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Synthesis and Properties of a Novel Water-Soluble Lactose-Containing Polymer and Its Cross-Linked Hydrogel

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ABSTRACT: A simple and efficient method for the synthesis of lactose-based homopolymers from lactose *O*-(*p*-vinylbenzyl)oxime (**4**) is described. Free radical polymerization of the new oxime monomers proceeded smoothly in an aqueous solution using potassium persulfate (KPS) and *N*,*N*,*N*′,*N*′-tetramethylethylenediamine (TMEDA) as the initiating system and gave water-soluble homopolymers in good yields. These synthetic lactose-based polymers had high molecular weights and narrow polydispersities (M_w/M_n: 1.20−1.35) as determined by size exclusion chromatography, in conjunction with multiangle laser light scattering (SEC−MALLS). The Mark−Houwink equation was obtained as $[\eta] = 2.15 \times 10^{-4} M_v^{0.73}$. When the monomer was copolymerized with the cross-linking reagent *N*,*N*′-methylenebis(acrylamide) (BisA) (16% mol), hydrogels were formed which swelled as much as 21-fold in deionized water. These gels have potential applications as biocompatible materials.

Introduction

Synthetic polymers containing side chain carbohydrates are considered high-value polymeric materials due to their potential as biocompatible materials with medical applications. These applications are generally based on the fact that cell−cell interactions between ogliosaccharides and lipids play an important role in various life processes. In order to understand these carbohydrate−protein interactions on a molecular level, Nishimura et al.[1−6] synthesized a number of glycoconjugates and studied their binding specificity with lectins. Their recent results[5] established that glycopolymers of related disaccharide derivatives have enhanced binding capacity with lectins based on a polymer sugar-cluster effect while synthetic trisaccharide or small sugar derivatives exhibit only weak affinity to the hemagglutinin molecules.[7] Biological characteristics of the sugar moiety have been successfully applied to the cell recognition marker of artificial carbohydrate polymers. For example, Kobayashi et al.[8] have reported the synthesis of polystyrene having pendant lactose residues and its application as substratum for liver cell cultures.

To date, there are several methods for the preparation of polymers having saccharide side-chain moieties based on ether,[1,5,6,9] amide,[3,8,10−13] urea,[14] and ester[15,16] formation. Some of these syntheses involve a number of protecting and deprotecting steps, however, making the process tedious and subject to byproduct formation. Moreover, polymerizability of the carbohydrate monomers is generally restricted due to steric hindrance caused by the bulky carbohydrate side chain, suggesting the usefulness of spacer arms to distance the sugar side chain from the polymerizable double bond. Styrene is relatively large and can form high molecular weight polymers. In addition, alkyloximes are stable in an aqueous medium. On the basis of these two simple observations, we envisioned that condensation of [*O*-(*p*-vinylbenzyl)oxy]amine (**3**, Scheme 1) with lactose would give a potential monomer with high sugar density. Although sugar oximes were prepared more than two decades ago,[17,18] to our knowledge no polymers derived from oxime-linked sugars have been reported.

In the present paper, we describe a facile and efficient method for the preparation of a new type of sugar homopolymer that incorporates oxime-linked pendant lactose moieties. This method involves the synthesis of (alkyloxy)amine **3**, condensation of this (alkyloxy)amine with lactose in pyridine catalyzed by acid, and subsequent free-radical polymerization of the resulting oxime monomer. The homopolymers obtained have high molecular weights and low polydispersities, which should maximize receptor binding affinities. Moreover, these kinds of polymers have potential applications in a variety of functional materials, e.g., hydrogels (obtained when polymerized with cross-linking reagents), drug-delivery systems, and stabilizers in dispersion polymerization.

Experimental Section

Materials. *N*-Hydroxyphthalimide, *N*,*N*′-methylenebis(acrylamide) (BisA), sodium hydride (60% dispersion in mineral oil), α-D-lactose monohydrate, potassium persulfate (KPS), and *N*,*N*,*N*′,*N*′-tetramethylethylenediamine (TMEDA) were obtained from Aldrich Chemical Co. and were used without further purification. Amberlyst 15 (hydrogen form) was purchased from Sigma Chemical Co., and hydrazine monohydrate, from Fisher Chemical. *p*-Vinylbenzyl chloride was obtained from Acros Organics and was used as received. *N*,*N*-dimethylformamide (DMF) was used after drying over 4 Å molecular sieves and subsequent distillation. All other chemicals and solvents were reagent grade and were used without further purification unless otherwise indicated.

