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Synthesis and characterisation of 1-methacroyl 3-salicyloyl 2-hydroxy propane and its derivatives – A structure–reactivity kinetic study

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Abstract. 1-Methacroyl-3-salicyloyl-2-hydroxy propane (MSHP) and its derivatives (methyl, methoxy, acetyl, thio, amino, chloro and bromo) have been prepared and characterised on the basis of elemental anaylsis, mass, IR, PMR and ^{13}C–NMR spectroscopic results. Formation of MSHP obeyed second order kinetics with a first order dependence on each of the [reactant] *viz.*, [salicylic acid] and [glycidyl methacrylate]. A structural change (substituent change) in the salicylic acid brought about a change in its reactivity during the formation of MSHP. Second order rate constants are in the order: 5-bromo < 5-chloro < acetyl < H < thio < 4-amino < 4-methyl < 4-methoxy < 4-chloro. Hammett's plot indicated a rho (ρ) value of 0·43. Deviation in the case of *p*-chloro substituent has been explained in terms of resonance interaction energy ($\Delta\Delta G$) parameters. Effective sigma ($\bar{\sigma}$) value of *p*-chloro has been found to be 0·86 with $\Delta\Delta G_p$ being 1·274 cal/mol. Isokinetic temperature (β) is far below the experimental temperature range (325–355 K) indicating the importance of entropy factors in controlling the reaction.

Keywords. 1-Methacroyl-3-salicyloyl-2-hydroxy propane; entropy factor; resonance interaction energy.

1. Introduction

Naturally occurring polymers such as carbohydrates, proteins and nucleic acid have been of interest to chemists in the recent past owing to their immense biological activity. A perusal of literature (Campbell and Sorenson 1961; Billmayer 1971; Braun *et al* 1972) shows that a variety of synthetic high polymers and copolymers have been obtained by the method of radical-induced vinyl polymerisation of olefinic monomers such as acrylamide, acrylonitrile, methyl methacrylate, styrene etc., under varied conditions. However, the synthesis of new monomers such as the title compounds and their utility in polymer chemistry is yet to be explored. Further, it is most convenient to introduce a polymerisable group into salicylic acid (Soutif *et al* 1983) as compared to various other organic compounds. Hence we took up a systematic study of the formation of monomers such as 1-methacroyl-3-salicyloyl-2-hydroxy propane (MSHP) and its derivatives from the interaction of salicylic acid (SA) and its derivatives (methyl, methoxy, acetyl, thio, amino, chloro and bromo). These monomers subsequently yield polymers under radical conditions. A quantitative analysis dealing with the effect of variation of structure on the reactivity of salicylic

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acid during the formation of MSHP, is one of the salient features of the present study. This report forms a part of our study on the "investigation of new organic compounds and their utility in synthetic high polymers".

2. Experimental

All the chemicals used are either E Merck or Fluka (AG) reagents. Benzene, acetonitrile and other solvents are further purified according to standard procedure (Vogel 1978).

2.1 *Synthesis of MSHP compounds*

Addition of salicylic acid (0·015 mol dm^{-3}) to glycidyl methacrylate (0·010 mol dm^{-3}) in the presence of pyridine gave a compound on heating the reaction mixture for 3 h at 75°. The compound thus obtained was washed several times with 5% $NaHCO_3$ and dil. HCl to remove unreacted salicyclic acid and pyridine respectively and its purity was checked by TLC (1:1 benzene, petroleum ether). The purified MSHP gave a violet colour with alcoholic $FeCl_3$.

2.2. *Kinetics of formation of MSHP compounds*

Requisite amounts of glycidyl methacrylate and suitable solvents (acetonitrile or benzene) were pipetted out into the reaction vessel and the reaction was initiated by adding suitable amounts of salicyclic acid at a desired temperature in an inert atmosphere. Progress of the reaction was followed titrimetrically by estimating the unreacted SA with standard alkali to phenolphthalene end point. The results obtained were randomly confirmed by the conductometric method also. Kinetic parameters obtained from both the methods agree well with an error of $\pm$ 3%.

3. Results and discussion

3.1 *Characterisation of MSHP compounds*

The MSHP compounds have been characterised by elemental analysis, IR, PMR and ^{13}C–NMR studies (tables 1 and 2). Boiling points of the MSHP compounds could not be determined owing to the self-association of MSHP to give a polymer. Purity of the compound was checked by TLC. Elemental analysis data agreed well with the expected values as indicated in table 1.

