

SYNTHESIS OF A NOVEL POLYFLUOROALKYL SUBSTITUTED 2-HYDROXYETHYL ACRYLATE AND ITS COPOLYMERS*

YANG Jin (杨进) and HUANG Weiyuan (黄维垣)

(Laboratory of Organofluorine Chemistry, Shanghai Institute of Organic Chemistry,

The Chinese Academy of Sciences, Shanghai 200032, China)

ABSTRACT

Polyfluoroalkyl substituted 2-hydroxyethyl acrylate **6** was synthesized in six steps using glycerol as a starting material. A preliminary investigation has been taken on the synthesis and characterization of copolymers of **6** and 2-hydroxyethyl methacrylate.

INTRODUCTION

2-Hydroxyethyl acrylate, methacrylate (HEMA) and their polymers had been investigated widely and thoroughly as water-soluble polymers applied in coating, medical materials and optical materials^[1]. Poly(2-hydroxyethyl methacrylate) and poly(2-hydroxyethyl methacrylate-co-methyl methacrylate) had been applied as plastic lenses and contact lenses in the early 60's^[2].

Fluorocarbons possess excellent solubility of oxygen and perfluorocarbon derivatives had been used as blood-substitute and oxygen-carrier^[3]. Incorporation of fluorocarbon residue into these polymers will significantly improve their oxygen transporting properties. Furthermore, due to the high hydrophobicity of fluorocarbon residue, fluorine-containing water-soluble polymers possess typical amphoteric properties and were used as polymer surfactants^[4]. Until now, there are few reports on the synthesis of fluorine-containing 2-hydroxyethyl acrylate^[5]. In the present article, we would like to report a novel and efficient method of synthesis of a fluorine-containing 2-hydroxyethyl acrylate and its copolymers.

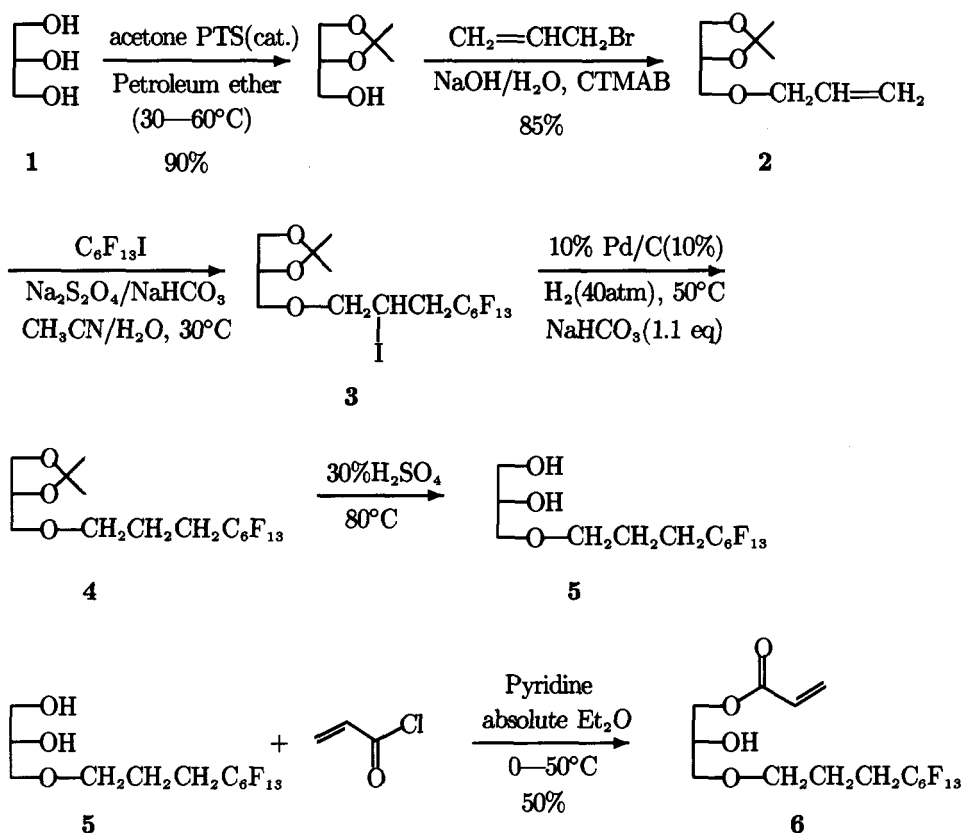
Dedicated to Professor Qian Renyuan on the occasion of his eightieth birthday

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RESULTS AND DISCUSSION

The synthetic scheme of the monomer is shown as follows, thus:



PTS=para-toluenesulfonic acid, CTMAB=cetyltrimethylammonium bromide.