General Procedures. Melting points were determined with a melting point apparatus (9100, Elecrothermal Engineering Ltd.) and are uncorrected. The elemental analyses were determined by Midwest Microlabs. High-resolution mass spectra was performed by the Advanced Instrumentation

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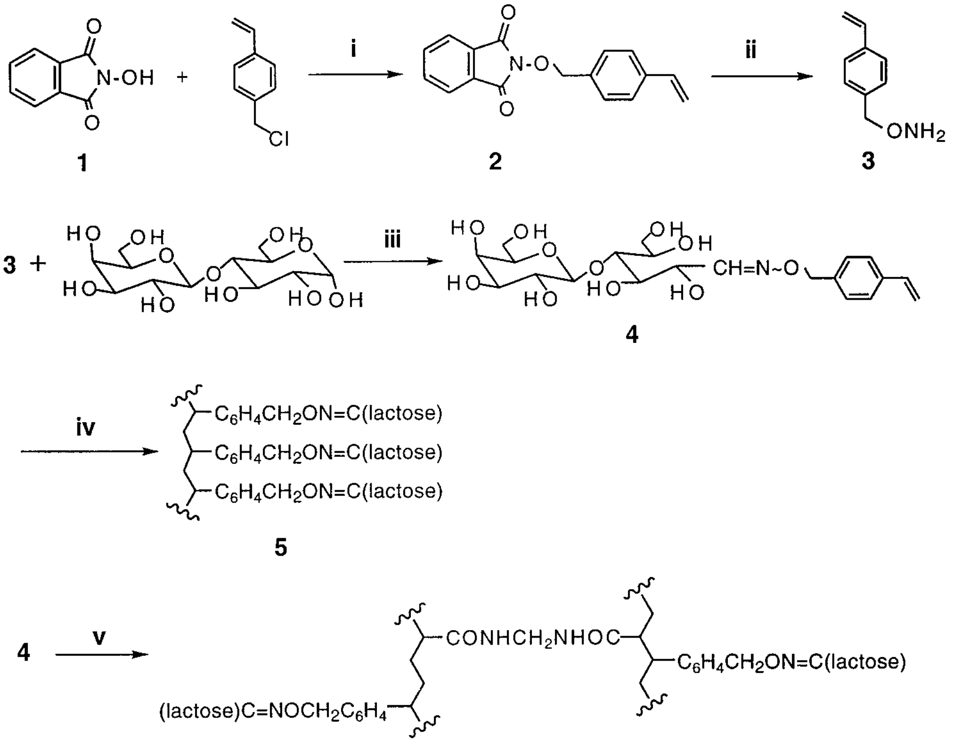
Scheme 1.[a] **Synthesis of Poly(D-lactose *O*-(*p*-vinylbenzyl)oxime) Gels with BisA as Cross-Linker**



[a] Reagents & conditions: (i) sodium hydride, DMF, room temperature, 1 h; then *p* -vinylbenzyl chloride, 50 °C, 10 h. (ii) hydrazine monohydrate, ethanol, reflux, 4 h. (iii) Amberlyst 15, pyridine, 75 °C, 5 h. (iv) KPS-TMEDA, H_2O, 24 h. (v) KPS-TMEDA, BisA, water, room temperature, 7 h.

Facility (University of California, Davis, CA). Optical rotations were determined with a JASCO DIP-370 digital polarimeter at 25 °C. ^{1}H-NMR and ^{13}C-NMR were recorded on a QE-300 instrument (General Electric, NMR-Instrumernts, Freemont CA) operating at 300 MHz in chloroform-*d* or dimethyl sulfoxide-d_6 using tetramethylsilane (TMS) as internal standards. Fourier transform infrared spectroscopy (FTIR) measurements were performed on a Galaxy 3000 FTIR (Mattson, Madison, WI) using KBr disks or neat samples between NaCl plates. Reactions were monitored by thin-layer chromatography (TLC) on a precoated plate of silica gel $60F_{254}$ (layer thickness, 0.25 mm; E. Merck, Darmstadt, Germany). All aqueous solutions were prepared with deionized water that had been passed through a Millipore Milli-Q plus water purification system. Homopolymer intrinsic viscosities were determined at 30.0 °C in millipore water using an Ubbelohde suspended level viscometer. Thermal stability studies were performed using a thermogravimetric analyzer (TGA) (TGA-50, Shimadzu). The temperature range in these experiments encompassed 30−700 °C at a heating rate of 20 °C/min using a dry nitrogen purge at a flow rate of 50 mL/min. Differential scanning calorimetry (DSC) was carried out under a nitrogen atmosphere on a Shimadzu DSC-50 instrument.

