REFERENCES

1. George, W. The ICI polyurethanes book. ICI polyurethanes and John Wiley & Sons, 1990.
2. Thomson, T. Polyurethane as Specialty Chemicals. Florida: CRC Press, 2005.
3. Stevens, M. P. Polymer Chemistry, an Introduction. New York: Oxford University Press, 1999.
4. Odian, G. Principles of polymerization. New York: John Wiley & Sons, 1993.
5. Dysons, R. W. Specialty Polymers. New York: Chapman and Hall, 1987.
6. Frisch, K. C. Recycling of Polyurethanes. Pennsylvania: Technomic, 1999.
7. Genge, K. Polyurethanes. Chichester: John Wiley & Sons, 1987.
8. Furukawa, M.; Mitsui, Y.; Fukumaru, T.; Kojio, K. Microphase-separated structure and mechanical properties of novel polyurethane elastomers prepared with ether based diisocyanate. Polymer 46 (2005): 10817-10822.
9. Kojio, K.; Fukumaru, T.; Furukawa, M. Highly Softened Polyurethane Elastomer Synthesized with Novel 1,2-Bis(isocyanate)ethoxyethane. Macromolecules 37 (2004): 3287-3291.
10. Takeichi, T.; Ujiie, K.; Inoue, K. High performance poly(urethane-imide) prepared by introducing imide blocks into the polyurethane backbone. Polymer 46 (2005): 11225-11231.
11. Yeganeh, H. and Shamekhi, M.A. Poly(urethane-imide-imide), a new generation of thermoplastic polyurethane elastomers with enhanced thermal stability. Polym. 45 (2004): 359-365.
12. Miyamoto, M.; Takashima, Y. and Kimura, Y. Preparation of novel thermally stable polyurea by the cationic ring-opening isomerization polymerization of polycyclic pseudourea. Macromolecules 31 (1998): 6822-6827.
13. Mallakpour, S. and Raheno, H. Synthesis and characterization of new polyureas based on 4-(4'-aminophenyl)urazole and various diisocyanates. J. Appl. Polym. Sci. 89 (2003): 2692-2700.

14. Lin, J.; Yuki, Y.; Kunisada, H. and Kondo, S. Synthesis and characterization of new aromatic polyamides, polyimides, and polyureas containing 1,3,5-triazine rings. J. Appl. Polym. Sci. 40 (1990): 2113-2122.

15. Rogulska, M.; Podkościelny, W.; Kultys, A.; Pikus, S.; Pożdzik, E. Studies on thermoplastic polyurethanes based on new diphenylethane-derivative diols. I. Synthesis and characterization of nonsegmented polyurethanes from HDI and MDI. Eur. Polym. J. 42 (2006): 1786-1797.

16. Mallakpour, S. and Zandi, H. Step-growth polymerization of 4-(1-naphthyl)-1,2,4-triazolidine-3,5-dione with diisocyanates. Polym. Bulletin. 57 (2006): 611-621.

17. Azzam, A. R.; Mohamed, K.S.; Tol, R.; Everaert, V.; Reynaers, H.; Goderis, B. Synthesis and thermo-mechanical characterization of high performance polyurethane elastomer based on heterocyclic and aromatic diamine chain extenders. Polym. Degrade. and Stab. 92 (2007): 1316-1325.

18. Qin, X.M.; Fang, F.; Yang, X.H.; Wang, X. L. and Zheng, Z. Preparation, morphology, and properties of polyurethane-urea elastomers derived from sulphone-containing aromatic diamine. J. Appl. Polym. Sci. 104 (2007):3554-3561.

19. Qin, X.M.; Xiong, J. W.; Yang, X.H.; Wang, X. L. and Zheng, Z. Synthesis and characterization of polyurethane urea based on fluorine-containing bisphenoxydiamine. J. Appl. Polym. Sci. 102 (2006): 1863-1869.

20. Jayakumar, R.; Rajkumar, M.; Nagendran, R. And Nanjundan, S. Studies on metal-containing polyurethanes based on divalent metal salts of mono(hydroxyethoxyethyl)phthalate. J. Macromol. Sci Pure. Appl. Chem. A. 38 (2001): 869-888.

21. Jayakumar, R,; Nanjundan, S. and Prabaharan, M. Developments in metal-containing polyurethanes, copolyurethanes and polyurethane ionomers. J. Macromol. Sci. Polym. Rev. C. 45 (2005): 231-261.

22. Jayakumar, R.; Nanjundan, S. and Prabaharan, M. Metal-containing polyurethanes, poly(urethane-urea)s and poly(urethane-ether)s. React. Funct. Polym. Rev. 66 (2006): 299-314.

23. Moroi, G. and Coibanu, C. Thermal behaviour of polyurethane interaction products with cobalt ions. Polym. Degrad. Stab. 78 (2002): 287-293.

24. Matsuda, H. and Takechi, S. Synthesis and properties of polymer from divalent metal salts of *p*-aminobezoic acid, diamine, and diisocyante. J. Apply. Polym. Sci. A: Polym. Chem. 28 (1990): 1895-1908.

25. Rajalingam, P. and Radhakrishnan, G. Synthesis and characterization of metal-containing polyurethane-ureas. Polymer 38 (1992): 2214-2216.

26. Arun prasath, R.; Vijayanand, PS. and Nanjundan, S. Studies on polyurethanes and polyurethane-ureas derived from divalent metal salts of mono(hydroxybutyl)hexolate. Polym. Int. 49 (2000): 1464-1472.

27. Jayakumar, R.; Rajkumar, M.; Nagendran, R. and Nanjundan, S. Synthesis and characterization of metal-containing polyurethane with antibacterial activity. J. Appl. Polym. Sci. 85 (2002): 1194-1206.

28. Jayakumar, R.; Lee, Y.-S. and Nanjundan, S. Studies on metal-containing copolyurethanes. Reac. & Funct. Polym. 55 (2003): 267-276.

29. Senthilkumar, N.; Raghavan, A. and Sultan Nasar, A. Novel-metal-containing polyurethane elastomers prepared using tetradentate Schiff base metal complexes. Macromol. Chem. Phys. 206 (2005): 2490-2500.

30. Chantarasiri, N.; Chulamanee, C.; Mananunsap, T. and Muangsin, N. Thermally stable metal-containing polyureas from hexadentate Schiff base metal complexes and diisocyanates. Polym. Degrad. Stab. 86 (2004): 505-513.

31. Chantarasiri, N.; Damrongkosit, T.; Jangwong, W.; Sridaeng, D. and Suebphan, S. Synthesis, characterization and thermal properties of metal-containing polyurethane-ureas from hexadentate Schiff base metal complexes. Eur. Polym. J. 40 (2004): 1867-1874.

32. Techaprasertporn, P. Synthesis of copolyurethane-ureas containing nickel and zinc 4,4′-dihydroxysaltrien metal complexes in the presence of dialcohols or diamines. Master's thesis, Program of Petrochemistry and Polymer Science, Chulalongkorn University, 2006.

33. Silverstein, Robert M. and Webster, Francis X. Spectrometric Identification of Organic Compounds (6^{th} ed.). United States of America: John Wiley & Sons, 1997

34. Jena, K.K.; Chattopadhyay, D.K.; Raju, K.V.S.N. Synthesis and characterization of hyperbranched polyurethane–urea coatings. Eur. Polymer. J. 43 (2007): 1825-1837.

35 Jayakumar, R.; Lee, Y. S.; Nanjundan, S.; Synthesis and characterization of calcium-containing poly(urethane-urea)s. J. Appl. Polym Sci. 90 (2003): 3488-3496.

36 Jayakumar, R.; Radhakrishnan, S.; Nanjundan, S.; Nanjundan, S. Studies on poly(urethane-ureas)s based on zinc salt of mono[hydroxyethoxyethyl]phthalate. React. & Funct. Polym. 57 (2003): 23-31.

37 Jayakumar, R. and Nanjundan, S. Calcium-containing poly(urethane-urea)s: synthesis, spectral, and thermal studies. J. Appl. Polym. Sci. Part A: Polym. Chem. 42 (2004): 1809-1819.

38 Jayakumar, R. and Nanjundan, S. Studies on metal-containing co-polyurethanes based on mono(hydroxyethoxyethyl)phthalate. J. Macromolecular Sci. Part A: Pure and Appl. Chem. 43 (2006): 945-954.

39 Jain, R.; Choudhary, V.; Narula, A. K. Studies on the curing kinetics of epoxy resins using mixture of nadic/or maleic anhydride and 4,4'-diaminodiphenyl sulfone. J. Therm. Anal. Cal. 90 (2007): 495-501.

40 Sharma, P.; Choudhary, V.; Narula, A. K. Curing kinetics and thermal stability of diglycidyl ether of bisphenol: mixture of aromatic imide-amines of benzophenone 3,3',4,4'-tetra-carboxylic acid anhydride and 4,4'-diaminodiphenylsulfone. J. Therm. Anal. Cal. 91 (2008): 231-236.

41 Mallakpour, S.; Rafiee, Z. Use of ionic liquid and microwave irradiation as a convenient, rapid and eco-friendly method for synthesis of novel optically active and thermally stable aromatic polyamides containing *N*-phthaloyl-L-alanine pendent group. Polym. Degrad. Stab. 93 (2008): 753-759.

42 Liaw, D.J. and Lin, S. P. Phosphorus-containing polyurethanes based on bisphenol-S, prepared by *N*-alkylation. Eur. Polym. J. 32 (1996): 1377-1380.