Infrared spectra of the compounds have been recorded on a Perkin-Elmer model 283 B spectrophotometer, using KBr pellets. The IR spectra indicated characteristic peaks at 1710 and 1665 cm^{-1} due to $\rangle C{=}O$ (ester), $\rangle C{=}C\langle$ frequencies respectively. A broad absorption has also been found between 3400 and 3500 cm^{-1} assignable to O–H groups. The aromatic and alkyl peaks are detected at their usual positions according to standard literature reports.

PMR spectra of MSHP compounds have been recorded on an FT–NMR model FX–90 MHz/300 MHz using $CDCl_3$ as solvent. ^{13}C–NMR spectra of MSHP compounds are recorded on a Bruker AM 300 instrument at 75·45 MHz.

Table 1. Analytical data of the MSHP monomer compounds.

Compound (Mol. formula)	Yield %	Elemental analysis found (calcd.) % C	H	Compound (Mol. formula)	Yield %	Elemental analysis found (calcd.)% C	H
MSHP	82	60·01	5·68	4-Me-MSHP	73	61·35	6·18
($C_{14}H_{16}O_6$)		(60)	(5·71)	($C_{15}H_{18}O_6$)		(61·22)	(6·12)
Acetyl-MSHP	74	59·73	5·48	4-MeO-MSHP	71	58·19	5·78
($C_{16}H_{18}O_7$)		(59·73)	(5·59)	($C_{15}H_{18}O_7$)		(58.7)	(5·80)
5-Cl-MSHP	79	59·43	5·18	4-Cl-MSHP	78	53·46	5·18
($C_{14}H_{15}O_6Cl$)		(53·50)	(5·05)	($C_{14}H_{15}O_6Cl$)		(53·50)	(5·05)
5-Br-MSHP	76	46·76	4·26	Thio-MSHP	64	56·79	5·35
($C_{14}H_{15}O_6Br$)		(46·93)	(4·19)	($C_{14}H_{16}O_5S$)		(56·75)	(5·41)
4-NH_2-MSHP	61	57·49	5·06				
($C_{14}H_{17}O_6N$)		(57·34)	(5·12)				

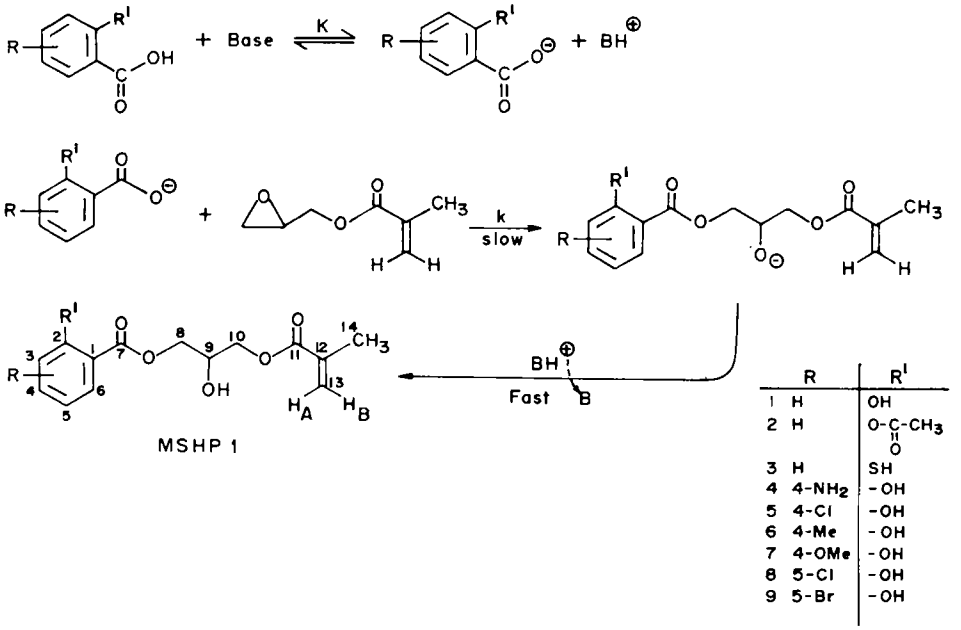
Table 2. NMR spectral data of the MSHP monomer compounds, Solvent = $CDCl_3$