Molecular weight measurements of polymer samples were performed at room temperature in 0.1 M $NaNO_3$ aqueous solution using a Waters Ultrahydrogel column containing cross-linked methacrylate gel as the matrix material at a flow rate of 0.67 mL/min. Light scattering measurements were performed using a Wyatt Technology DAWN-F DSP instrument equipped with an He−Ne laser (λ_0 = 632.8 nm), and duplicate measurements were performed in all cases. The weight-average molecular weight (M_w), number-average molecular weight (M_n), and the polydispersity index (M_w/M_n) were obtained using Astra software.

***N*-(*O*-(*p*-Vinylbenzyl)oxy)phthalimide (2).** *N*-Hydroxyphthalimide (**1**; 16.32 g, 0.10 mol) was dissolved in 150 mL of dry DMF and placed in a round-bottom flask equipped with a condenser that was fitted with a drying tube. Sodium hydride (4.8 g, 60% in mineral oil, 0.12 mol) was added to the above solution at room temperature, and the color changed from light yellow to red. The reaction was kept at room temperature and stirred for an additional 1 h at which time *p*-vinylbenzyl chloride (15.30 g, 0.10 mol) was added. The flask was placed in an oil bath at 50 °C and, after 10 h, the solvent was removed under reduced pressure. The residue was dissolved in 150 mL of chloroform, and the solution was washed with aqueous 0.20 N sodium hydroxide solution and water and then concentrated. The product was crystallized from cyclohexane twice to yield 23.4 g (84%) of light yellow crystal. TLC (EtOAc/hexane 1:1) R_f 0.80. Mp: 123.0−123.5 °C. ^{1}H NMR (300 MHz, $CDC1_3$): δ 5.19 (s, 2H), 5.26 (d, J = 10.9 Hz, 1H), 5.75 (d, J = 17.6 Hz,1H), 6.69 (dd, J = 17.6 Hz, 10.9 Hz, 1H), 7.40 (d, J = 8.1 Hz, 2H), 7.49 (d, J = 8.1 Hz, 2H). 7.75 (m, 4H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 79.36, 114.59, 123.31, 126.19, 128.69, 129.95, 133.02, 134.28, 136.16, 138.35, 163.31. IR (KBr disk): 3056, 3027, 2925, 2890, 2850, 1789, 1737, 1629, 1464, 1384, 1186, 1130, 1081 cm^{-1}.

[*O*-(*p*-Vinylbenzyl)oxy]amine (3). One equivalent of *N*-(*O*-(*p*-vinylbenzyl)oxy)phthalimide (14.0 g, 0.05 mol) was dissolved in 125 mL of ethanol in a 250 mL, three-necked, round-bottom flask fitted with a reflux condenser and mechanical stirrer. After refluxing for 0.5−1 h, the starting material dissolved. To this mixture was added dropwise a solution of 1.5 equiv of hydrazine monohydrate (3.75 g, 0.075 mol) in 10 mL of ethanol. After the addition was complete, a white stiff crystalline mass started to precipitate. Refluxing and vigorous mechanical stirring were continued for 4 h, at which time the precipitate was filtered off and the filtrate was concentrated to dryness. The combined solids were mixed with an aqueous potassium hydroxide solution (15 g of KOH and 85 mL of water), and the aqueous mixture was extracted with anhydrous ether several times (1 × 100 mL, 4 × 50 mL). The combined ether solutions were then washed with four portions of 30 mL 2% aqueous potassium carbonate solution and dried over anhydrous potassium carbonate. The ether was evaporated to yield a viscous light yellow liquid; yield 95% (7.09 g). TLC (EtOAc/hexane 1:1) R_f 0.61. ^{1}H NMR (300 MHz, DMSO-d_6): δ 4.63 (s, 2H), 5.24 (d, $J = 10.9$ Hz, 1H), 5.79 (d, $J = 10.7$ Hz, 1H), 6.03 (s, 2H), 6.71 (dd, $J = 10.7$ Hz, 10.9 Hz, 1H), 7.33 (d, $J = 8.0$ Hz, 2H), 7.42 (d, $J = 8.0$ Hz, 2H), ^{13}C NMR (75 MHz, DMSO-d_6): δ 77.02, 114.05, 126.18, 128.52, 136.65, 136.66, 138.13. IR (neat, NaCl plate): 3315, 3243, 3085, 3047, 3024, 3004, 2914, 2854, 1629, 1583, 1512, 1425, 1361, 1187, 991, 910, 825 cm^{-1}.