APPENDICES

APPENDIX A

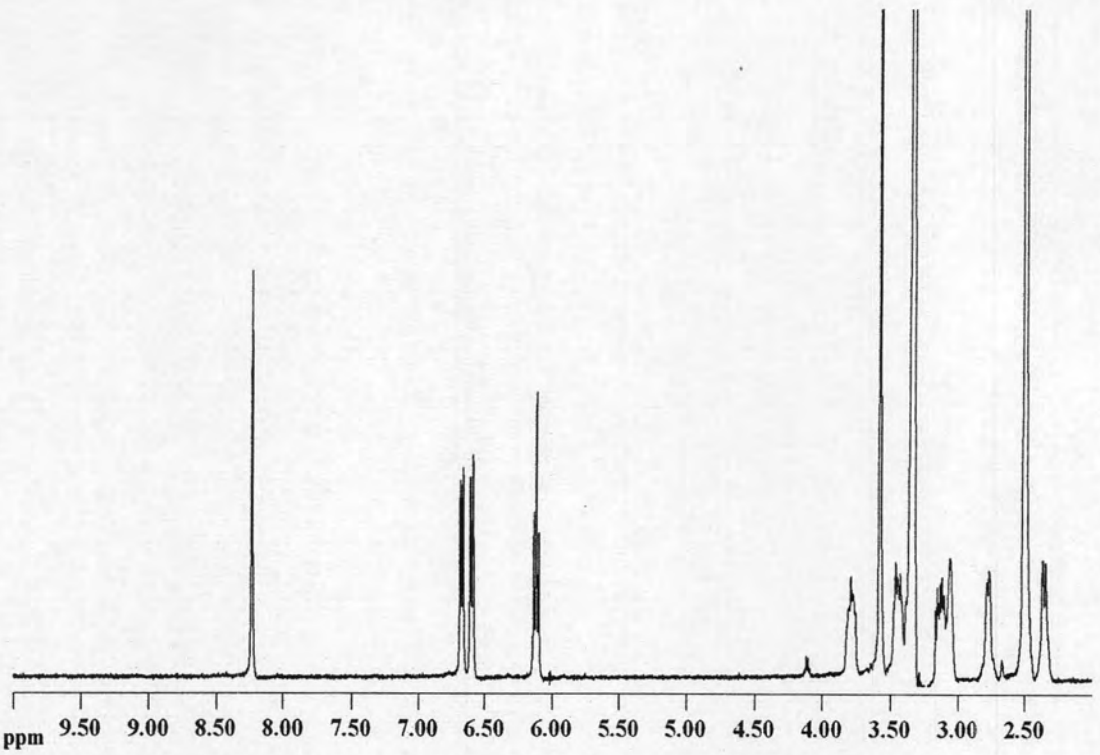

Figure A.1 ^{1}H NMR spectrum of ZnSalOMe$_2$trien in DMSO-d_6

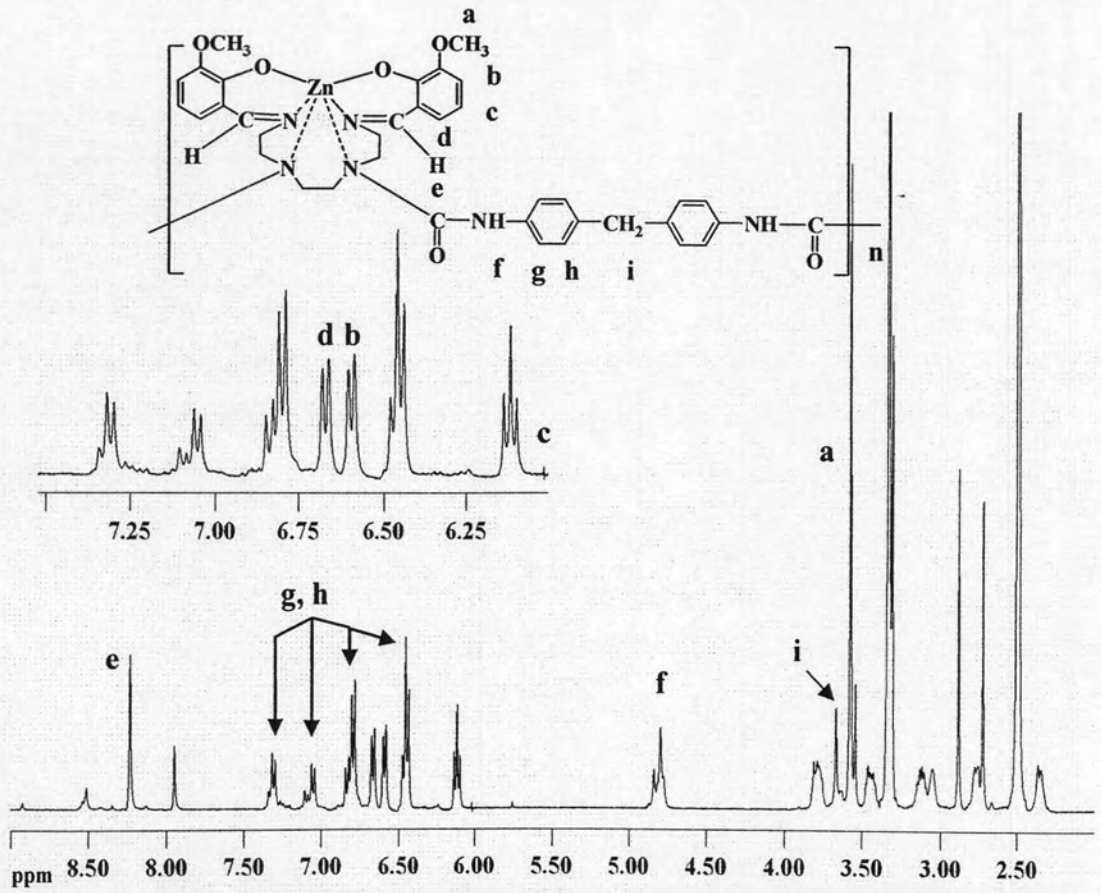

Figure A.2 ^{1}H NMR spectrum of ZnSalOMe$_2$trien –MDI in DMSO-d_6

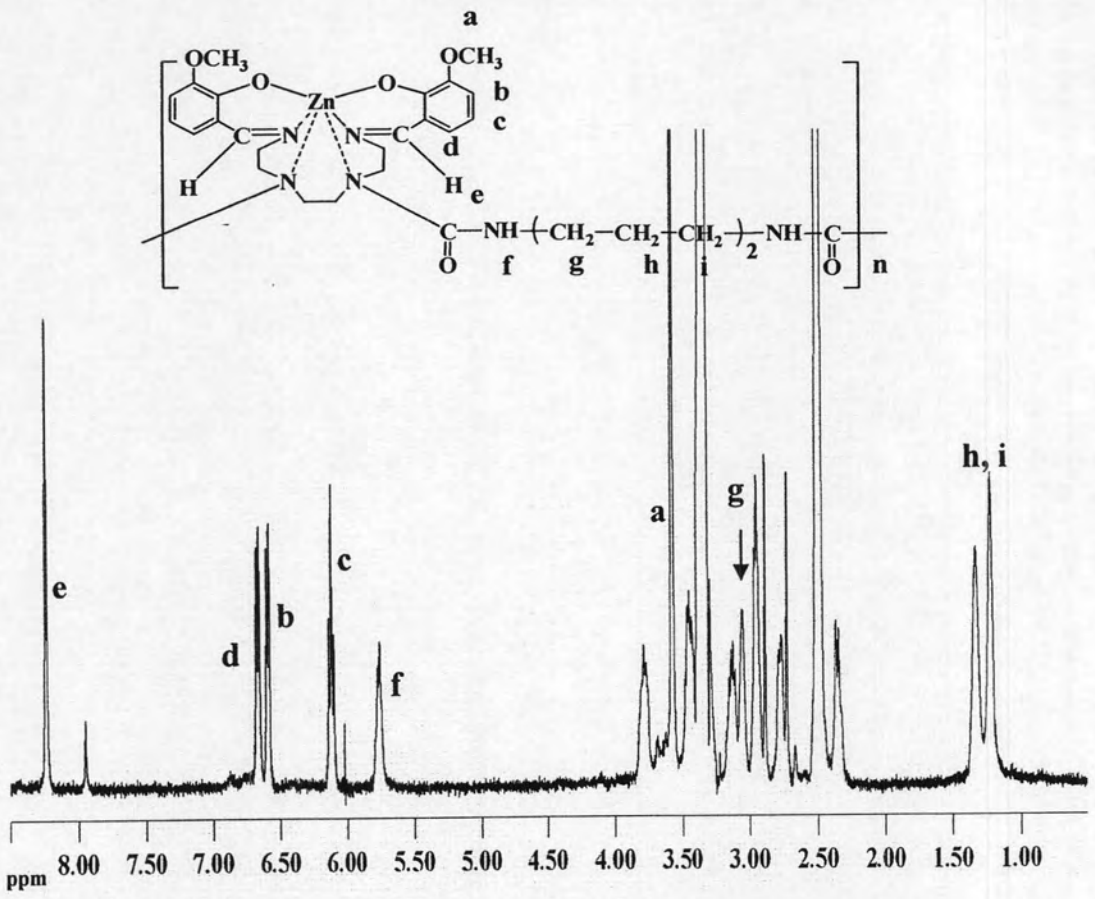

Figure A.3 ^{1}H NMR spectrum of ZnSalOMe$_2$trien-HMDI in DMSO-d_6

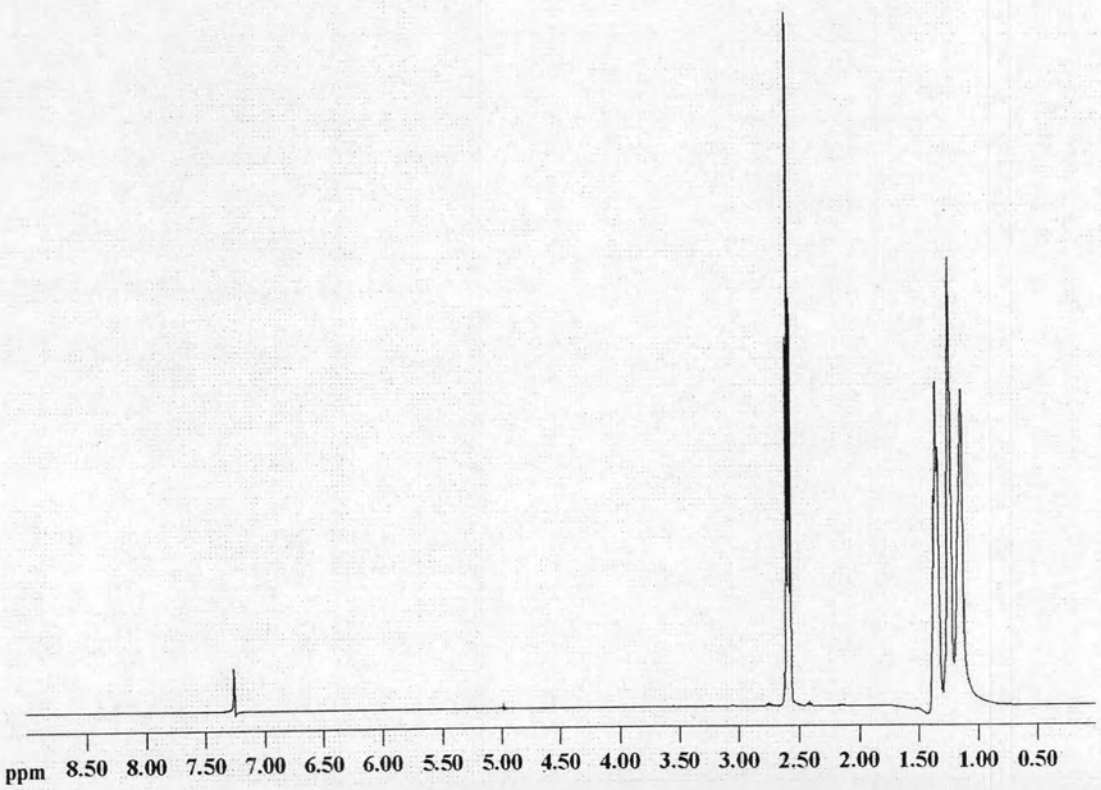

Figure A.4 ^{1}H NMR spectrum of HMDA in DMSO-d_6 + $CDCl_3$

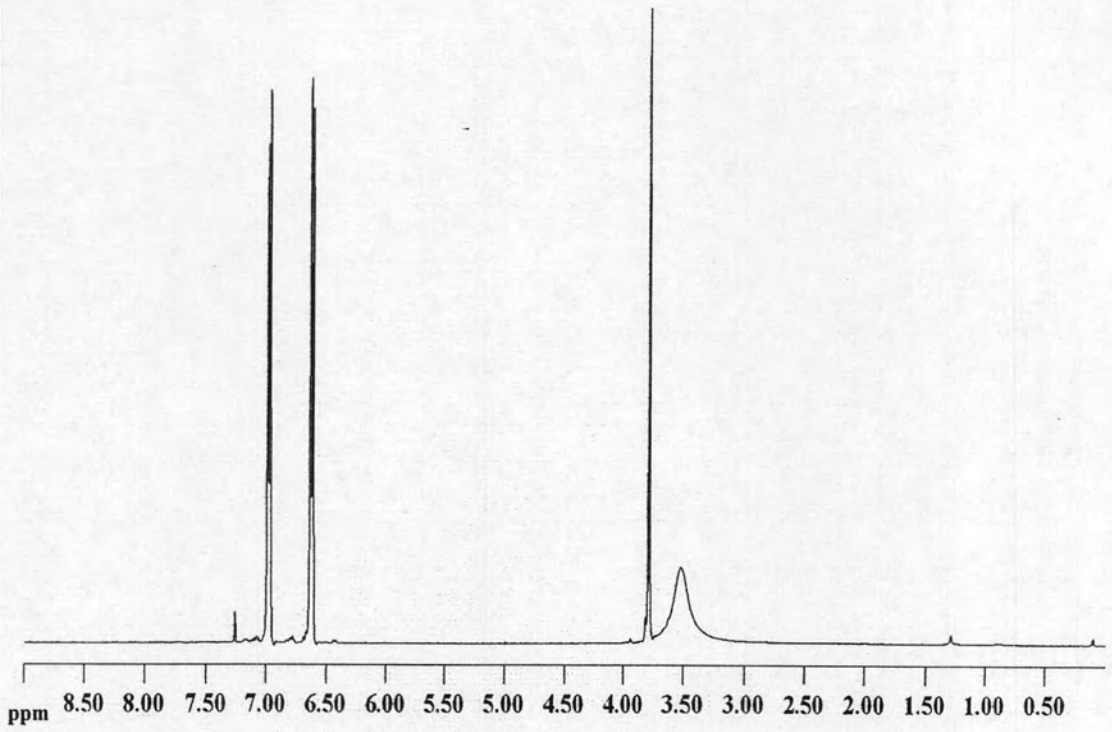