MSHP 300 MHz Protons (^{13}C–NMR)	2-Acetyl MSHP 80 MHz (^{13}C–NMR)**	5-Cl MSHP 80 MHz (^{13}C–NMR)	4-Me MSHP 80 MHz (^{13}C–NMR)	4-MeO MSHP 80 MHz (^{13}C–NMR)**
(112)	—	(112·85)	(112·56)	—
10·6	2·36	10·5	10·3	10·6
(161·65)		(160·16)	(161·05)	
6·97(*d*)	6·9	6·8	6·15	6·2
(119·21)		(119·25)	(117·21)	
7·45(*dd*)	7·4	7·3		3·4
(135·95)		(135·62)	(134·22)	
6·88(*dd*)	6·8	—	6·6(*d*)	6·7
(117·57)			(119·05)	
7·86(*d*)	7·8	7·7	7·5	7·4
(129·86)		(129·05)	(128·27)	
	3·9–4·5*			
(169·82)		(168·91)	(170·20)	
4·46–4·56(*M*)	3·9–4·5*	4·1–4·5(*M*)	4·18–4·56(*M*)	4·2–4·6
(67·95)		(67·94)	(68·35)	
3·88(*M*)	3·9–4·5*	4·9	3·87(*br*)	3·9
(73·18)		(73·70)	(78·92)	
4·23–4·35(*M*)	3·9–4·5*		4·25–4·56(*M*)	4·2–4·6
(65·71)		(65·38)	(65·28)	
	3·9–4·5*			—
(169·43)		(167·46)	(169·28)	
	3·9–4·5*			
(135·6)		(135·93)	(134·79)	
6·16 H_A(*s*)	6·1 H_A(*s*)	6·00 H_A(*s*)	6·0 H_A(*s*)	6·1 H_A
5·63 H_B(*s*)	5·6 H_B(*s*)	5·6 H_B(*s*)	5·5 H_B(*s*)	5·6 H_B
(126·52)		(126·60)	(126·50)	
1·96(*s*)	1·9(*s*)	1·9(*s*)	1·93(*s*)	1·9(*s*)
(19·01)		(18·17)	2·34 $4CH_3$	3·54 $0CH_3$
			(18·37)	

* Protons of carbon numbers 7 to 12 appeared as irregular multiplet.
** ^{13}C NMR – Not recorded.

PMR data are recorded in table 2. A singlet at δ 1·96 may be due to the methyl proton and two singlets at δ 6·16 and 5·63 due to vinylic protons H_A and H_B respectively. Methylenic ($C-CH_2-$) protons of methacrylate appear at δ 4·23 to 4·35 as multiplets whereas salicylate–CH_2 appear at δ 4·46 to 4·58 as multiplets. The difference in their chemical shifts may be due to the greater electron-withdrawing nature of the phenyl group. Tertiary protons of –CH–OH appear around δ 3·70 to 3·88 as broad peaks. D_2O exchangeable protons of Ph–OH and CH–OH appear at δ 10·6 and 4·62 respectively. The aromatic protons appear around δ 6·97 to 7·86. The ^{13}C-NMR spectrum shows the appropriate signals for 14 chemically different carbon atoms. The signals at 169·82 ppm and 169·43 ppm were assigned to the carbonyl groups situated at C-7 and C-11. The ethylenic carbons appear at 135·6 ppm (C-12) and 126·52 ppm (C-13). The signals at 112·0 ppm (C-1), 161·65 ppm (C-2), 119·21 ppm (C-3), 135·95 ppm (C-4), 117·57 ppm (C-5) and 129·86 ppm (C-6) were assigned to the carbons of the benzene ring and are comparable to the signals due to the corresponding carbons of salicylates. The lone carbon appearing at 19·01 ppm upfield was readily assignable to the $-CH_3$ carbon. The three further upfield signals at 67·95, 73·18 and 65·71 ppm were assigned to aliphatic carbons of C-8, C-9 and C-10 respectively.

On the basis of the foregoing spectroscopic and analytical data the structure of the synthesised compound is shown as indicated in scheme 1 and confirmed as MSHP.



Scheme 1.