D-Lactose *O*-(*p*-Vinylbenzyl)oxime (4). One equivalent of α-D-lactose monohydrate (9.05 g, 0.025 mol) was dissolved in 200 mL of pyridine in a 500 mL round-bottom flask fitted with a reflux condenser. To this was added 5.3 g of solid acid Amberlyst 15 followed by dropwise addition of 1.1 equiv of [*O*-(*p*-vinylbenzyl)oxy]amine (**3**, 4.10 g, 0.028 mol) dissolved in 15 mL of pyridine using 3−4 drops of nitromethane as the inhibitor. After the addition was complete, the reaction mixture was heated to 75 °C for 5 h. After this time, the solid acid was removed by filtration and the solvent was evaporated under reduced pressure to give a foamlike solid. The solid was redissolved in methanol, the mixture was filtered, and the filtrate was precipitated in anhydrous ether. The resulting white powder was dried to yield 10.24 g (92%) of **4** [two isomers (*E*:*Z* = 80:20) were obtained]. TLC (metanol) R_f 0.70, $[\alpha]_D$ −1.4 (*c* 0.100 g/dL, water). ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.49 (d, 0.8H) (*E* isomer), 7.45 (d, 2H), 7.33 (d, 2H), 6.80 (d, 0.2H) (*Z* isomer), 6.73 (dd, 1H), 5.83 (d, 1H), 5.25 (d, 1H), 5.20−3.30 (m, 23H). ^{13}C NMR (75 MHz, DMSO-d_6): δ 154.43 (*Z* isomer), 152.56 (*E* isomer), 137.72, 136.77, 136.57, 128.56, 126.36, 124.36, 104.79, 83.92 (*Z* isomer), 81.84 (*E* isomer), 75.57, 74.66, 73.54, 72.09, 71.49, 71.37, 68.89, 68.23, 62.48, 60.52. IR (KBr disk): 3382, 2927, 2886, 1630, 1565, 1407, 1369, 1319, 1047, 914 cm^{-1}. HRMS Calcd for $C_{21}H_{31}NO_{11}$ $(M + H)^+$: 474.1966. Found: 474.1968. Anal. Calcd for $C_{21}H_{31}NO_{11}$: C, 53.39; H, 6.36; N, 3.00. Found: C, 53.07; H, 6.75; N, 2.89.

Homopolymer 5 from Oxime 4 Monomer. An example of the general polymerization procedure is described as follows. Under an inert N_2 atmosphere, a small flask was charged with 20 mL of degassed deionized water (freeze/pump/thaw cycles) and a small magnetic stir bar. Monomer **4** (3.88 g) was added to make a solution, and the flask was placed in a water bath at 30.0 °C. After thermal equilibrium was reached, KPS (16.65 mg, 61.5 mmol) and 0.41 mL of 0.15 M TMEDA aqueous solution (61.5 mmol) was added to the mixture. After 24 h, the flask was removed from the water bath, and the reaction mixture was precipitated in methanol, washed, and dried under reduced pressure to a constant weight. A water-soluble polymer as an amorphous white powder (3.24 g, 84.5%) was obtained: η_{inh} 0.14 (30 °C, water). ^{1}H NMR (300 MHz, DMSO-d_6): δ 7.8−6.8 (brd, ArH and CH−NO), 5.0−4.2 (brd, CH_2 and sugar H), 4.2−3.2 (brd, sugar H). IR (KBr disk): 3473−3403 (broad), 2924, 1633, 1421, 1369, 1074 cm^{-1}.

Hydrogel Synthesis from Oxime Monomer (4). Monomer (**4**, 4.73 g, 0.01 mole) was added to 10 g of degassed water under N_2 in a flask with a stir bar. BisA (0.25 g, 1.6 mmol) was then added, and the flask was kept in a water bath at 25 °C. After thermal equilibrium was reached, KPS (13.52 mg, 0.05 mmol) and 0.33 mL of 0.15 M TMEDA aqueous solution (0.05 mmol) was added to the mixture. The polymerization was continued for 7 h and a gel was formed.

Swelling of Gels and Swelling Ratio Measurement. The gel sample was cut into 80 mg samples and immersed in deionized water at room temperature for a 72 h period. The swelling ratios (SR) of gel samples were measured using a thermogravimetric analyzer (TGA). The sample (ca. 20 mg) was purged with dry N_2 at 70−80 °C[18] until a constant weight was attained. The SR was calculated by dividing the uptaken solvent by the dry weight of the sample.