Figure A.5 ^{1}H NMR spectrum of DAP in DMSO-d_6 + $CDCl_3$

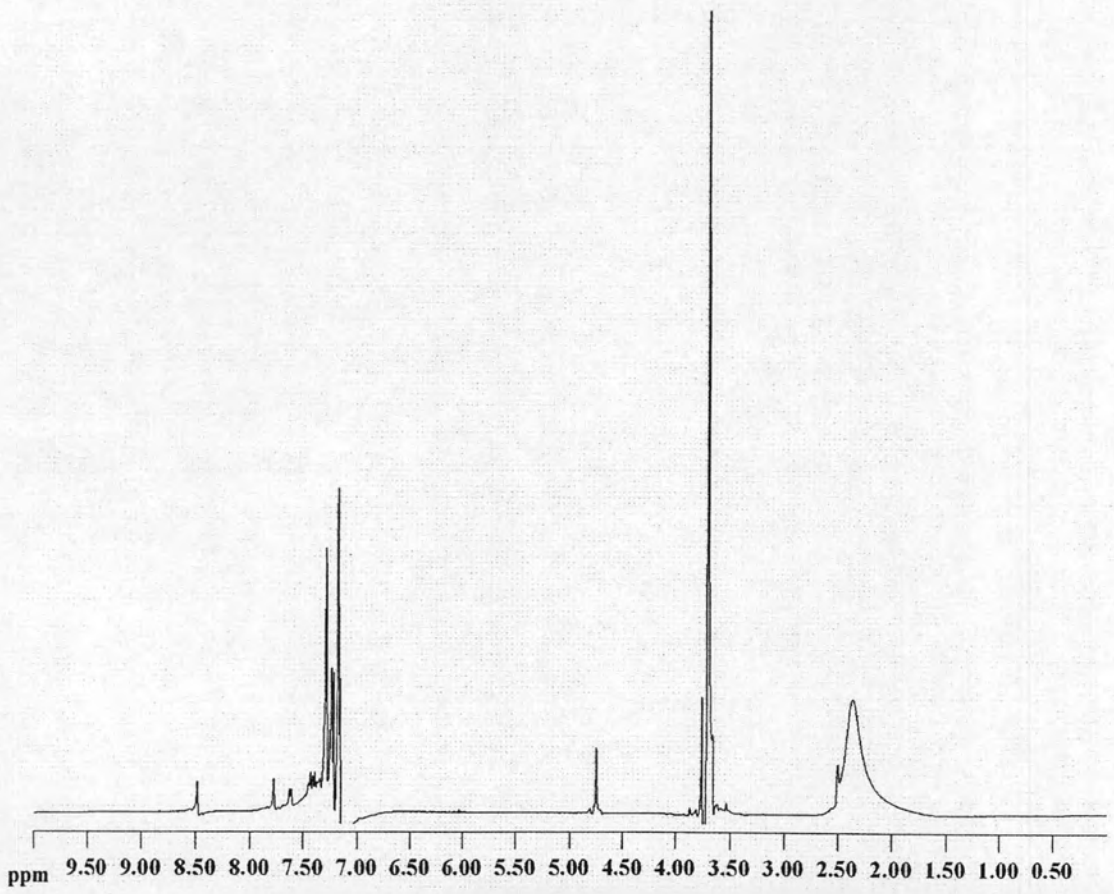

Figure A.6 ^{1}H NMR spectrum of XDA in DMSO-d_6 + $CDCl_3$

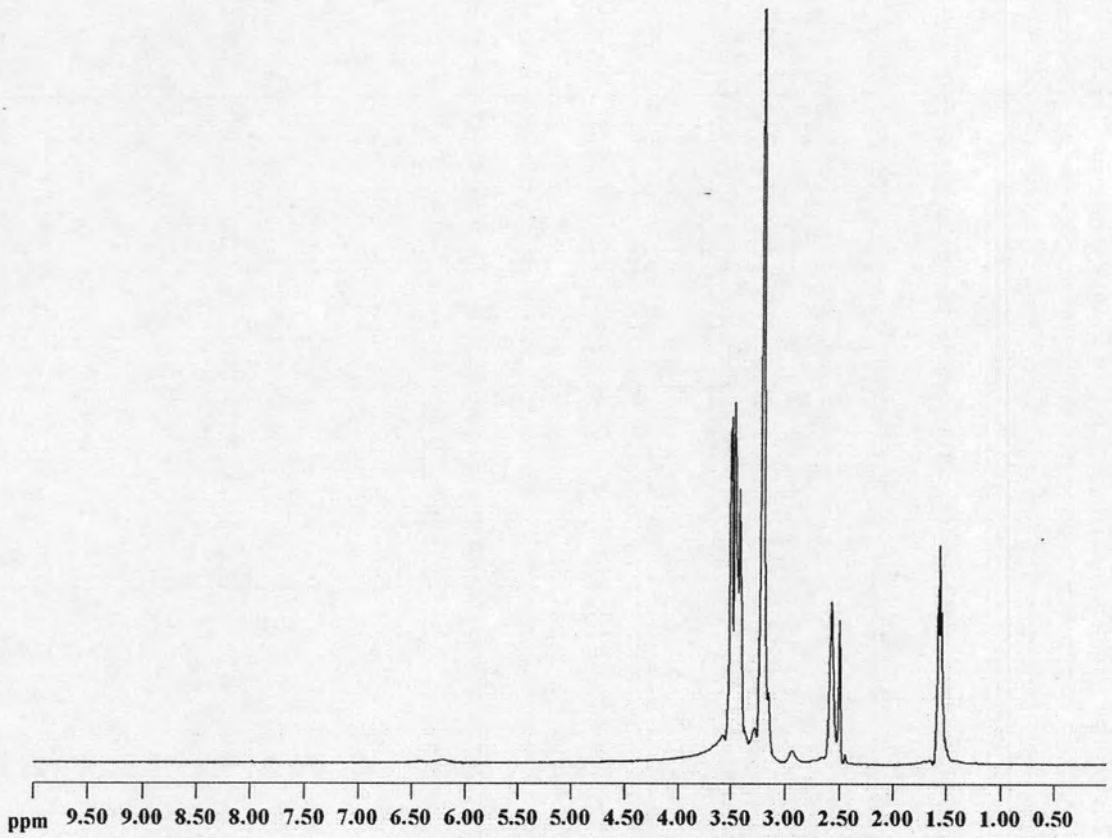

Figure A.7 ^{1}H NMR spectrum of TDA in DMSO-d_6 + $CDCl_3$

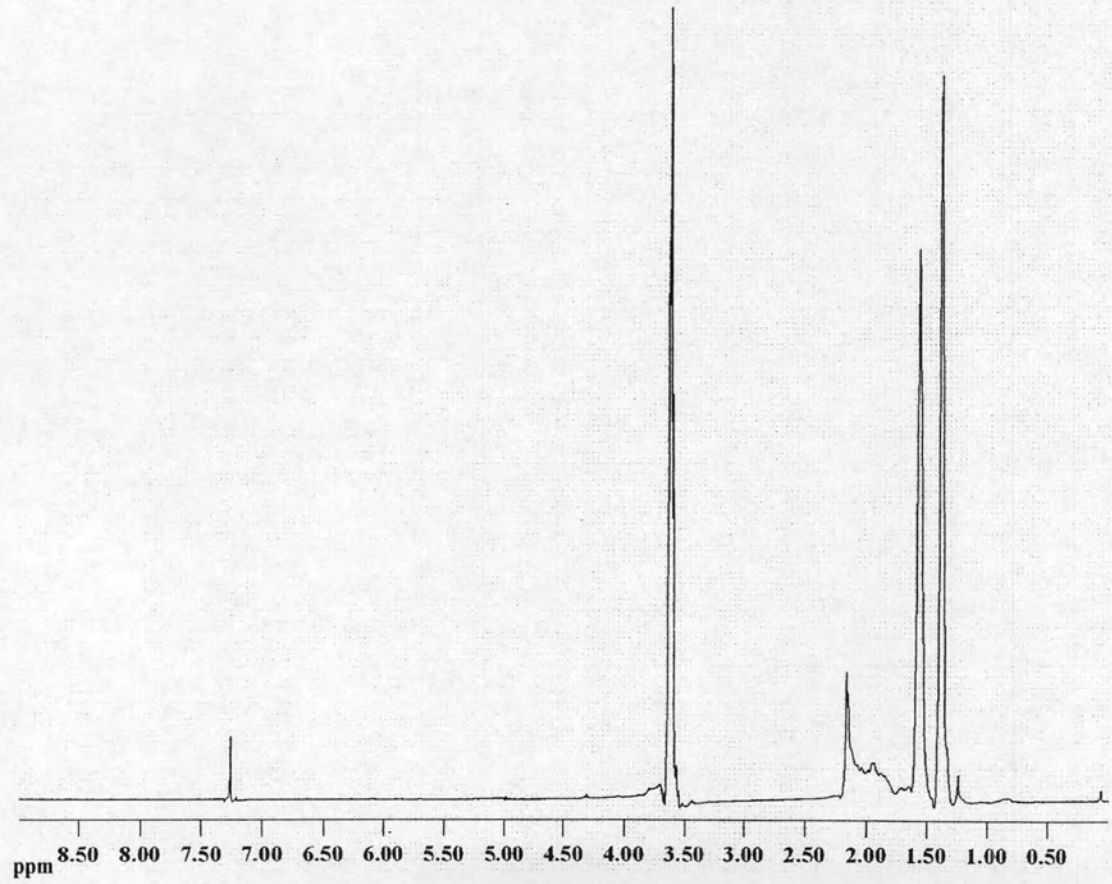

Figure A.8 ^{1}H NMR spectrum of HMDO in DMSO-d_6 + $CDCl_3$

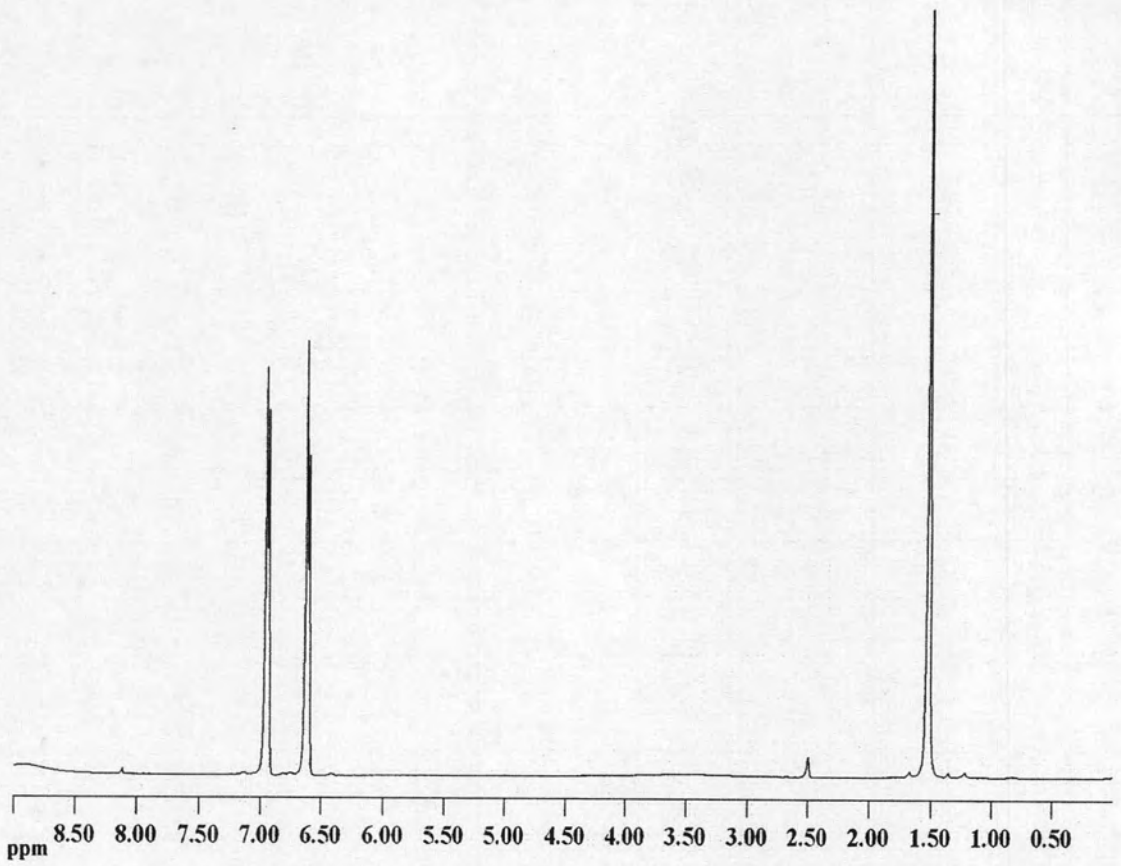

Figure A.9 ^{1}H NMR spectrum of BPA in DMSO-d_6 + $CDCl_3$

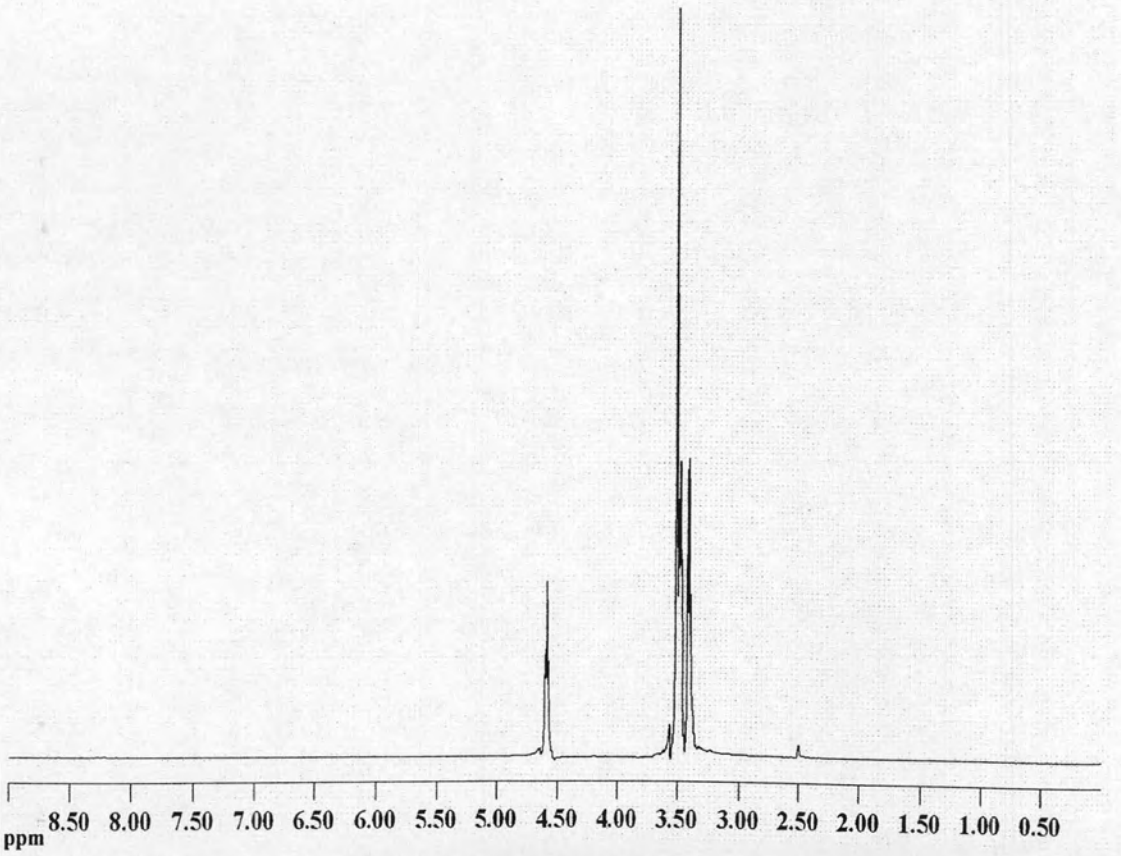

