Effect of Polymer Concentration on Structure and Rheology of Poly (Sodium Acrylate) Hydrogels

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Hydrogels are three dimensional crosslinked polymer networks that are usually swollen in a solvent and also can absorb substantial amount of water. In the present study we have seen the effect of polymer concentration on the rheological properties of poly (sodium acrylate) hydrogels. By rheology it was seen that till polymer concentration of 25 wt% was used, the elasticity as well as the strength of the hydrogel increased after which the value saturated. The loss modulus determined also followed a similar trend but when the polymer concentration was beyond 25wt% a marginal drop was observed. The mechanical spectra of the prepared hydrogels showed the characteristics of a strong gel. Complex viscosity of the hydrogels was also evaluated by experiments which also showed characteristics as same as the mechanical spectra.

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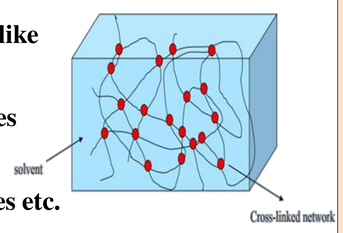
Abstract

The effect of varying initial monomer concentration on the microstructure and rheological properties of poly (sodium acrylate) hydrogel was investigated. It was seen that as polymer concentration increased, mechanical strength and elasticity of the network also increased till 25 wt% beyond which it saturates. The frequency sweep results showed predominant elastic response typical for a strong gel. A solid-like mechanical response was also confirmed by analyzing complex viscosity of respective hydrogels.

BACKGROUND

- Hydrogels are hydrophilic crosslinked three dimensional polymer network.
- Can absorb substantial amount of water.
- Polymer network is usually swollen in a solv
- Exhibits both solid like and liquid like behaviour.
- Common examples ,polysaccharides DNA/RNA, Mucin-lining the stomach, intestines etc.

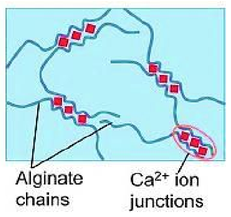


Classification

Crosslinking

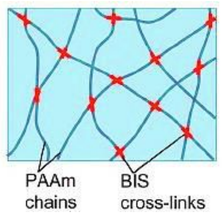
Physical gel

- Non-covalently crosslinked, hydrogen bonding, Vander Waals force etc.
- Reversible gels, sol-gel phase transition.
- Ex: Agarose, gelatin, alginate etc.



Chemical gel

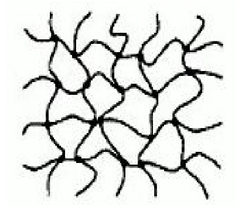
- Covalently crosslinked by strong forces.
- Permanent gels.
- Ex: Poly acrylic acid, Poly vinyl alcohol, Poly sodium acrylate etc.



Structure

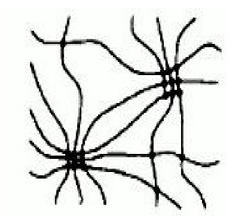
Homogeneous

- Ideal crosslinking
- High polymer chain mobility



Heterogeneous

- Strong interpolymer interaction
- Polymer chains are virtually immobile.



➢ *Many factors effect structure of hydrogels*

- Polymer concentration
- Crosslinker concentration
- Temperature
- Solvent pH

PURPOSE

Why Poly (Sodium acrylate) gels?

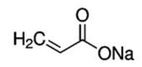
- Polyelectrolyte hydrogel, excellent response to external stimuli.
- Tissue engineering.
- Cell therapy.
- Contact lenses.
- Stem cells.
- Drug delivery.
- Wound dressing.
- Cancer treatment

OBJECTIVES

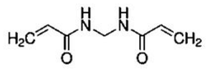
- To investigate the effect of polymer concentration on gel structure.
- To synthesise hydrogels with homogeneous structure
- Using rheology to characterize the mechanical stability of hydrogels.

