

# Poly[*N*-methyl-*N*-*p*-styrenesulphonylformamide] An Effective *N*-Formylating Agent\*

Ardeshir Khazaei\*\* and Ebrahim Mehdipour

Department of Chemistry, Faculty of Science, University of Bu-Ali Sina, Hamadan, I.R. Iran

Received 3 April 1999; accepted 5 September 1999

## ABSTRACT

In this work poly[*N*-methyl-*N*-*p*-styrenesulphonylformamide] was prepared and used as formylation reagent for various kinds of amines. This polymer can be synthesized from reaction between poly[*N*-methyl-*p*-styrenesulphonamide] and refluxing formic acid. The latter polymer was prepared from free radical polymerization of *N*-methyl-*p*-styrenesulphonamide by using the azobisisobutyronitrile (AIBN) as an initiator. *N*-Methyl-*p*-styrenesulphonamide was synthesized from commercial 4-vinylbenzene sulphonic acid sodium salt, phosphorous pentachloride and methylamine. Poly[*N*-methyl-*N*-*p*-styrenesulphonylformamide] can formylate both aliphatic and aromatic amines in good yields at temperatures of 40–138 °C and in appropriate solvents. One of the advantages in using this reagent is the mild temperature and neutral condition of the reaction system. Also, the synthesized formylating reagent polymer is stable towards heat, air and moisture. The polymer can be recovered and reused. The synthesized compounds including polymeric reagent and *N*-formamides were identified by <sup>1</sup>H NMR, IR spectrometers. The molecular weight of polymer was determined by GPC.

**Key Words:** polymer support, reagent, synthesis, formylation, amines

## INTRODUCTION

Formylation is a very important process in organic synthesis. An excellent review describes the numerous formylating methods and formylating agents available [1]. Typical *N*-formylation agents are formic halides, anhydrides and esters, formic acid and *N*-formyl derivatives. Formylation reactions employing formyl

halides or anhydrides are difficult to carry out due to the instability of these reagents [2]. Isopropenyl formate is a fast formylating reagent, but its preparation involves a multi-step synthesis [3]. Other reagents require the use of expensive catalysts [4–6]. *N*-Formyl derivatives have been extensively used for the formylation of amines, imines and alcohols [2, 7–11].

Commercially available *N*-formylimidazole is

(\*) Part of this paper was introduced in the 13th Congress of Iranian Society of Chemistry and Chemical Eng., February 1999, Tarbiat Modarress University, Tehran, Iran.

(\*\*) To whom correspondence should be addressed.

an effective formylating agent, but it is extremely hygroscopic, becoming liquid in air within several minutes [12]. 4-Formyl-2-methyl-1,3,4-thiadiazoline-5-thione selectively formylates primary and secondary amines under neutral conditions, but it can be troublesome to isolate from 2-methyl-1,3,4-thiadiazoline-5-thione [2]. A major problem following an organic synthesis is the isolation of the desired product free from contaminations due to solvents, catalysis, byproducts and starting materials. We now describe the previously unreported use of the stable and easily accessible poly[*N*-methyl-*N*-*p*-styrenesulphonylformamide] as a convenient *N*-formylating agent. This reaction is based on this fact that nucleophilic attack on the carbonyl group of the reagent occurs easily because the acidity of nitrogen is strong. The synthesized formylated polymer was reacted with various primary and secondary amines to give corresponding formamides with high yields. The recovered polymer was formulated and reused many times without diminishing in activity.

## EXPERIMENTAL

### Apparatus

IR and <sup>1</sup>H NMR spectra were recorded using a Shimadzu 435-U-04 spectrophotometer (KBr pellets) and a 90 MHz Jeol FT-NMR spectrometer, respectively.

### Reagents

Commercial 4-vinylbenzenesulphonic acid sodium

salt was obtained from Fluka AG. All other chemicals were obtained from Merck. The mixture of CF<sub>3</sub>COOH and CDCl<sub>3</sub> were used as solvent for <sup>1</sup>H NMR.