Results and Discussion

Monomer Synthesis. Having chosen styrene as the basis for a derivative that contains pendant lactose, a synthetic scheme had to be developed to enable derivation of the molecule in such a manner as to allow lactose incorporation. The synthetic route we developed is shown in Scheme 1. The synthesis of compound **3** was based on a similar procedure developed by Kobayashi and co-workers,[19] while both compound **3** and the oxime monomer formation (**3** → **4**) are reported here for the first time.

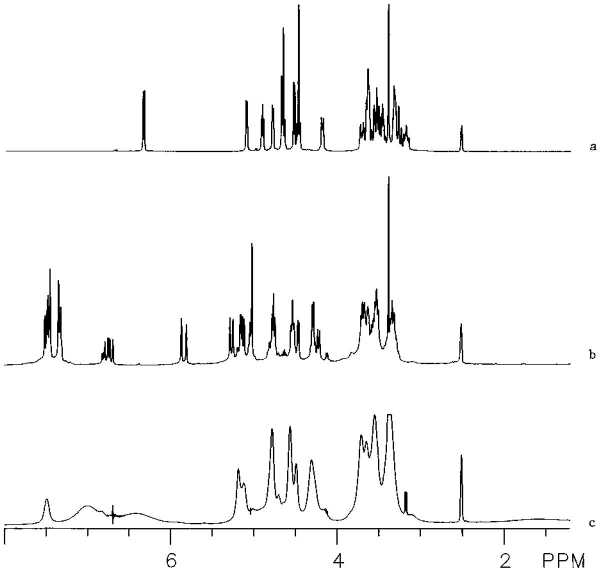


Figure 1. 300 MHz ^{1}H NMR spectra of (a) α-D-lactose (**3**), (b) oxime monomer **4**, and (c) homopolymer **5** in DMSO-d_6.

The first method investigated for the synthesis of **3** was Kashima's.[20] *p*-Vinylbenzyl chloride was added to a mixture of hydroxyamine hydrochloride and 2 equiv of potassium *tert*-butoxide in *tert*-butyl alcohol. Three products were found, and separation on a large scale proved difficult. Fortunately, using another method,[19] pure compound **3** was obtained in high yield by two steps. Thus, deprotonation of *N*-hydroxyphthalimide (**1**) in DMF at room temperature followed by vinylbenzylation, delivered light yellow crystals of compound **2** in 84% yield. Although a compound similar to **2** could be recrystallized in methanol,[15] compound **2**, which was easily crystallized in cyclohexane, could not be crystallized in methanol or ethanol even after refrigeration for 2 days. The hydrazination of compound **2** to **3** was straightforward and of high yield (95%).

In order to examine solvent and acid effects on oxime formation, the reaction was carried out in various media. The solvent systems tested were methanol, ethanol, methanol−water, pyridine, and DMSO. Different acids such as HCl and Amberlyst 15 were also used. The product dissolved in all of the solvents mentioned above, but the results showed that no reaction occurred in methanol, ethanol, or methanol−water systems (with or without acid catalysts). However, both DMSO and pyridine promoted the reaction in excellent yield when catalyzed by Amberlyst 15. The resulting monomer was soluble in water, methanol, ethanol, dimethyl sulfoxide, 1,4-dioxane, *N*,*N*-dimethylformamide, and tetrahydrofuran.

Charateristic IR absorption bands of the amine **3** ($-ONH_2$) and oxime **4** (C=N−O) were found at 3315, 3243, and 1630 cm^{-1}, respectively. The ^{1}H NMR spectral data (Figure 1b) revealed that two isomers (*E* and *Z*) were obtained during the condensation of **3** with lactose; the more stable *E* isomer makes up 80% of the mixture and has the higher chemical shift (7.49 ppm), while the *Z* isomer (20% of the mixture) has a chemical shift of 6.80 ppm. The anomeric proton of lactose is at