Glycerol 1, 2-acetonide^[6] was converted to the corresponding 3-O-allyl ether (2) by reaction with allyl bromide and aqueous sodium hydroxide solution in the presence of a phase transfer catalyst. Reaction of 2 with perfluoroalkyl iodide initiated with sodium dithionite gave 3. In order to avoid the use of highly toxic organotin compounds for the hydrodeiodination of 3, we chose to use Pd/C catalyzed high pressure hydrogenation to give 4 in high yields.

Acid hydrolysis of 4 gave 1-O-(3-polyfluoroalkyl) glycerol (5), which could also be synthesized from 2 directly through perfluoroalkylation, reduction and hydrolysis, without purification of the intermediates in an overall yield of 40%.

The selective esterification of 5 with acryloyl chloride and pyridine following the method reported by Paleta et al.^[5] gave the monomer 6 in good yield.

So the titled monomer 3-O-polyfluoroalkyl glycerol 1-acrylate 6 was synthesized

in six steps in an overall yield of 15% from glycerol.

As a preliminary study, we chose to copolymerize the monomer **6** with hydroxyethyl methacrylate in aqueous DMF. Thus, a varying amount of fluoromonomer **6** and 10 mmol 2-hydroxyethyl methacrylate were dissolved in the mixed solvent of 4ml DMF and 6ml water and purged with nitrogen for 30 min. The mixture was stirred in a 50°C oil bath and the initiator ammonium persulfate (1 mol% of total monomers) was then injected into the mixture. The polymerization was continued for 18 h at 50°C. After that, the solution was poured into excess methanol, and the precipitate was collected and dried in a vacuum oven at 40°C for 24 h to give the copolymer. The detailed results are shown in Table 1.

Table 1 The copolymerization of **6** and 2-hydroxyethyl methacrylate

Entry No.	Fluoromonomer content in the total monomer mixture (mol%)	Polymer conversion (%)	Fluorine content in polymers* (wt%)	Fluoromonomer content in polymers (mol%)	Intrinsic viscosity (dl/g)**	Molecular weights of copolymers ($\times 10^{-4}$)
CP-F6-A	2.0	84	1.91	0.92	1.086	2.0
CP-F6-B	1.3	90	0.97	0.46	1.135	2.13
PHEMA	—	95	—	—	3.45	10.4

* Determined by anionic chromatography

** Measured by capillary viscometer at $30 \pm 0.1^\circ\text{C}$ in DMF solution

The fluorine content (weight content) in the polymers could be determined by anionic chromatography so the fluoromonomer **6** content in the copolymers could be calculated using the following equation:

$$\text{Fluoromonomer content (mol\%)} = 116 \times F\% \div (247 - 390 \times F\%)$$

where F: fluorine content in copolymers determined by anionic chromatography. The results (shown in Table 1) indicated that the fluoromonomer **6** could be introduced into the copolymers with satisfactory conversion. In other words, it means that the method of solution polymerization is suitable for copolymerization of fluoromonomer **6** with 2-hydroxyethyl methacrylate.

The intrinsic viscosities of the polymer solution in DMF measured at $30 \pm 0.1^\circ\text{C}$ by capillary viscometer are shown in Table 1. Because of the low content of fluoromonomer **6** in the copolymers, the molecular weights of these copolymers could be estimated based on the Mark-Houwink-Sakurada equation as follows^[7]:

$$[\eta] = 10.6 \times 10^{-3} M^{0.7}$$

The lower values of intrinsic viscosities and calculated molecular weights of these copolymers as compared to that of poly(2-hydroxyethyl methacrylate) may be related to a lower polymerization rate of fluoromonomer **6** than to that of 2-hydroxyethyl methacrylate.

Further study on the properties of these copolymers is in progress.

EXPERIMENTAL

All melting points and boiling points were uncorrected. IR spectra were measured with Shimadzu IR-440 spectrometer using liquid films and KBr pellets for solid. ^1H NMR spectra were recorded on Varian EM-360A, FX-90Q, AM-200 and AMX-600 spectrometer using TMS as internal standard. ^{19}F NMR spectra were recorded on EM-360L spectrometer at 56.4 MHz using TFA as external standard. In ^{19}F NMR spectra, chemical shifts (ppm) were positive for upfield shifts. Mass and HRMS spectra were taken on a Finnigan GC-MS-4021 spectrometer. Fluorine content was measured using ionic chromatography Dionex 2010i from Dionex Corporation. The column chromatography was performed by using silica gel H, particle size 10–40 μ purchased from Qingdao Ocean Chemical Factory.

Preparation of compound 2

According to the method in ref. [8].

Preparation of compound 3.

A mixture of 20 mmol compound **2**, 22 mmol perfluoroalkyl iodide dissolved in 30 ml CH_3CN and 7 ml water was stirred in 30°C, a mixture of 3 g $\text{Na}_2\text{S}_2\text{O}_4$ and 1.5 g NaHCO_3 was then added batchwise. After that, the mixture was stirred for 4 h. The progress of the reaction was monitored by ^{19}F NMR. After the completion of the reaction the mixture was cooled to room temperature, 30 ml water was added and then extracted with ether (3 $\times$ 30 ml), the organic layer was washed with saturated NaCl solution, dried over anhydrous Na_2SO_4 . After removal of solvent the residual mass was purified through a short chromatographic column and used directly in the next step.

