligible (0.02%). At last growth of polymer chain is terminated by the combination of two radicals (either both polymer radicals or one polymer radical and one initiator radical).



The overall equation for the polymerization process is as follows



III. RESULT AND DISCUSSION

The polystyrene was characterized by FTIR (Figure 1). The absorption bands at 3500-3000 cm^{-1} are assigned to =C-H aromatic stretching vibration. The peaks at 2900 cm^{-1} and 2800 cm^{-1} are assigned to -CH_2 and –CH aliphatic stretching vibration. The bands at 1630 cm^{-1} and 1550 cm^{-1} indicates deformation vibration of C-H in benzene ring. The bands at 750 cm^{-1} and 699 cm^{-1} can be attributed to C-H out of plane bending vibration of benzene ring.

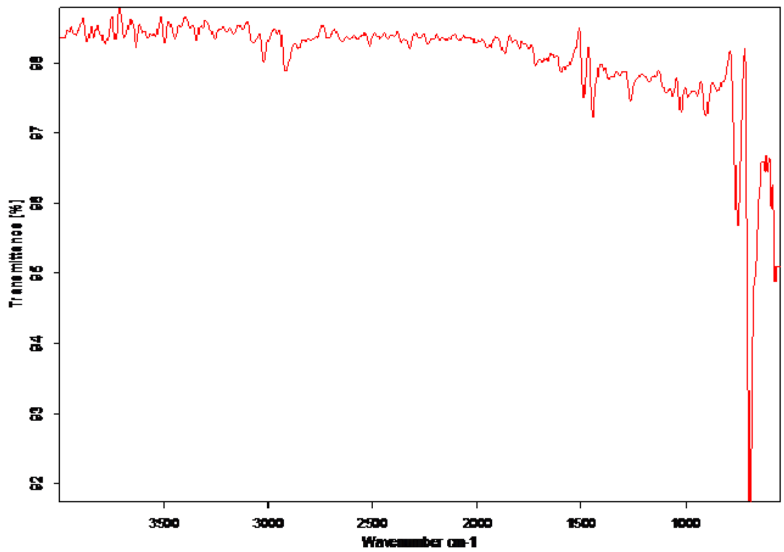


Figure 1. FTIR Spectrum of Polystyrene

The polymer was characterised by X-ray diffraction crystallography (XRD) (Figure 2) which shows that polymer is amorphous in nature.

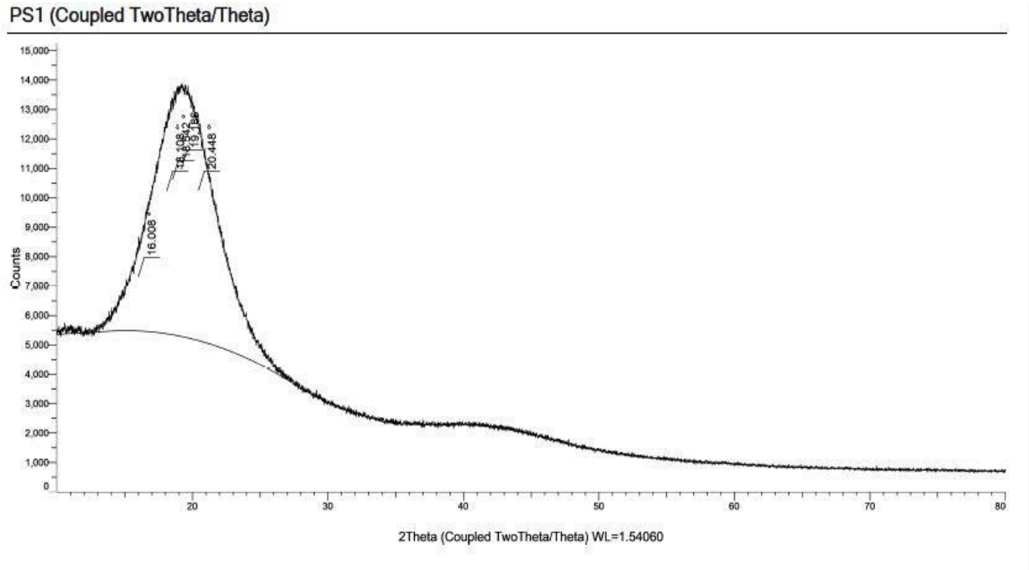


Figure 2. X ray Diffraction of Polystyrene

A polymer molecular structure strongly affects crystallinity. If it is regular and orderely, it will be crystalline otherwise the polymer would be amorphous. There are two kinds of polystyrene one is atactic polystyrene and another one is syndiotactic. The atactic polystyrene is amorphous in nature and syndiotactic is crystalline.

To determine the molecular weight of prepared polymer and polydispersity Gel permeation chromatography (GPC) was carried out and it is shown in Figure 3. Gel permeation chromatography is a type of size exclusion chromatography, that separates polymer on the basis of size, typically in organic solvents. The polymers are seperated to analyze as well as to purify the desired product. When characterizing polymers, it is important to consider the dispersity (Đ) as well the molecular weight. With GPC, number average molecular weight (Mn), the weight average molecular eight (Mw) and the viscosity molecular weight (Mv) can be calculated.

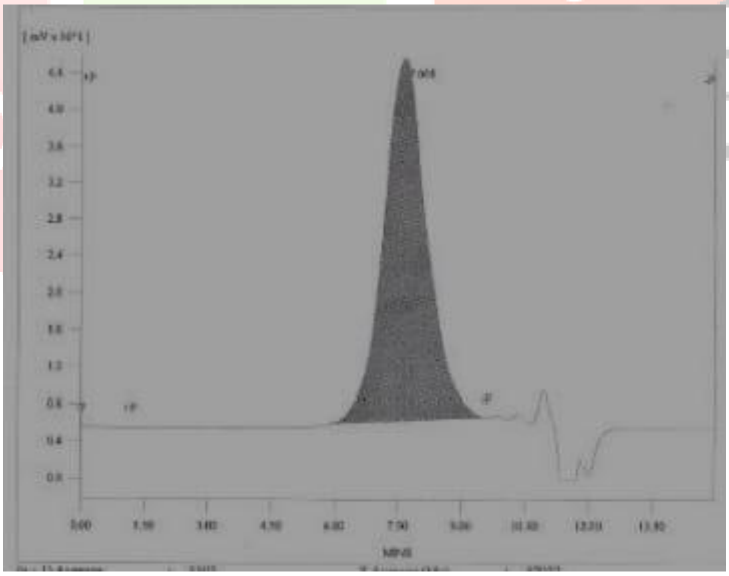


Figure 3. Gel permeation chromatography of Polystyrene

The GPC of polystyrene sample gives the number average molecular weight (Mn) of 7388 and weight average molecular weight (Mw) of 16801. Therefore, the poly dispersity (Mw/Mn) was found to be 2.274.

IV. CONCLUSION

Polystyrene was synthesised from styrene by free radical polymerisation with benzoyl peroxide initiator. The viscosity of the mixture begins to increase when the polymerisation of styrene starts. The viscosity of solution continued to increase until it get completely solidified.

V. ACKNOWLEDGEMENT

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