Figure A.10 ^{1}H NMR spectrum of TEG in DMSO-d_6

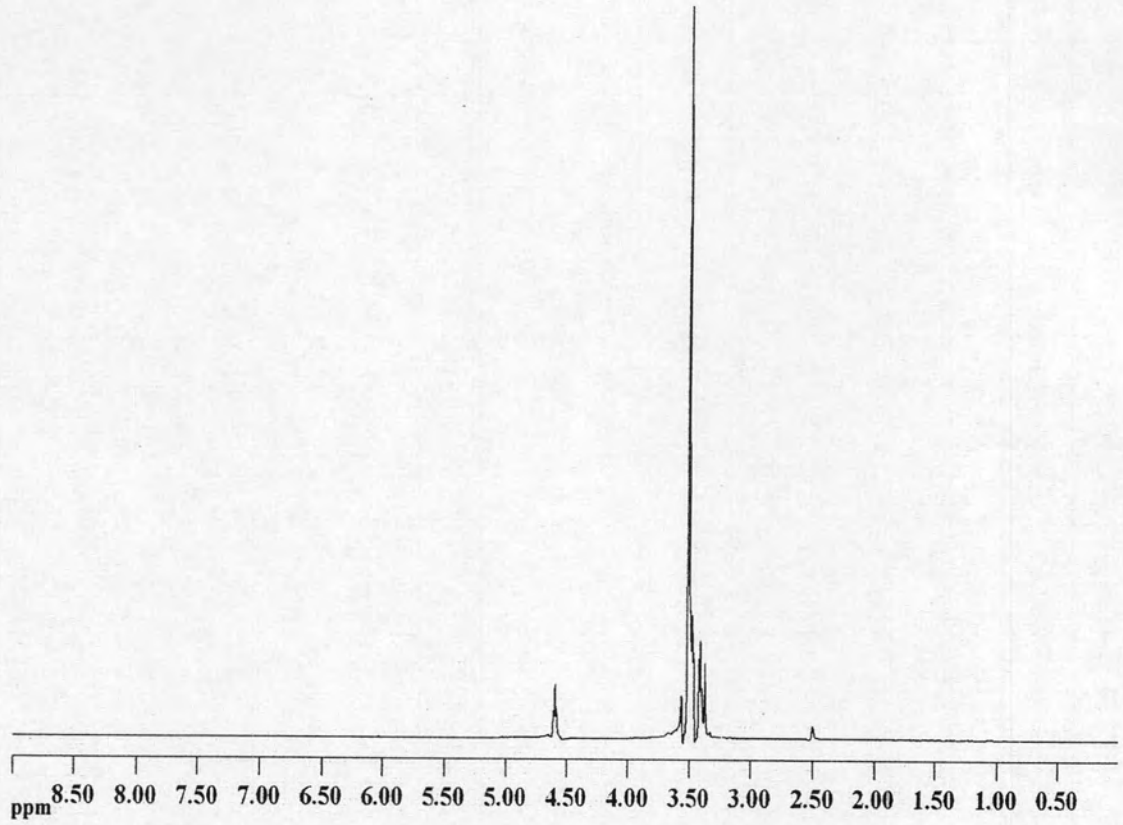

Figure A.11 ^{1}H NMR spectrum of PEG in DMSO-d_6

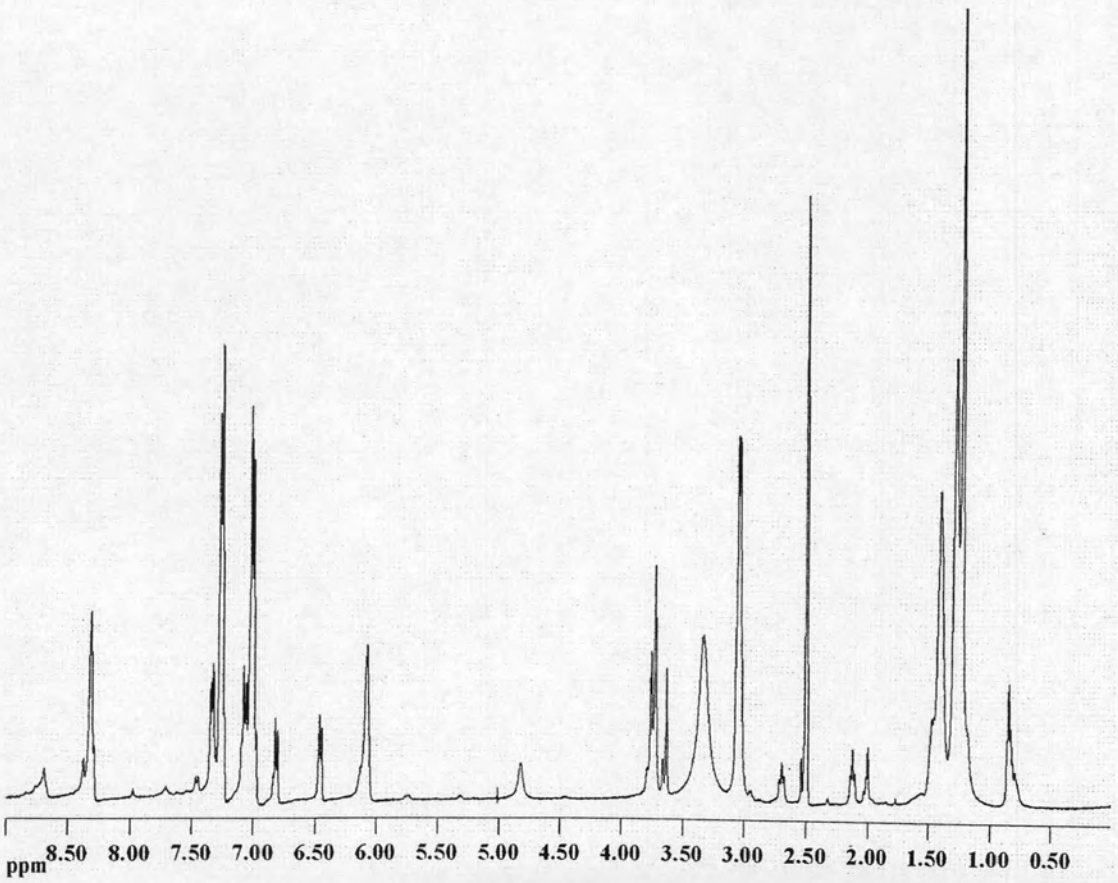

Figure A.12 ^{1}H NMR spectrum of MDI-HMDA (1:1) in DMSO-d_6

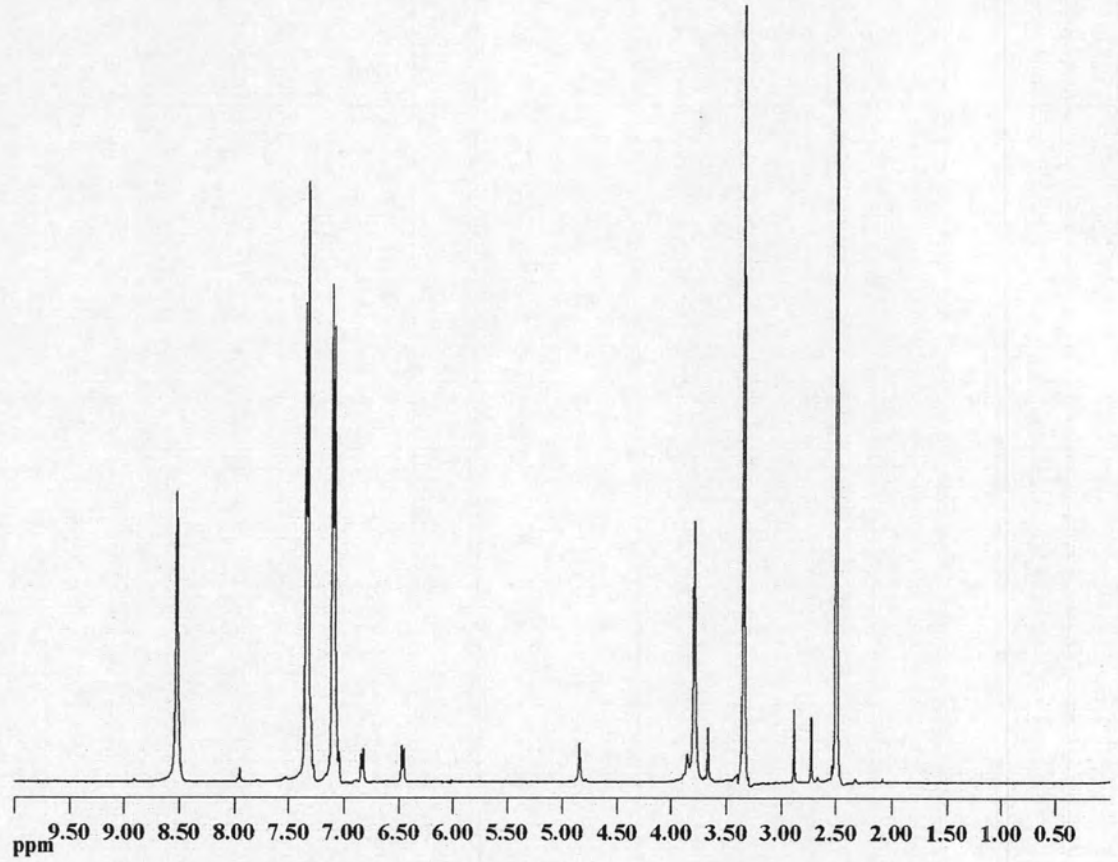

Figure A.13 ^{1}H NMR spectrum of MDI-DAP (1:1) in DMSO-d_6

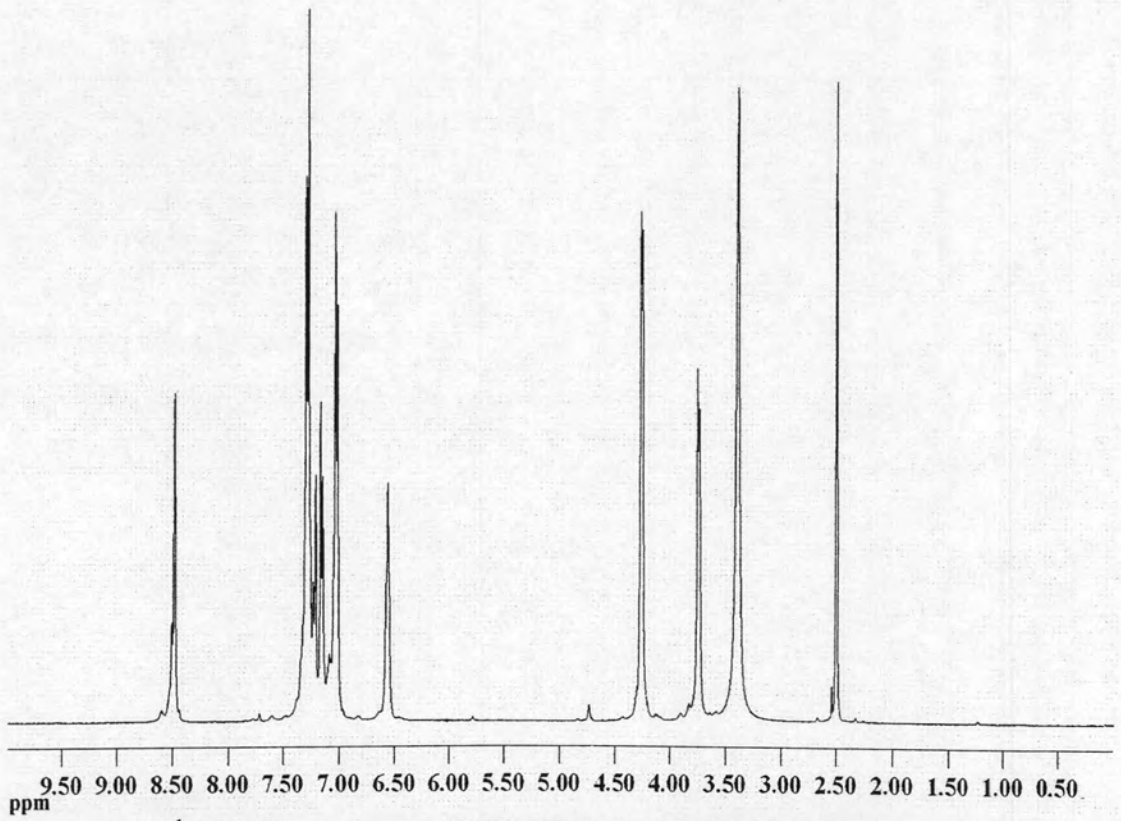

Figure A.14 ^{1}H NMR spectrum of MDI-XDA (1:1) in DMSO-d_6

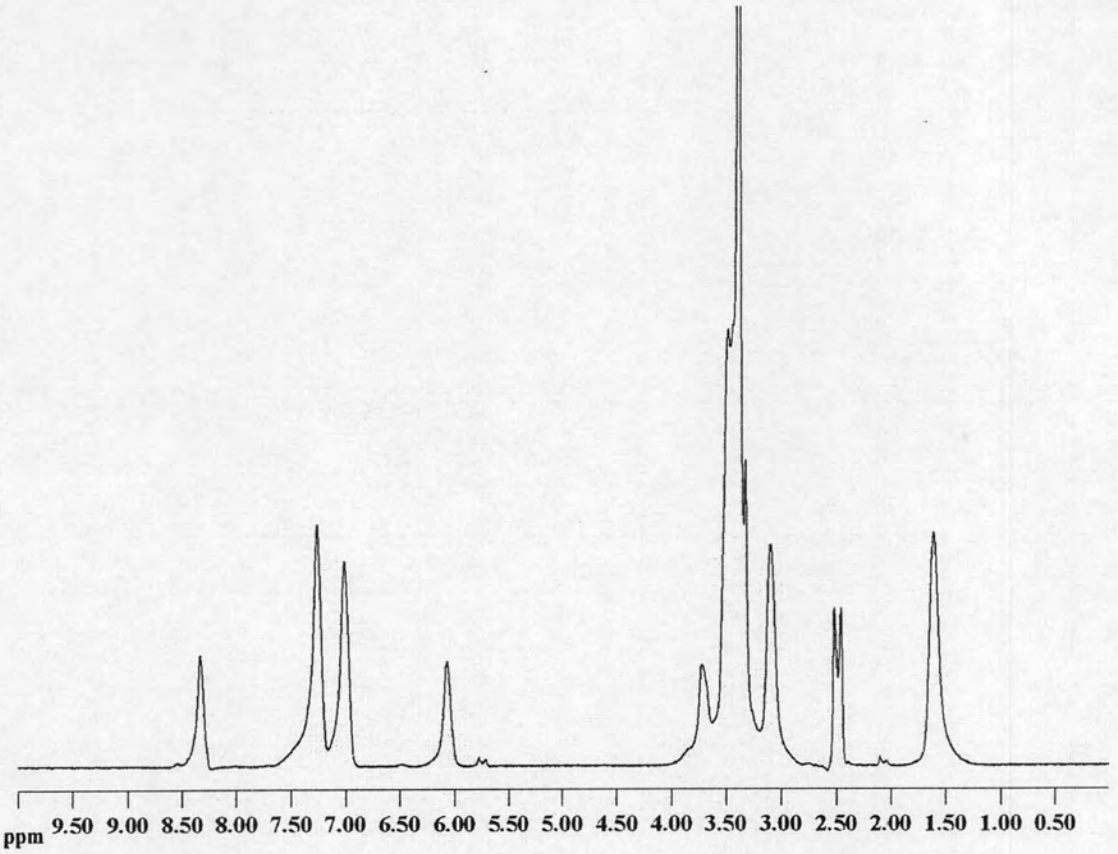

Figure A.15 ^{1}H NMR spectrum of MDI-TDA (1:1) in DMSO-d_6