MATERIALS AND METHODS

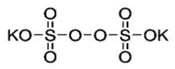
Chemicals used



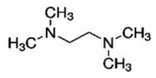
Sodium acrylate (SA)



N,*N*′-Methylenebis(acrylamide) (Bis)

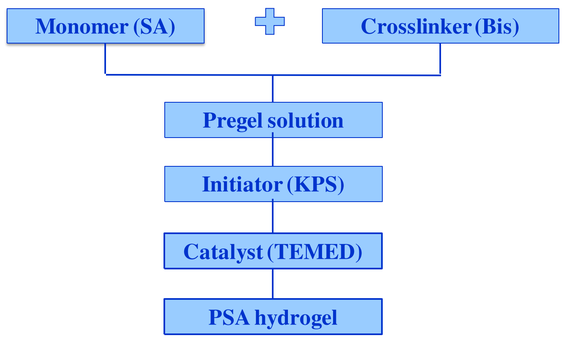


Potassium persulfate (KPS)



N,*N*,*N*′,*N*′-Tetramethylethylenediamine (TEMED)

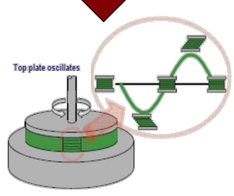
Hydrogel preparation



RHEOLOGY

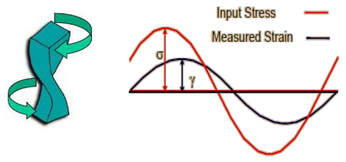
Rheology -the science of **deformation** and **flow**

- Most materials are not completely solid nor completely liquid, they are **viscoelastic**.
- A sample sandwiched between two parallel plates experiences a strain or shear rate.
- Typically a sinusoidal signal is applied to the sample.
- From the shear profile the typical material properties can be calculated.



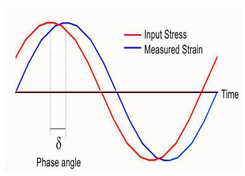
Oscillation plates rotate back and forth

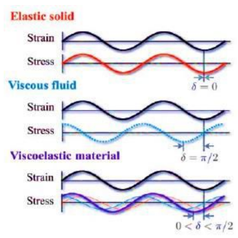
- From oscillation we can measure the complex modulus, the stiffness of the material.
- The higher the modulus, tougher the material.
- Calculated from how much a sample moves for a given force



$$\text{Modulus } (G^* = G' + G'') = \frac{shear\ stress}{shear\ strain} = \frac{\tau}{\gamma}$$

- We can also calculate the phase angle
- Different types of materials have different phase angle between applied and measured signal





- Phase angle $< 45°$ –solid like
- Phase angle $> 45°$ –liquid like

RESULTS AND DISCUSSION

Strain Sweep

- At low applied strain and within LVR G'>G", has behaviour more close to solid than liquid.
- At higher shear strain, hydrogel exhibited non-linear viscoelastic behaviour, both G' and G" decrease, followed by a cross-over.
- All hydrogel samples showed **viscoelastic** response with change in applied strain.
- With rise in polymer concentration G' increased, indicating enhancement of gel strength.

Frequency sweep

- G' is an order of magnitude higher than G", predominance of elastic response over viscous behaviour. Signature of **strong gel**.
- As polymer concentration increases, rigidity of the sample also increases.
- The loss modulus also increases, with increase in polymer concentration upto $25wt\%$ after which there is a marginal drop for $30wt\%$ polymer concentration.

Complex viscosity

Complex viscosity was analysed using

$$\eta^*(\omega) = \frac{(G'^2 + G''^2)^{1/2}}{\omega}$$

Complex viscosity shows a power law dependence with frequency

$$\eta^*(\omega) = \omega^{-\nu}$$

- For an ideal crosslinked gel exponent=1
- For all the samples only a marginal change in exponent from 0.94 to 0.96 is seen with increase in polymer concentration.
- The hydrogels were basically elastic over the entire frequency range.

CONCLUSION

- ✓ There is an **enhancement** in gel rigidity with rise in polymer concentration till $25wt\%$ beyond which it saturates.
- ✓ The loss modulus shows **perfect correlation** with storage modulus.
- ✓ All the samples show characteristics of **strong gel** system, storage modulus values two orders of magnitude higher than loss modulus values.
- ✓ Thus hydrogels with **desired microstructural** properties to suit specific applications can be synthesised.

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Acknowledgments

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