Preparation of compound 4

A mixture of compound **3**, 1.1 eq NaHCO_3 and 10 wt% Pd/C in 40 ml anhydrous ethanol was placed in 100 ml autoclave. Hydrogen was pressed in and pressurized to 40 atm. The autoclave was stirred at 50°C for 38 h until no more hydrogen absorption was observed, the content was then cooled to room temperature, excess hydrogen gas was bled off, and the mixture was filtered. After removal of solvent the residual mass was used in the next step directly without further purification.

Preparation of compound 5

Compound 4 dissolved in 50 ml 4 N H_2SO_4 solution was stirred at 80°C for 6 h. After cooled to room temperature, 50 ml ethyl acetate was added. The mixture was then neutralized with solid NaOH to $\text{pH}=6-7$, and the organic layer was separated, the aqueous layer was extracted with ethyl acetate (3×40 ml), the combined organic layer and the ethyl acetate extracts were dried over anhydrous Na_2SO_4 . After removal of organic solvent, the residue was purified through a chromatographic column to give compound 5^[8].

$^1\text{H NMR}$ ($(\text{CD}_3)_2\text{CO}$), δH (ppm): 1.7–2.4 (6 H, m, $2\text{OH}+2\text{CH}_2$), 3.4–4.0 (7 H, m,)

$^{19}\text{F NMR}$ ($(\text{CD}_3)_2\text{CO}$), δF (ppm): 4.9 (3 F, s, CF_3), 38.2 (2 F, s, $-\text{CF}_2-$), 46.2, 47.2, 50.3 (8 F, m, 4CF_2).

Preparation of compound 6

A mixture of 5 mmol compound 5, a small amount of p-methoxyphenol and 10 mmol anhydrous pyridine in 30 ml anhydrous ethyl ether was stirred with external ice-water bath cooling. Ten mmol acryloyl chloride dissolved in 5 ml anhydrous ethyl ether was added dropwise. The mixture was stirred for 2 h at 0°C and then heated to 40°C and the stirring was continued at this temperature for 6 h. After cooled to room temperature, 30 ml water was added, the resulting mixture was extracted with ethyl ether (3×40 ml), the organic layer was washed with saturated NaCl solution and dried over anhydrous Na_2SO_4 . After removal of organic solvent, the residue was purified through column chromatography to give compound 6.

$^1\text{H NMR}$ (CD_3OD), δH (ppm): 1.7–2.5 (2 H, m, $-\text{CH}_2-$), 2.8–3.2 (2 H, m, $-\text{CH}_2\text{CF}_2-$), 3.8–4.35 (7 H, m), 5.82 (1 H, d $\times$ d, $=\text{CH}_2$, $^3J_{\text{HH}}=10.3\text{ Hz}$), 6.1 (1 H, m, $-\text{CH}=\text{CH}-$), 6.45 (1 H, d $\times$ d, $=\text{CH}_2$, $^3J_{\text{HH}}=10.3\text{ Hz}$); $^{19}\text{F NMR}$ ($(\text{CD}_3)_2\text{CO}$), δF (ppm): 4.9 (3 F, s, CF_3), 38.2 (2 F, s, $-\text{CF}_2-$), 46.2–50.3 (8 F, m, $-\text{CF}_2-$); MS (m/z): 507 (M^++1), 19.08), 489 (M^+-OH , 100), 417 (13.70), 129 (66.39); IR (film): 3440 (OH), 3010, 1760, 1660, 1260, 1180; HRMS: (for $\text{C}_{15}\text{H}_{15}\text{O}_4\text{F}_{13}$): Calc: 506.0763; Found: 506.0821.

Polymerization

A mixture of 10 mmol 2-hydroxyethyl methacrylate and varying amount of compound 6 dissolved in 4 ml DMF and 6 ml deionized water in 50 ml capped round bottomed flask was purged with nitrogen for 30 min. The initiator ammonium persulfate (1 mol% of monomers) was injected into the solution and the mixture was stirred at $50 \pm 0.5^\circ\text{C}$ for 18 h. After cooling to room temperature, the resulting mixture was poured into excess acetone and the polymer was obtained as a white precipitate which was collected by filtration, and dried in a vacuum oven at 40°C

for 24 h before used for characterization.

Characterization of polymers

1. The fluorine content of copolymers was determined by ionic chromatography, the model of the instrument is: Dionex 2010i.

2. The polymers are readily soluble in DMF, the intrinsic viscosities of the DMF solution of these polymers were measured using capillary viscometer at $30 \pm 0.1^\circ\text{C}$.

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Keywords:

3-O-polyfluoroalkyl glycerol 1-acrylate; Synthesis; Copolymerization; 2-hydroxyethyl methacrylate

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