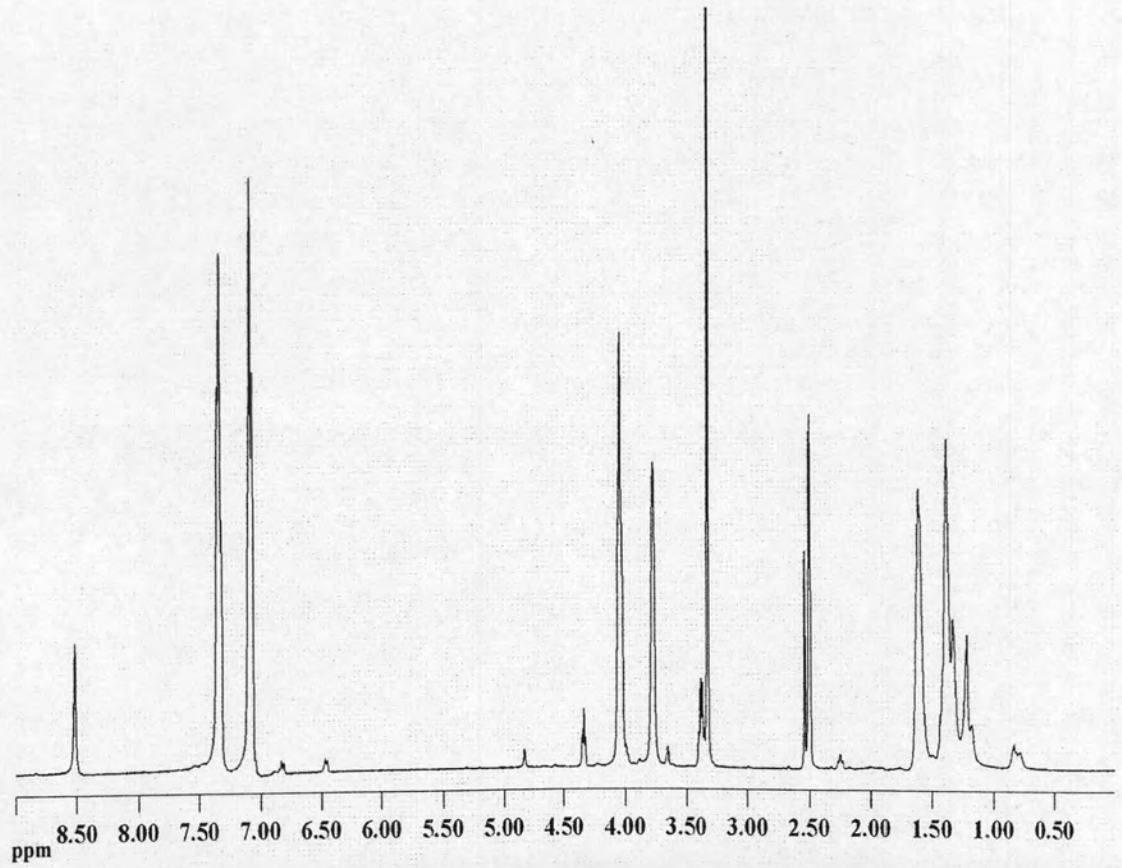

Figure A.16 ^{1}H NMR spectrum of MDI-HMDO (1:1) in DMSO-d_6

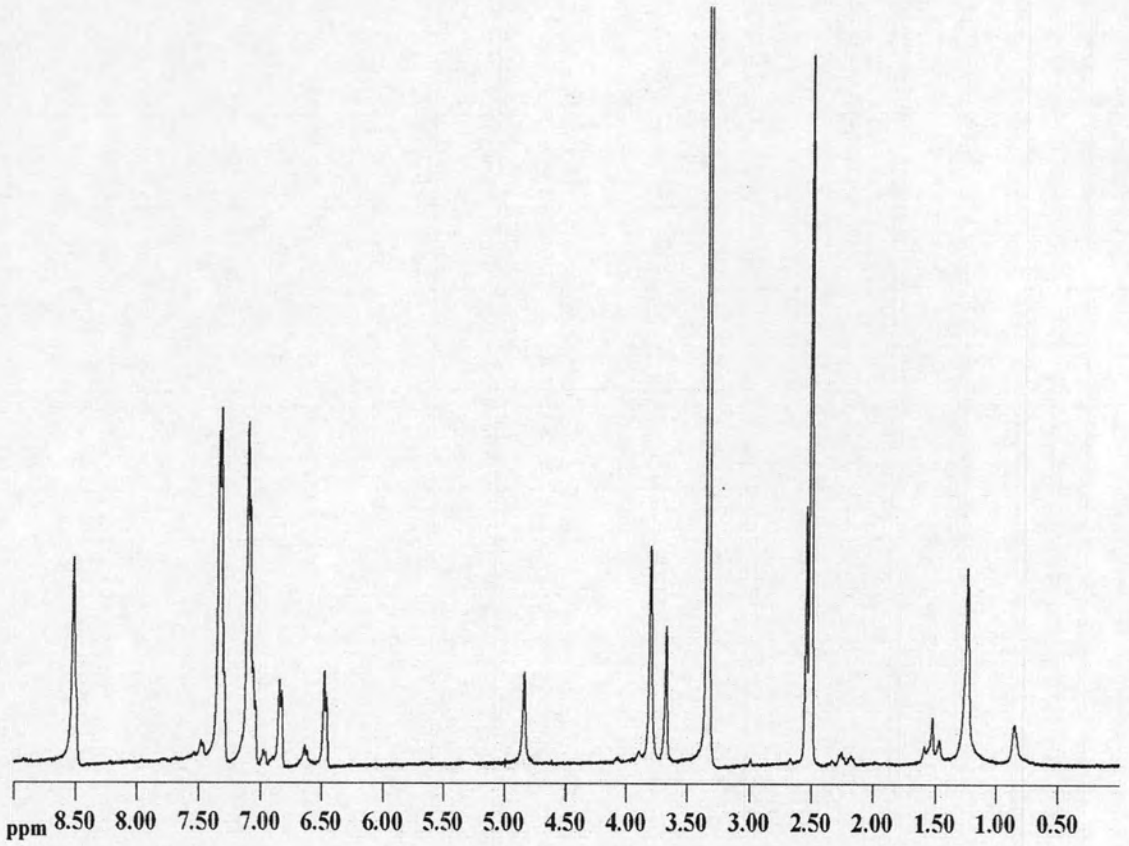

Figure A.17 ^{1}H NMR spectrum of MDI-BPA in DMSO-d_6

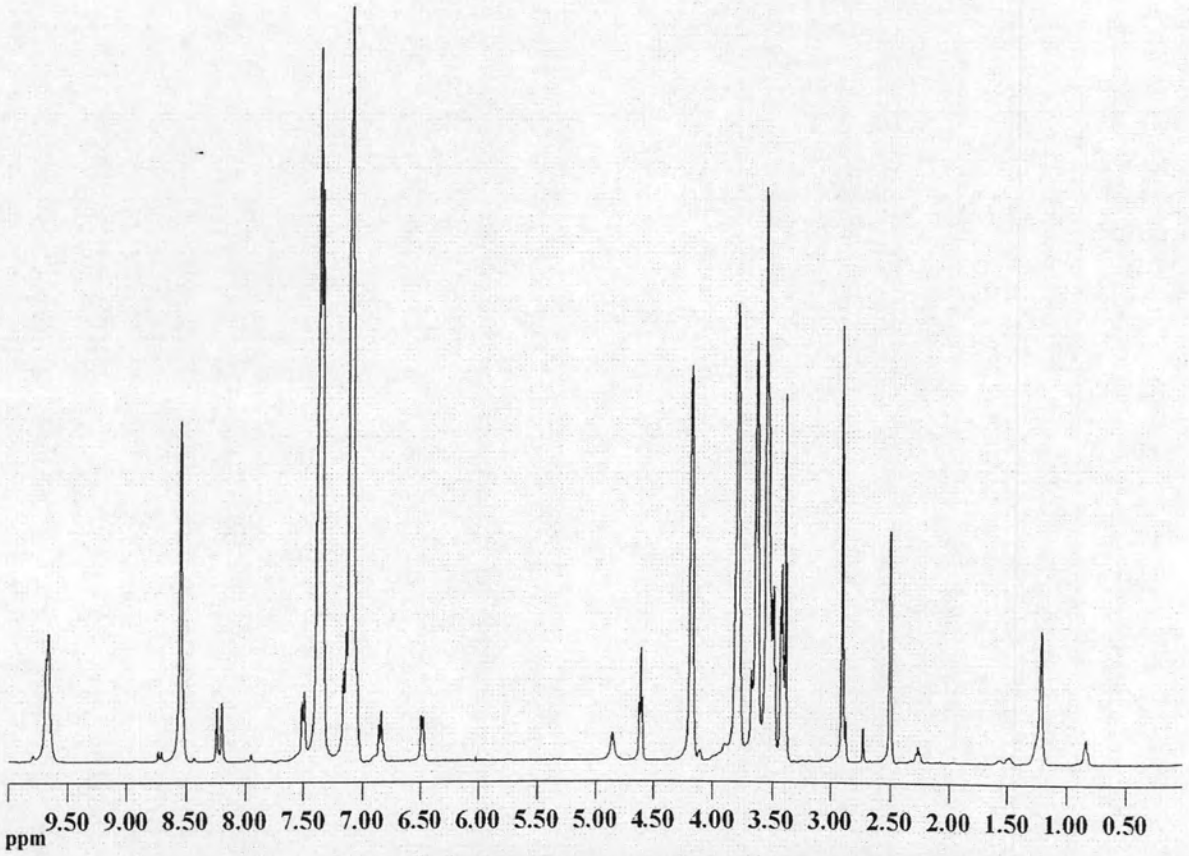

Figure A.18 ^{1}H NMR spectrum of MDI-TEG in DMSO-d_6

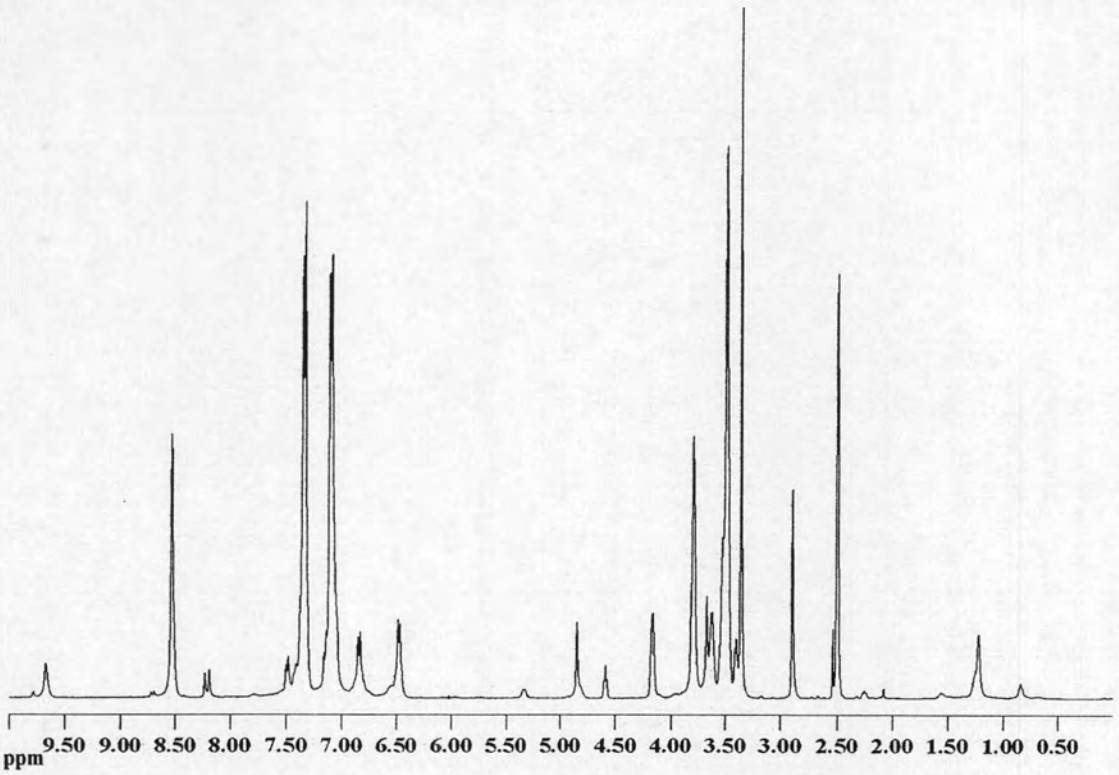

Figure A.19 ^{1}H NMR spectrum of MDI-PEG (1:1) in DMSO-d_6

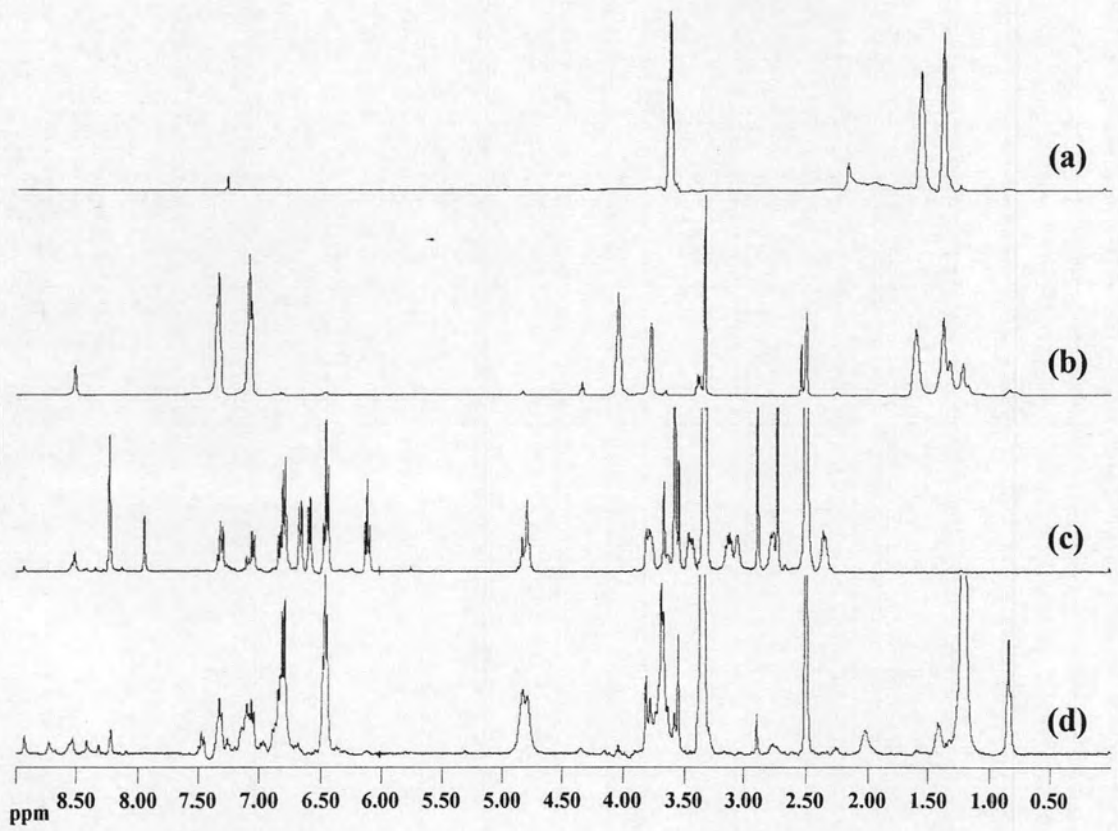

Figure A.20 ^{1}H NMR spectra of (a) HMDO; (b) MDI-HMDO;