3.2 *Salient kinetic features*

The title reaction was conducted in nonaqueous (benzene and/or acetonitrile) media in the presence of pyridine as the base. (i) Stoichiometry of the reaction was found to be 1[SA]:1[GM]. (ii) Under the conditions [GM] ≫ [SA], the plots of log $[SA]_0/[SA]_t$ vs time (figure 1A) have been found to be linear and passing through origin, indicating

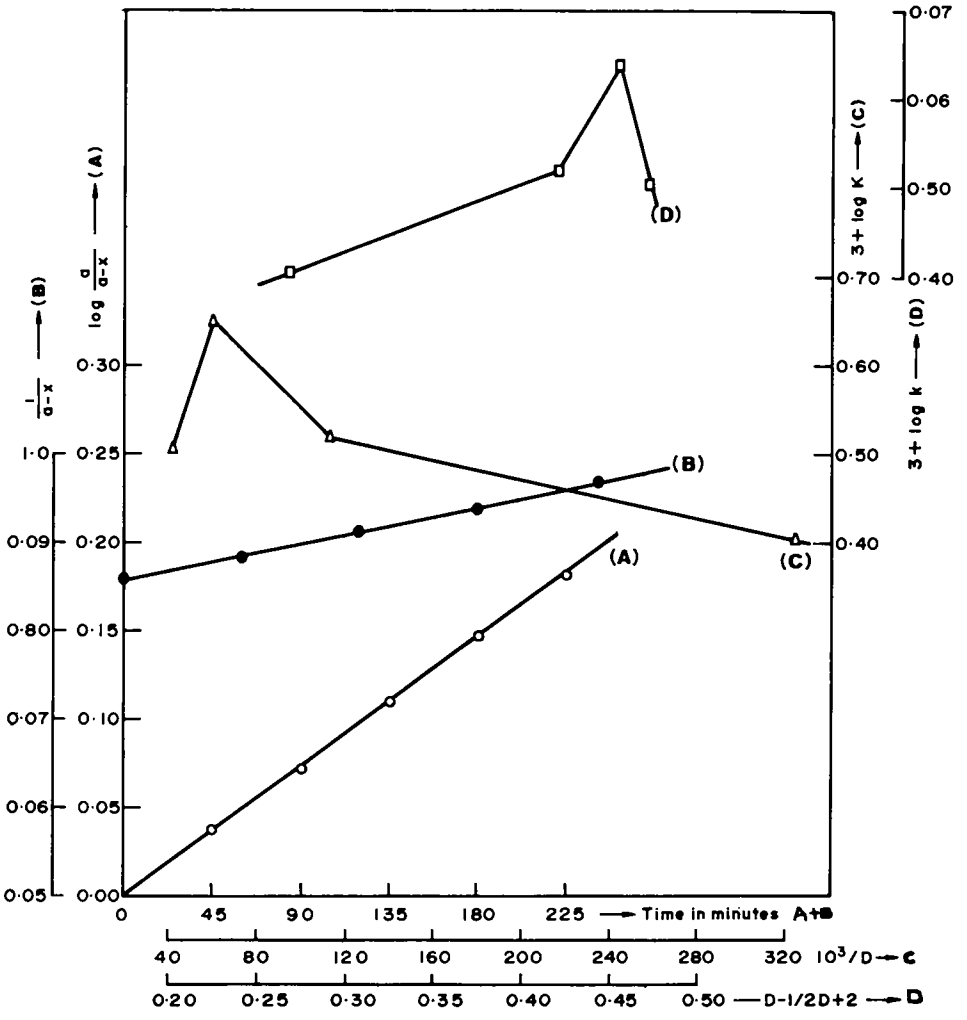


Figure 1. (A) Plot of log $(a/a-x)$ vs time [SA] = 0·02 mol dm^{-3}; [GM] = 1·2 mol dm^{-3}; Temp = 333 K; solvent = benzene. (B) Plot of $(1/a-x)$ vs time [SA] = 0·05 mol dm^{-3}; [GM] = 0·05 mol dm^{-3}; Temperature = 323 K; solvent = benzene. (C) plot of log k' vs $10^3/D$; (D) plot of log k' vs $(D-1)/(2D+1)$.