### Preparation of Poly[*N*-methyl-*N*-*p*-styrenesulphonamide]

Poly[*N*-methyl-*N*-*p*-styrenesulphonamide], mp: 180 °C, was prepared on 30 g scale from 4-vinylbenzenesulphonic acid sodium salt, PCl<sub>5</sub>, methylamine and AIBN with respect to literature [13], only instead of ammonia, methylamine was used.

### Preparation of Poly[*N*-methyl-*N*-*p*-styrenesulphonylformamide]

A sample of yellow finely-divided powdered poly[*N*-methyl-*p*-styrenesulphonamide] (6.0 g) was added to 50 mL of formic acid. The mixture was refluxed for 24 h and the formic acid was heated to evaporate for 2 h. The solid was washed twice with distilled water and then it was dried in vacuo. The yield of formylated polymer, mp 145, was 6.2 g (91%).

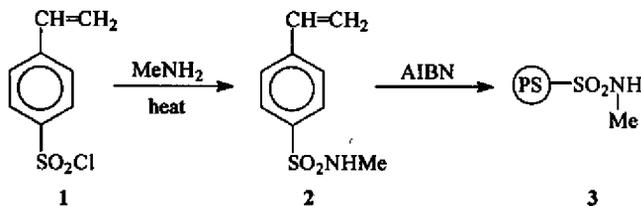
### General Procedure for Formylation of Amines

A solution of amine 5 (10 mmol) was added dropwise to a solution of polymer 4 (15 mmol) in 30 mL THF. The solution was reached to indicated temperature (Table 1). After completion of the reaction (identified by TLC), the water was added and the recovered polymer 3 was isolated by filtration. The CH<sub>2</sub>Cl<sub>2</sub> (2×25 mL) was added to residue and the organic layer was removed. MgSO<sub>4</sub> was used to dry the organic layer. After filtration, the solvent was evaporated to afford the pure compounds.

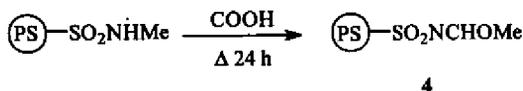
Table 1. *N*-Formamides prepared from the reactions of formylating polymer with various aliphatic and aromatic amines.

Entry	R <sub>1</sub>	R <sub>2</sub>	Solvent	Temperature (°C)	Time (h)	Yield (%)	Melting point (°C)
1	Et	Et	THF	40	0.5	83	*176
2	Me	Me	THF	40	0.7	80	*153
3	PhCH <sub>2</sub>	H	THF	40	1	70	60
4	Ph	H	THF	65	2	70	49
5	1-Naphthyl	H	THF	65	2.5	65	139
6	2-NO <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	H	Xylene	138	6	60	120
7	-CH <sub>2</sub> COOH	H	THF	65	3	65	138

\* = bp



Scheme I



Scheme II



Scheme III

### Reformylation of Recovered Poly[*N*-methyl-*p*-styrenesulphonamide]

The recovered polymer 3 (4.0 g) was reformylated for 24 h as previously discussed. The obtained polymer was reused for formylation.

## RESULTS AND DISCUSSION

Several methods have been used for formylation of

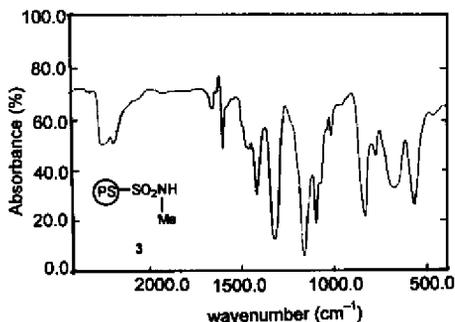


Figure 1. IR Spectrum of poly[*N*-methyl-*N*-*p*-styrenesulphonamide].

amines as discussed previously. The first step of the procedure is based on the reaction of methylamine and *p*-styrenesulphonylchloride and then polymerization was carried out with AIBN according to Scheme I.