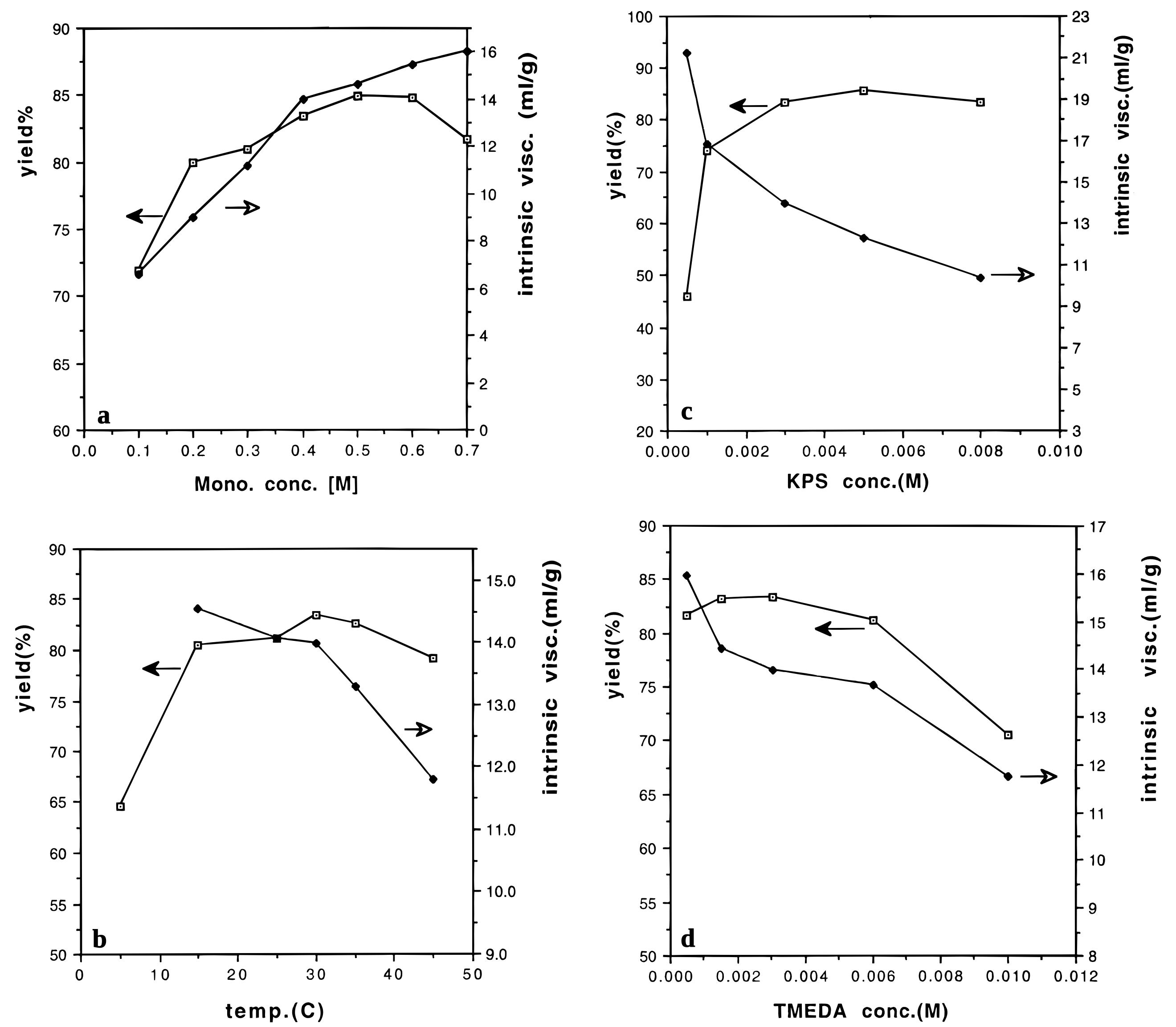


Figure 2. (a) Effect of the monomer concentration on the conversion (*y*%) and polymer intrinsic viscosity. [KPS] = [TMEDA] = 0.003 M, temp. = 30 °C, 24 h. η_{inh}: 30 °C, H_2O. (b) Effect of the polymerization temperature on the conversion (*y*%) of the monomer and polymer intrinsic viscosity. [Monomer] = 0.40 M, [KPS] = [TMEDA] = 0.003 M, 24 h. η_{inh}: 30 °C, H_2O. (c) Effect of the KPS concentration on the conversion (*y*%) of the monomer and polymer intrinsic viscosity. [Monomer] = 0.40 M, [TMEDA] = 0.003 M, temp = 30 °C, 24 h. η_{inh}: 30 °C, H_2O. (d) Effect of the TMEDA concentration on the conversion (*y*%) of the monomer and polymer intrinsic viscosity. [Monomer] = 0.40 M, [KPS] = 0.003 M, temp. = 30 °C, 24h. η_{inh}: 30 °C, H_2O.

6.35 ppm (Figure 1a), and the two amine protons at 6.03 ppm of **3** disappeared upon oxime formation. In addition, the two-proton singlet at 4.63 ppm of **3** was shifted to lower field (5.06 ppm) as a result of the C=N—O group. The ^{13}C NMR spectra also revealed that two isomers were formed, and the chemical shifts of the two oxime carbons appeared at 154.43 and 152.56 ppm for the *Z* and *E* isomers, respectively.