first order in [SA]. (iii) When equal concentrations of [SA] and [GM] were used in the reaction, the plot of $[SA]_r^{-1}$ vs time (figure 1B) was linear, with a positive slope and a definite intercept on the ordinate, indicating second-order kinetics. From the foregoing observations, order in [GM] can also be found to be unity. (iv) Variations of dielectric constant (D) on the rate of the reaction has been studied by taking binary solvent mixtures of benzene and acetonitrile. Pseudo first-order rate constants (k') have indicated rather a small change over a wide variation of dielectric constants. The pseudo first-order rate constant (k') of the reaction gradually increases with an increase in the percentage of acetonitrile ($\simeq$ upto 35% v/v), and decreases in highly polar media (above 35% v/v of acetonitrile). Amis and Kirkwood plots (figure 1, C, D) (Amis 1966) have been found to be nonlinear. In order to know the role of solvent–solute

interactions, the k'-data are used in the plot of log k' vs mole fraction of benzene which indicated a nonlinear curve (figure not shown). A change in the trend may be at best attributed to a change in the reactive species from a less polar to a more polar medium. In less polar media, the formation of carboxylate ion may be more likely due to intramolecular hydrogen bonding arising from the phenolic hydrogen to the carboxyl oxygen in a salicyclic acid moiety. However, in highly polar media active carboxylate anion formation may not be likely due to intermolecular hydrogen bonding. On the basis of the foregoing discussions, a most probable mechanism could be envisaged as the reaction between pyridine base (B) and SA to form carboxylate ion and BH (protonated pyridine) in the pre-equilibrium step. The carboxylate ion intermediate thus formed reacts with glycidyl methacrylate (GM) in the rate limiting step to give the first stage product. This is an example of a regiospecific addition reaction (SA to GM) in which salicylate anion attacks a less substituted oxirane ring (Hassnor 1985) to give an MSHP anion in the slow step. The MSHP anion thus formed further reacts with the conjugate acid (BH^+) generated in the first step to give MSHP as shown in scheme 1.

For scheme 1 the rate law works out to be

$$\frac{-\mathrm{d[SA]}}{\mathrm{d}t} = \frac{\mathrm{d[MSHP]}}{\mathrm{d}t} = \frac{kK[\mathrm{SA}]\mathrm{B}[\mathrm{GM}]}{1+K[\mathrm{B}]} \tag{1}$$

or

$$k' = \frac{kK[\mathrm{B}][\mathrm{GM}]}{1+K[\mathrm{B}]}. \tag{2}$$

At constant [B] (2) can be written as,

$$k' = k''[\mathrm{GM}]$$

where $k'' = (k\,K[\mathrm{B}])/(1+K[\mathrm{B}])$.

Second-order rate constants (k'') have been evaluated at different temperatures in a 25° range (318 to 335 K) and the corresponding activation parameters (Laidler 1971) are compiled in table 3. Pseudo first-order rate constants (k') and second-order rate constants show the order of reactivity of various salicylic acids as: 5-bromo < 5-

Table 3. Kinetic and thermodynamic parameters.
Solvent = benzene; temperature = 333 K

Salicylic acid	$10^2 k''$ ($dm^3\,mol^{-1}\,s^{-1}$)	$\Delta H^{\neq}$ ($kJ\,mol^{-1}$)	$\Delta G^{\neq}$ ($kJ\,mol^{-1}$)	$-\Delta S^{\neq}$ ($JK^{-1}\,mol^{-1}$)
4-Chloro	3·14	25·4	91·4	198
4-Methoxy	1·68	43·2	93·1	150
4-Methyl	1·50	41·2	93·4	156
4-Amino	1·39	42·0	93·6	155
Thio	1·10	67·9	94·3	79·3
Salicylic acid	1·08	60·1	94·3	103
Acetyl	1·01	23·2	94·5	214
5-Chloro	0·933	49·9	94·7	134
5-Bromo	0·801	62·8	95·1	97·1