(c) ZnSalOMe$_2$trien-MDI; (d) ZnSalOMe$_2$trien-MDI-HMDO

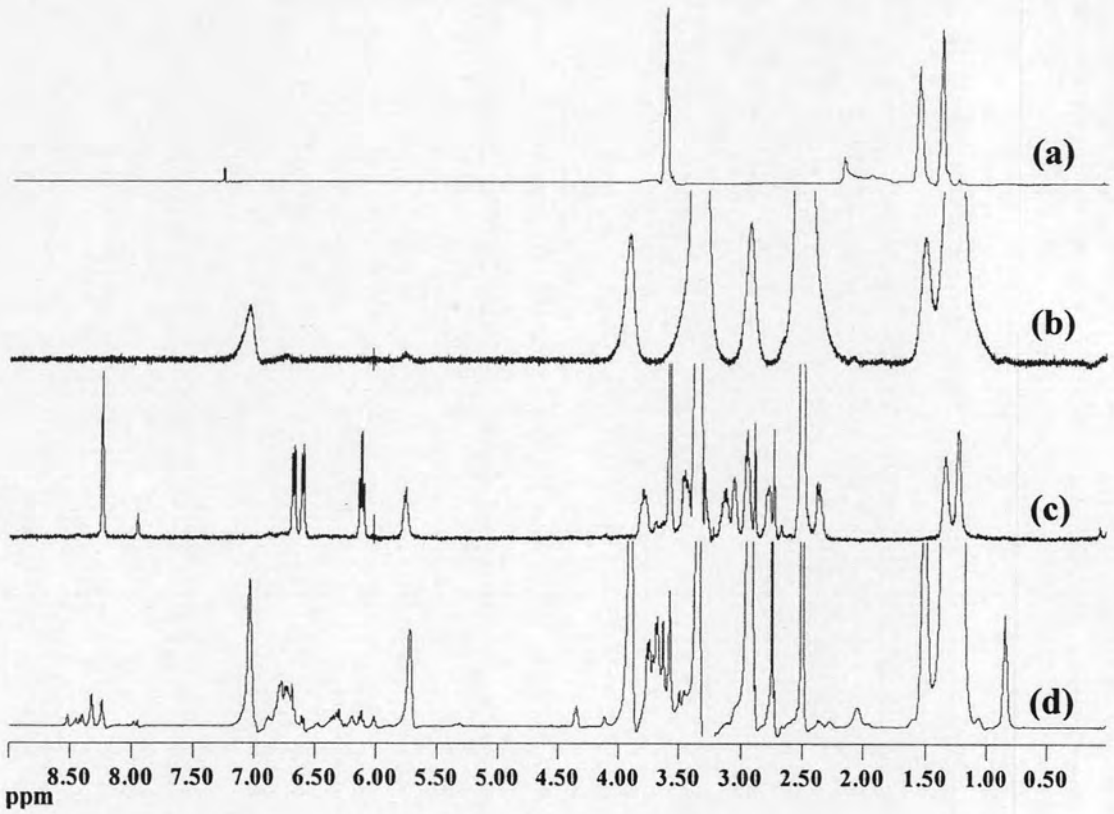

Figure A.21 ^{1}H NMR spectra of (a) HMDO; (b) HMDI-HMDO; (c) ZnSalOMe$_2$trien-HMDI; (d) ZnSalOMe$_2$trien-HMDI-HMDO

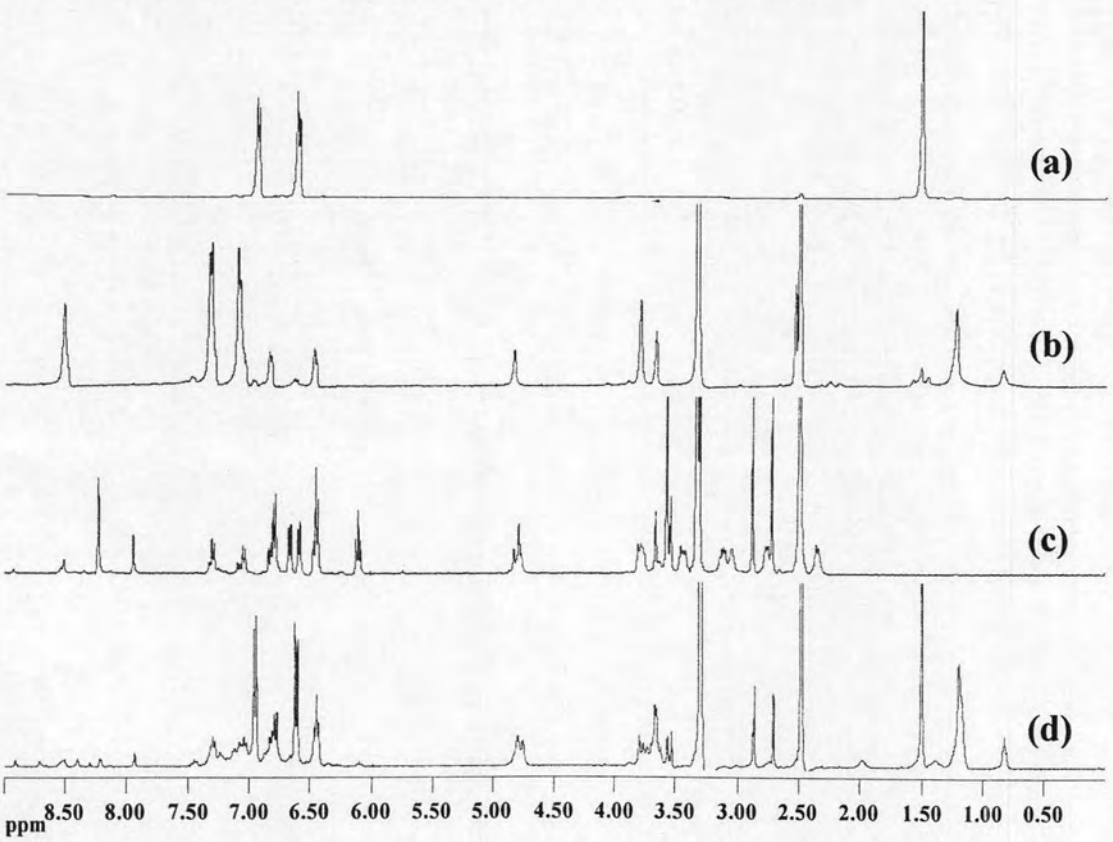

Figure A.22 ^{1}H NMR spectra of (a) BPA; (b) MDI-BPA; (c) ZnSalOMe$_2$trien-MDI; (d) ZnSalOMe$_2$trien-MDI-BPA

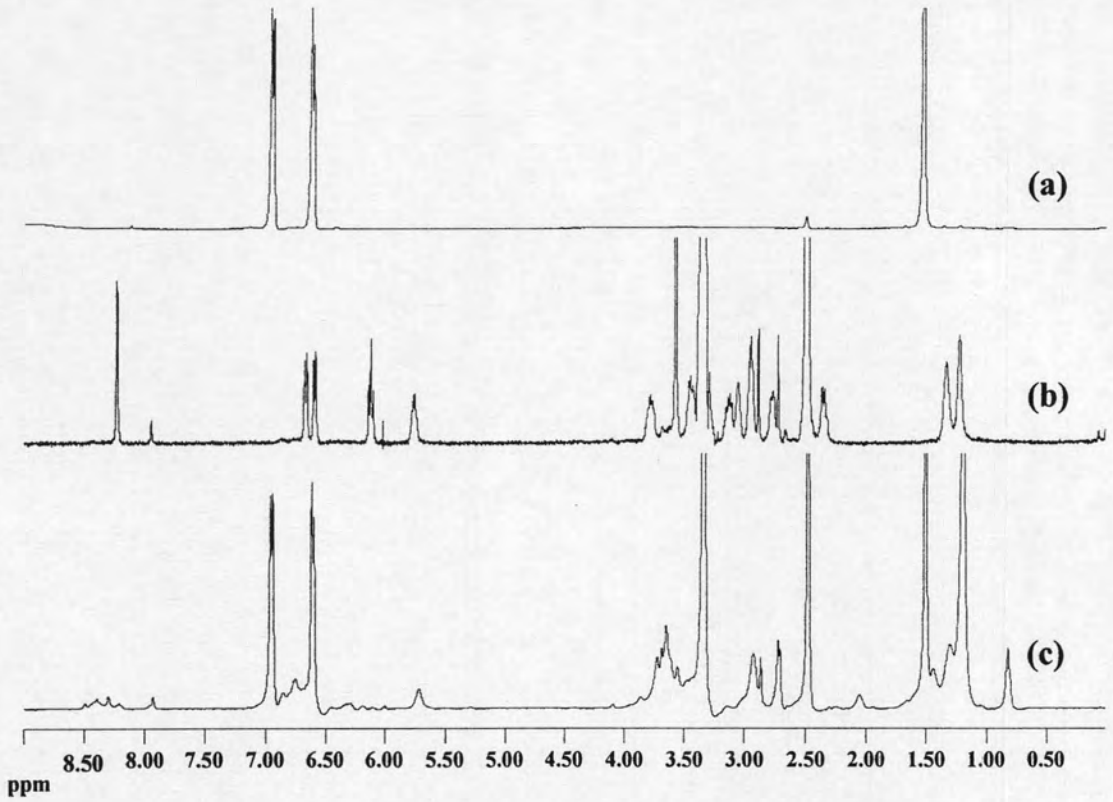

Figure A.23 ^{1}H NMR spectra of (a) BPA; (b) ZnSalOMe$_2$trien-HMDI; (c) ZnSalOMe$_2$trien-HMDI-BPA