Polymerizations. All homopolymerizations were performed in deionized water using KPS—TMEDA as the initiation system. Under all conditions examined, a homogeneous water-soluble polymer formed during the polymerization. Increasing monomer concentration did enhance the yield to some degree (Figure 2a). However, the yield decreased when the monomer concentration was higher than 0.6 M. Typical of free-radical polymerizations, the intrinsic viscosity of the polymer increased with increasing monomer concentration. The yields exceeded 80% when monomer concentrations ranged from 0.20 to 0.70 M.

Based on the results in Figure 2a, the monomer concentration was set at 0.40 M for subsequent studies. The effect of temperature on yield (%) and intrinsic viscosity of the polymer is shown in Figure 2b. It is commonly known that chain transfer increases with temperature, leading to shorter chains and lower viscosities. Yields exceeded 80% at and above 15 °C and were independant of temperature (when the temperature ≥15 °C). The temperature in subsequent studies was fixed at 30 °C, at which temperature the highest yield was obtained.

Figure 2c shows the effect of KPS concentration on the yield and polymer intrinsic viscosity. When the KPS concentration was 1.0 × 10^{-3} M, the yield was higher than 74%. However, differences in yield were small within a KPS concentration range of 3 × 10^{-3} to 8 × 10^{-3} M. As expected in free radical polymerization, the polymer intrinsic viscosity decreased as the KPS concentration increased. The KPS concentration in subsequent studies was fixed at 3 × 10^{-3} M.

Table 1. Polymerization of Oxime 4

	reaction conditions[a]		polymer				
entry	$[\text{monomer}]_0/[\text{KPS}]_0/\text{TMEDA}]_0$	temp (°C)	yield (%)	$10^{-6}\,M_w$	$10^{-6}\,M_n$	M_w/M_n	$[\eta]$ (mL/g)[b]
1	33:1:1	30	71.8	1.56	1.24	1.25	6.6
2	133:1.67:1	30	85.6	3.87	3.05	1.27	12.3
3	133:1:1	15	80.5	4.16	3.22	1.29	14.6
4	133:1:0.16	30	81.6	6.29	4.65	1.35	16.0
5	133:0.5:1	30	74.1	5.25	4.36	1.20	16.9
6	133:0.16:1	30	45.8	7.20	6.26	1.30	21.2

[a] Polymerization ran in water for 24 h. [b] Determined in water at 30 °C.

Figure 2d shows the TMEDA concentration influence on the yield and intrinsic viscosity at a fixed concentration of monomer (0.40 M) and KPS (3 × 10^{-3} M). The yields (generally ≈80%) appear independent of TMEDA concentration except for a low yield at 10^{-2} M TMEDA. The intrinsic viscosity decreased as the TMEDA concentration increased. These results are consistent with the results reported by Feng[21] and Yao,[22] but contrary to the results reported by Gupta and Bansil.[23] TMEDA accelerates the homolytic scission of KPS, yielding the sulfate free radical ($SO_4^{\bullet -}$) TMEDA free radical $(CH_3)_2NCH_2CH_2(CH_3)NCH_2^{\bullet}$ and the hydroxyl ($HO^{\bullet}$) radical.

Polymer Characterization. Polymer properties were determined by size exclusion chromatography–multiangle laser light scattering (SEC–MALLS), viscometry, and thermogravimetric analysis (TGA). The weight-average molecular weight (M_w) and number-average molecular weight (M_n) were measured by SEC–MALLS and are summarized in Table 1. Comparing the feed ratios of entries 1, 2, 3, 5, and 6 with the molecular weight, it is obvious that as the monomer–initiator ratio increases, the molecular weight also increases. Also, for entries 3 and 4, both having the same monomer–KPS feed ratio, the molecular weight is different even though entry 3 was run at low temperature, proving that TMEDA is involved in the initiation and consequently affects the molecular weight. All polydispersities in Table 1 were well below the theoretical limit of 1.5 typical for a free-radical polymerization process. Two possible reasons for low polydispersity are (1) the samples are fractionated by precipitation into methanol and/or (2) the SEC software has truncated the long retention part of the polymer peak.

The correlation between molecular weight and intrinsic viscosity, expressed by Mark–Houwink (M–H) parameters, was obtained as $[\eta] = 2.15 \times 10^{-4} M_v^{0.73}$ (M_v = viscosity-average molecular weight) (see Figure 3) for a M_w in the range of 1.56×10^6 to 7.20×10^6. The value $a = 0.73$ suggests that water is a good solvent for the resulting polymer.