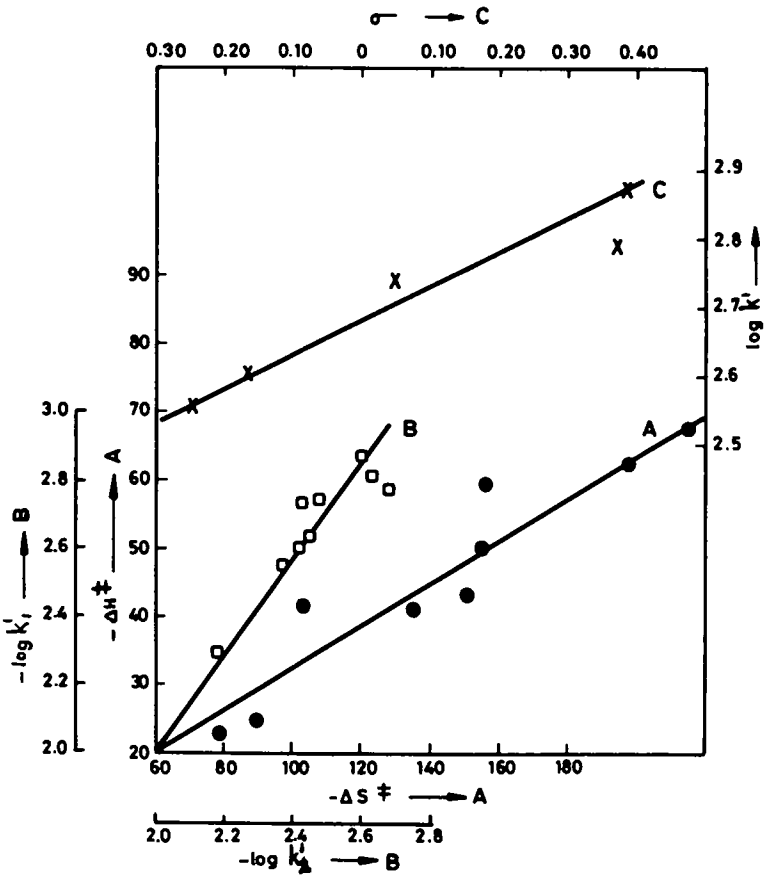


Figure 2. (A) Plot of $\Delta H^{\neq}$ vs $\Delta S^{\neq}$; (B) plot of log k'_1 vs log k'_2, k_1 is at 333° K; k_2 is at 353° K; (C) plot of log k' vs σ.

chloro < acetyl < H < thio < 4-amino < 4-methyl < 4-methoxy < 4-chloro. When these data are used in Hammett's equation (Hammett 1940), the plot (figure 2C) indicates a rho (ρ) value of 0·43 which is found to decrease with an increase in temperature. Surprisingly, only *p*-chloro derivatives scattered from linearity. Deviations recorded in the case of *p*-chloro may probably be explained by the mesomeric para interaction energy ($\Delta\Delta G_p$) parameters. Consequently, the effective sigma ($\bar{\sigma}$) value and $\Delta\Delta G_p$ have been evaluated for the *p*-chloro substituent using the rho (ρ) value obtained from figure 2C and the value of (ρ) and $\Delta\Delta G_p$ (in cal/mol) are found to be 0·86 and 1·274 respectively. The $\Delta\Delta G_p$ value indicates a less pronounced electron-withdrawing effect between the substituent and the reaction centre in the transition state than that predicted (Rajanna *et al* 1983).

In order to know the nature of the reaction the thermodynamic data and rate constant data have been cast into Leffler's and Exner's plots (Leffler 1955; Exner 1972). A linear plot of $\Delta H^{\neq}$ as a function of $\Delta S^{\neq}$ (Leffer's plot) indicates that the isokinetic temperature β is 312 K. By and large a similar value (308 K) has been obtained from the linear plot of log k' at 333 K vs log k' at 343 K. The value of β is far below the experimental temperature range (325–350 K) indicating that the reaction

is controlled by entropy factors. Further the linearity of Leffler's and Exner's plots indicate the validity of the proposed mechanism at all temperatures. Negative entropy of activation values for all the substrates clearly indicate greater solvation of the transition state.

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References

Amis E S 1966 *Solvent effects on reaction rates and mechanisms* (London: Academic Press) p. 43
Billmayer F W 1971 *Textbook of polymer science* (New York: Wiley Interscience)
Braun D, Cherdron H and Kern W 1972 *Techniques of polymer synthesis and characterization* (New York: Wiley Interscience)
Campbell T W and Sorenson W R 1961 *Preparative methods of polymer chemistry* (New York; Wiley Interscience)
Exner O 1972 *Coll. Czech. Chem. Commun.* **37** 1425
Hammet L P 1940 *Physical organic chemistry* (New York: McGraw Hill)
Hassnor A 1985 *Small ring-heterocyclic compounds* (New York: John Wiley & Sons)
Laidler K J 1971 *Chemical kinetics* (New Delhi: Tata-McGraw Hill)
Leffler J J 1955 *Org. Chem.* **20** 1202
Rajanna K C, Saiprakash P K and Umadevi Y 1983 *Indian J. Chem.* **B22** 292
Soutif C J, Brosse C and Janaki Ram Rao C 1983 *Makromol. Chem., Rapid Commun.* **4** 645
Vogel A I 1978 *A Textbook of practical organic chemistry* (London: Longmans)