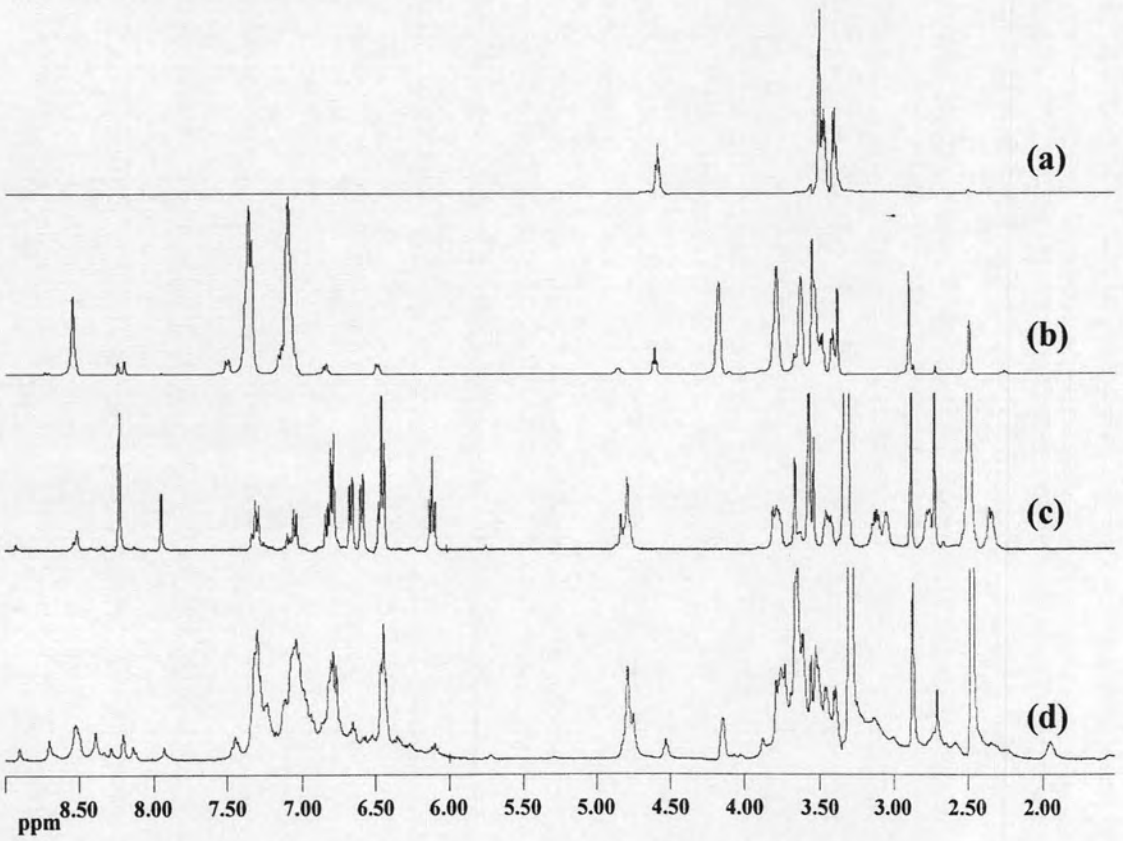

Figure A.24 ^{1}H NMR spectra of (a) TEG; (b) MDI-TEG; (c) ZnSalOMe$_2$trien-MDI; (d) ZnSalOMe$_2$trien-MDI-TEG

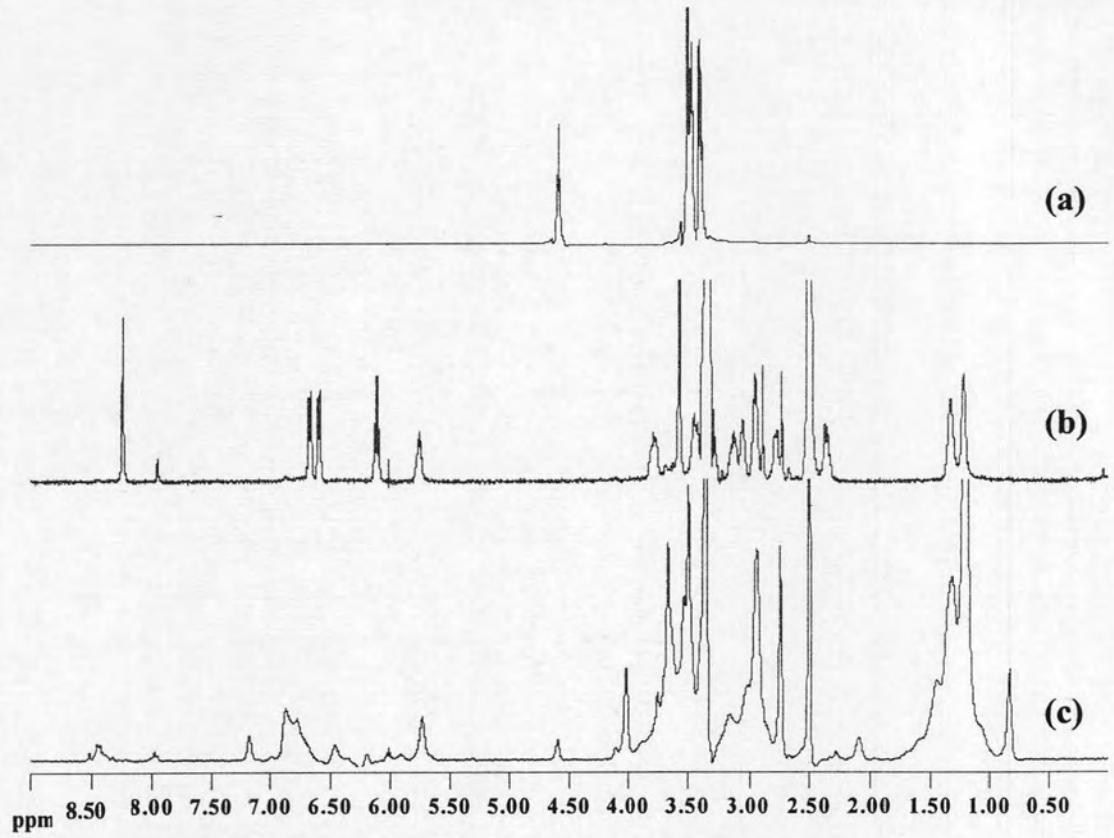

Figure A.25 ^{1}H NMR spectra of (a) TEG; (b) ZnSalOMe$_2$trien-HMDI; (c) ZnSalOMe$_2$trien-HMDI-TEG

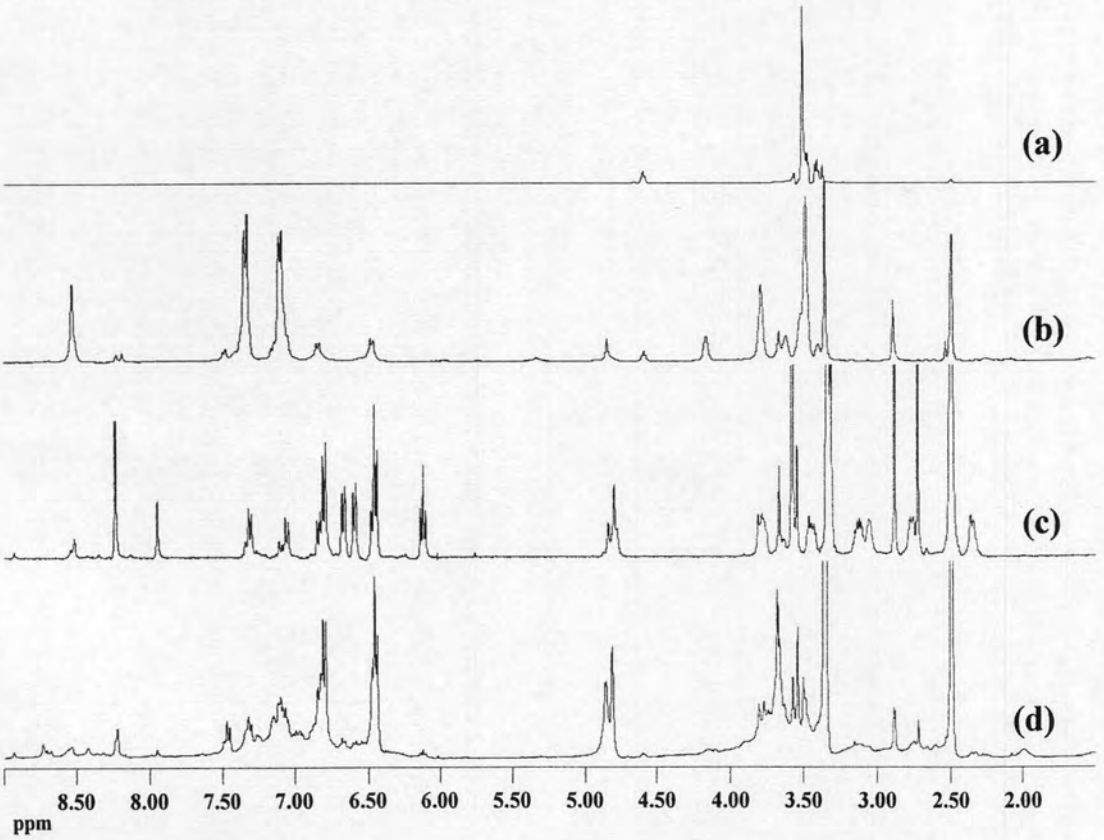

Figure A.26 ^{1}H NMR spectra of (a) PEG; (b) MDI-PEG; (c) ZnSalOMe$_2$trien-MDI; (d) ZnSalOMe$_2$trien-MDI-PEG

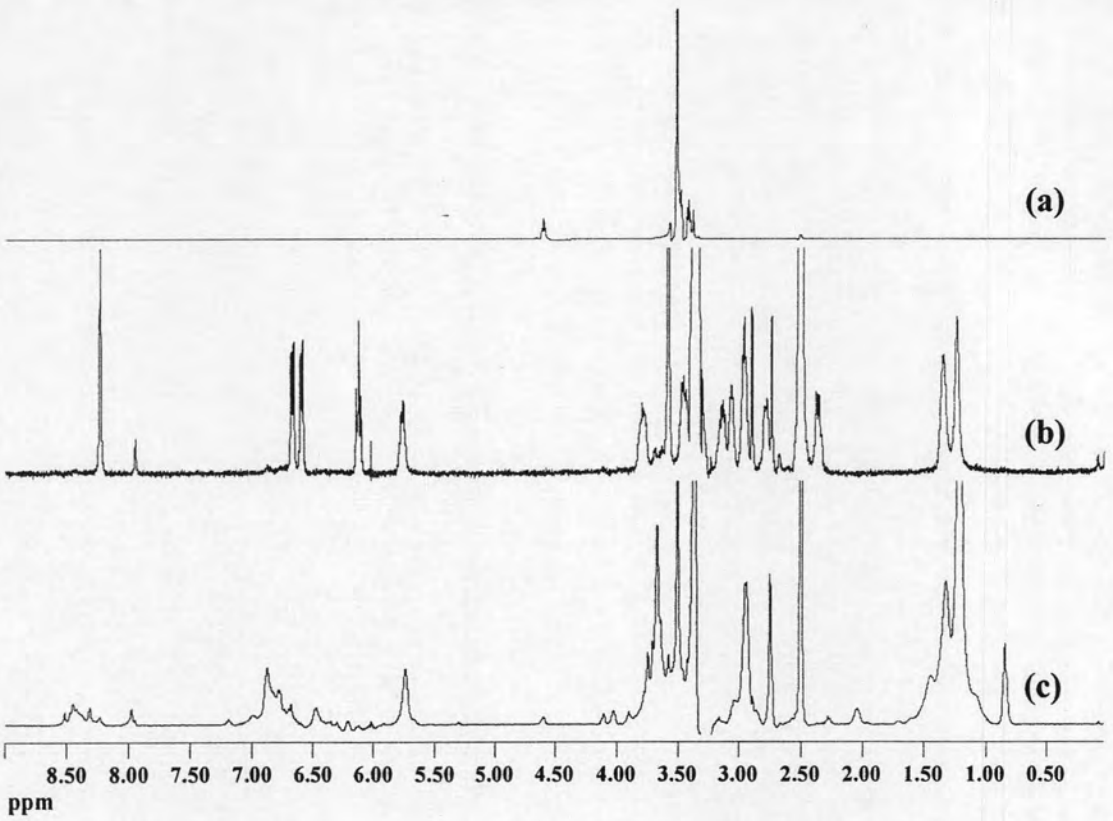

Figure A.27 ^{1}H NMR spectra of (a) PEG; (b) HMDI-PEG;
(c) ZnSalOMe$_2$trien-HMDI; (d) ZnSalOMe$_2$trien-HMDI-PEG