Thermal stabilities of lactose, monomer, and homopolymer can be seen from Figure 4. All of the samples were heated at a steady rate as weight loss was monitored. It is obvious that lactose has a low thermal stability, while the homopolymer starts to decompose at a temperature of 248 °C. The temperatures where 50% weight loss occurs for lactose, monomer and polymer are 316, 370, and 417 °C, respectively. Clearly, there is a two-stage degradation for the polymer; the first is degradation associated with the sugar moieties, and the second is the thermal degradation of the polystyrene main chain. The absence of a crystallization peak in the DSC study indicates the amorphorous nature of this polymer.

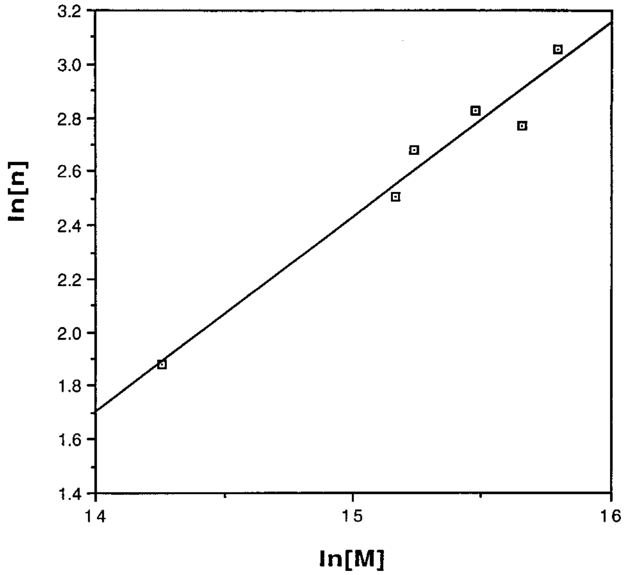


Figure 3. Mark–Houwink relationship for linear homopolymer **5** in water at 30 °C in the range (1.56–7.20) × 10^6. $[\eta]$ in $cm^3/g = 2.15 \times 10^{-4} M_v^{0.73}$.

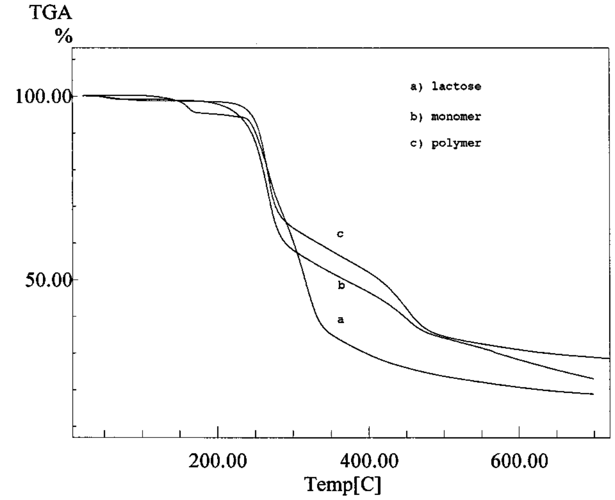


Figure 4. Thermogravimetric curve for (a) α-D-lactose, (b) oxime monomer **4**, and (c) homopolymer.

Hydrogel synthesis was performed in water to take advantage of the high aqueous solubility of the sugar monomer and the high swelling ability of the resulting hydrogel. The initiator was still the KPS–TMEDA system to take advantage of its low initiation temperature (room temperature or even lower) and consequently increase the network of the gel. Gelation at room temperature occurred within 1 h under the given conditions. To ensure complete reaction, the mixture was maintained at room temperature for an additional 6 h. Polymerization in the presence of 1 M monomer concentration and 16% BisA (mol % relative to total monomer) resulted in a gel that absorbed ≈21-fold its dry weight in water. This novel sugar monomer is currently being used to synthesize copolymer hydrogels in our lab.

Conclusions

The main conclusions of the work are as follows:

1. Oxime monomer is obtained in three steps with a yield of 73% and can be homopolymerized in aqueous solution using KPS−TMEDA as the initiator with a yield as high as 85%.

2. The homopolymer has a narrow polydispersity (M_w/M_n: 1.20−1.35) compared with the general free-radical polymerization and high molecular weight (M_n ranged from 1.24×10^6 to 6.26×10^6).

3. The sugar monomer can be cross-linked by *N,N′*-methylenebis(acrylamide) (16% mol) and the resulting hydrogel has a swelling ability as high as 21-fold in water.

4. The polymer is amorphous and has a high thermal stability.

This kind of synthetic carbohydrate polymer may be useful as a new type of biocompatible material with a high potential of developing advanced functions. On the basis of their characteristics, hydrogels produced in this manner are potentially useful in biomaterials.

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