IR Spectrum of polymer 3 shows N–H vibration at 3200  $\text{cm}^{-1}$  and S=O absorptions at 1310 and 1170  $\text{cm}^{-1}$  for asymmetric and symmetric stretching, respectively (Figure 1).  $^1\text{H}$  NMR spectrum shows a single peak at 4.22 ppm assigned to N–H group (Figure 2). The molecular weight of polymer was determined by GPC and found to be 5521 before reaction and 5306 after reaction.

The second step was formylation of polymer. The polymer was reacted with refluxing formic acid (for about 24 h) to give *N*-formylated polymer as shown in Scheme II.

IR spectrum of polymer 4 shows C=O stretching vibration at 1700  $\text{cm}^{-1}$  and S=O absorption at 1170 and 1330  $\text{cm}^{-1}$  (Figure 3).  $^1\text{H}$  NMR spectrum shows a single peak at 9.1 ppm assigned to the CHO group (Figure 4). The last step is reaction between formylated polymer and amines (Scheme III).

The formylated polymer reacts with amines to give formamides, which can formylate a variety of amines in good yields (Tables 1 and 2).

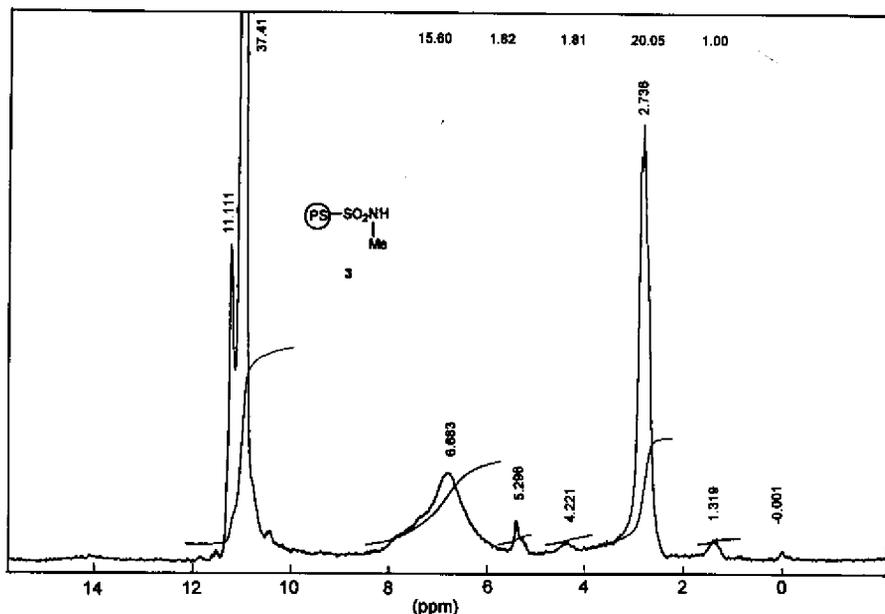


Figure 2. <sup>1</sup>H NMR Spectrum of poly[*N*-methyl-*N*-*p*-styrenesulphonamide].

As demonstrated in Tables 1 and 2, poly[*N*-methyl-*N*-*p*-styrenesulphonylformamide] can formylate aliphatic and aromatic amines in good yields at the temperatures indicated and in THF solvent. Also aliphatic amines are formylated faster than aromatic amines. Even deactivated aromatic amine such as 2-nitroaniline is formylated by this reagent to corresponding formamide on heating.

The IR and <sup>1</sup>H NMR spectra were obtained to identify all the products.

The reagent is stable, non-hygroscopic and resistant to air and heat. As we expect, the nucleophilic attack on the carbonyl group of the reagent occurs easily because acidity of the nitrogen is strong. The reaction is carried out under neutral conditions and the polymer is recovered and it can be reused many times.

Table 2. Identification by <sup>1</sup>H NMR and IR spectrometry for various synthesized formamides.

Compound	<sup>1</sup> H NMR (δ)	IR (cm <sup>-1</sup> )
1a	8.1(1H), 2.8-3(6H)	(1660 C=O)
2b	8.05(1H), 3.7(2H), 1.2(3H)	(1640 C=O)
3c	8.12(1H), 7.15-7.4(5H), 6.75(1H), 4.4(2H)	(1610 C=O), (3200 NH)
4d	9.12(1H), 8.3(1H), 7.05-7.6(5H)	(1650 C=O), (3250 NH)
5e	9(1H), 7.8-7.2(7H), 8.1(1H)	(1650 C=O), (3250 NH)
6f	10.32(1H), 8.8-7.7(4H), 8.6(1H)	(1650 C=O), (3200 NH)
7g	(D <sub>2</sub> O), 8.1(1H), 4.0(2H)	(1820 C=O), (3300 NH)

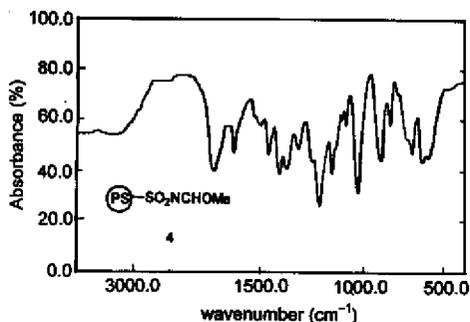


Figure 3. IR Spectrum of poly[*N*-methyl-*N*-*p*-styrenesulphonylformamide].

## CONCLUSION

From the obtained results, we found that poly[*N*-methyl-*N*-*p*-styrenesulphonylformamide] synthesized from the reaction of poly[*N*-methyl-*p*-styrenesulphonylformamide] and formic acid on heating is an effective *N*-

fomylating agent. Poly[*N*-methyl-*N*-*p*-styrenesulphonylformamide] was identified by IR, <sup>1</sup>H NMR and GPC. This polymer is reacted with amines in appropriate solvent and in temperatures indicated.

Poly[*N*-methyl-*N*-*p*-styrenesulphonylformamide] can formylate a wide range of amines including aliphatic and aromatic in excellent yields. The total synthesis and processes of reactions are simple. The reaction condition is easy and also the polymeric reagent is stable and the recovered polymer can be reused. The product can be separated easily, and the purification and identification of prepared formamides are straightforward.

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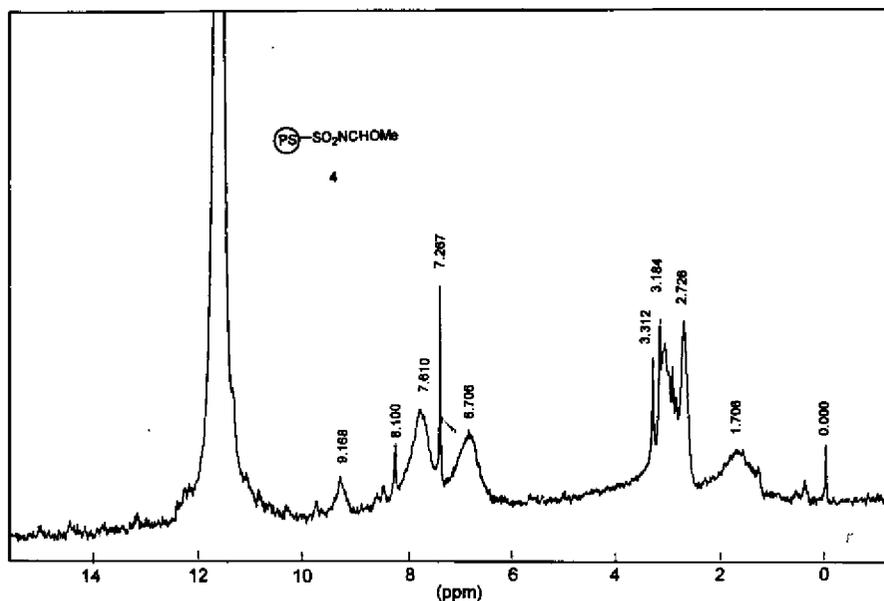


Figure 4. <sup>1</sup>H NMR Spectrum of poly[*N*-methyl-*N*-*p*-styrenesulphonylformamide].

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