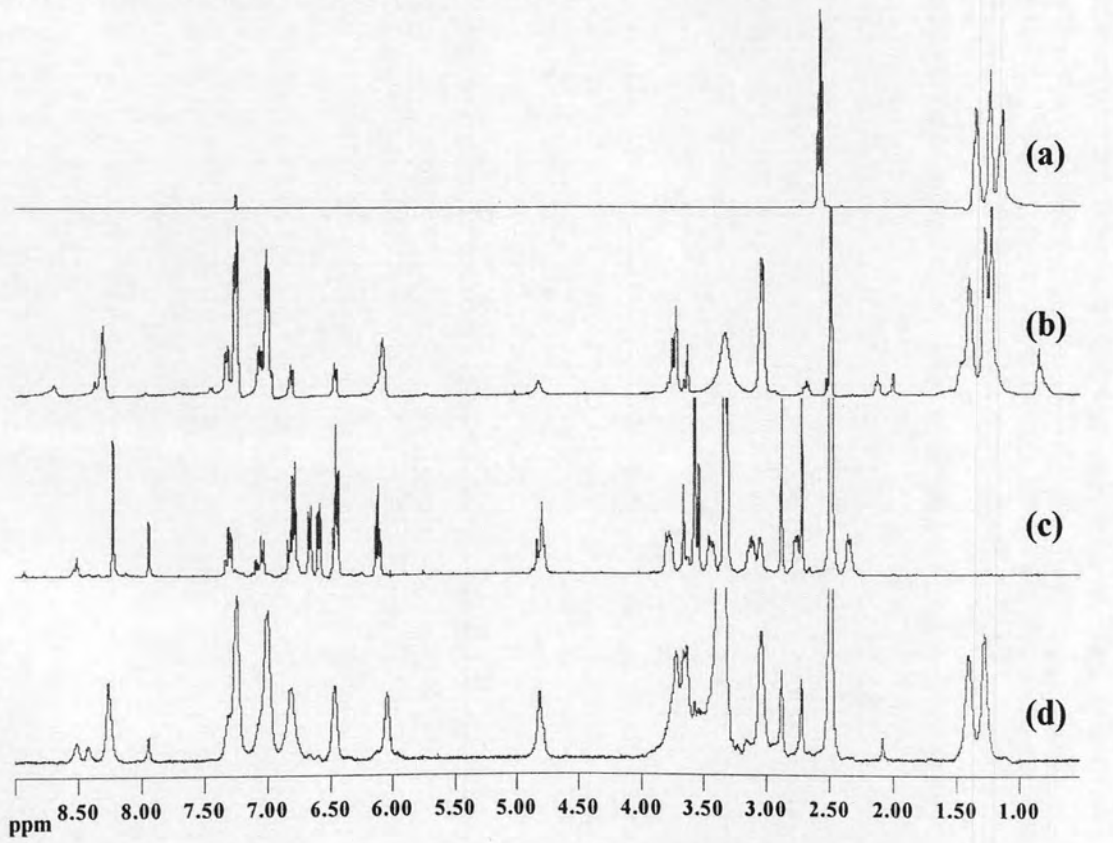

Figure A.28 ^{1}H NMR spectra of (a) HMDA; (b) MDI-HMDA;
(c) ZnSalOMe$_2$trien-MDI; (d) ZnSalOMe$_2$trien-MDI-HMDA

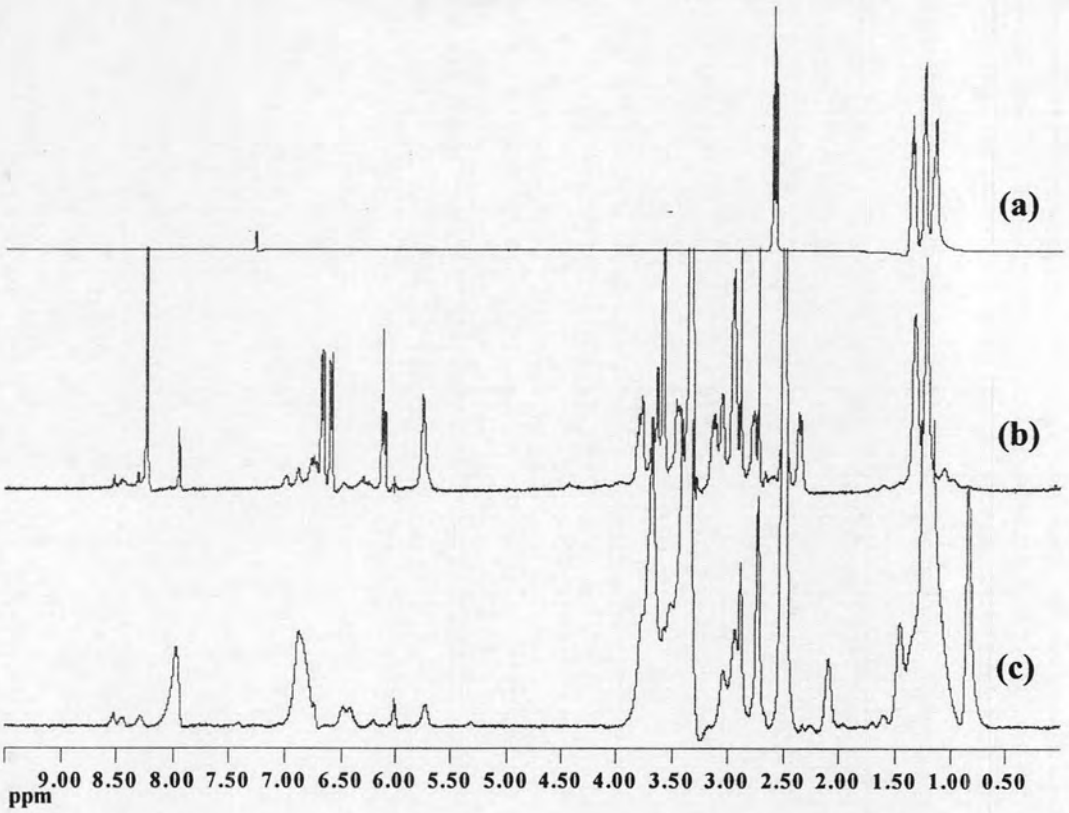

Figure A.29 ^{1}H NMR spectra of (a) HMDA; (b) ZnSalOMe$_2$trien-HMDI; (c) ZnSalOMe$_2$trien-HMDI-HMDA

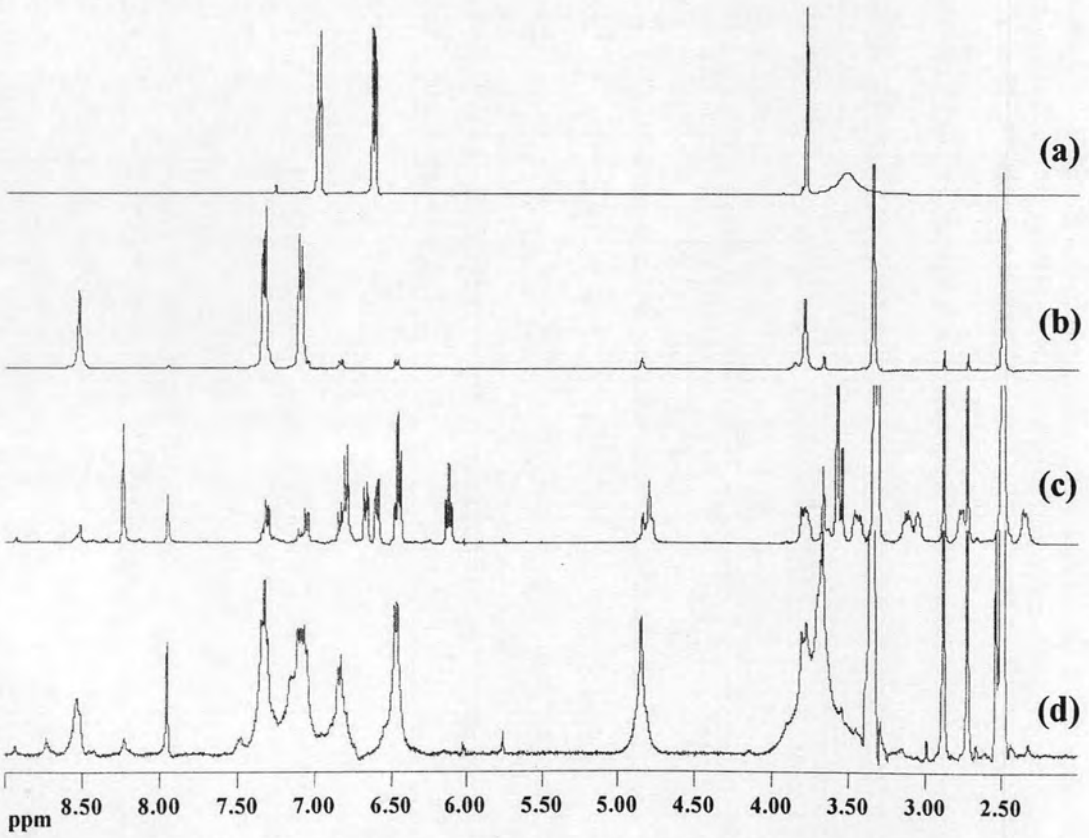

Figure A.30 ^{1}H NMR spectra of (a) DAP; (b) MDI-DAP; (c) ZnSalOMe$_2$trien-MDI; (d) ZnSalOMe$_2$trien-MDI-DAP

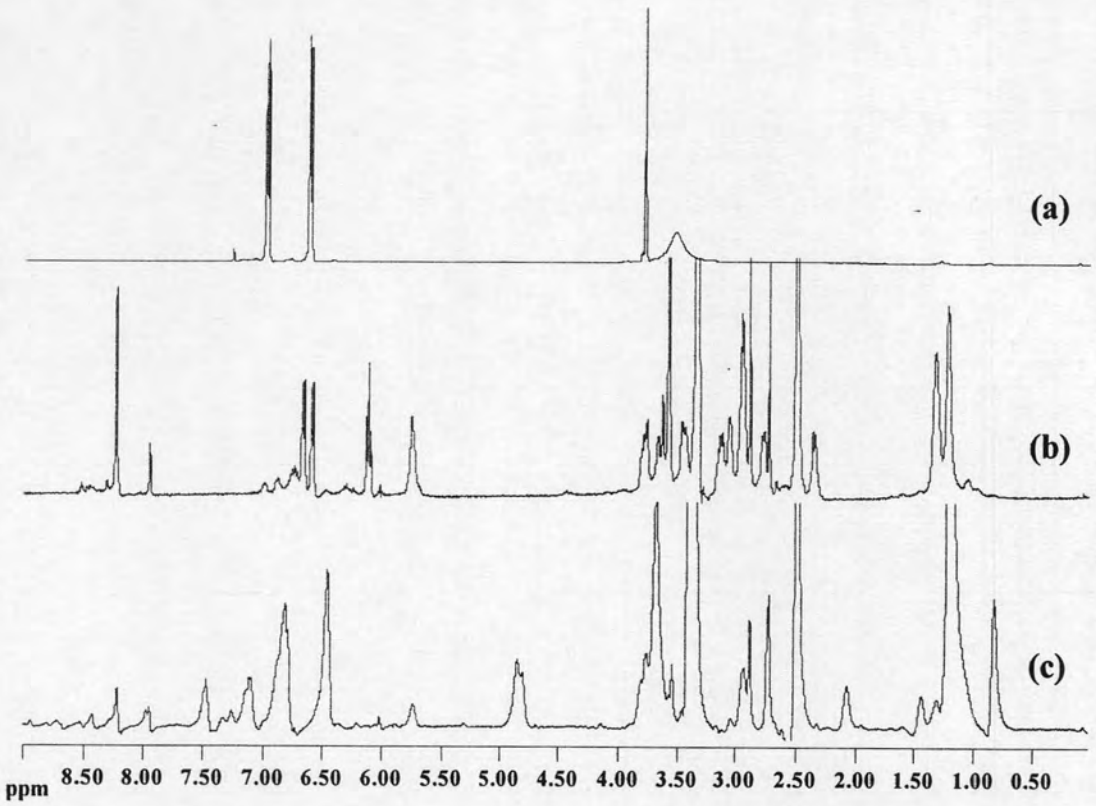

Figure A.31 ^{1}H NMR spectra of (a) DAP; (b) ZnSalOMe$_2$trien-HMDI; (c) ZnSalOMe$_2$trien-HMDI-DAP

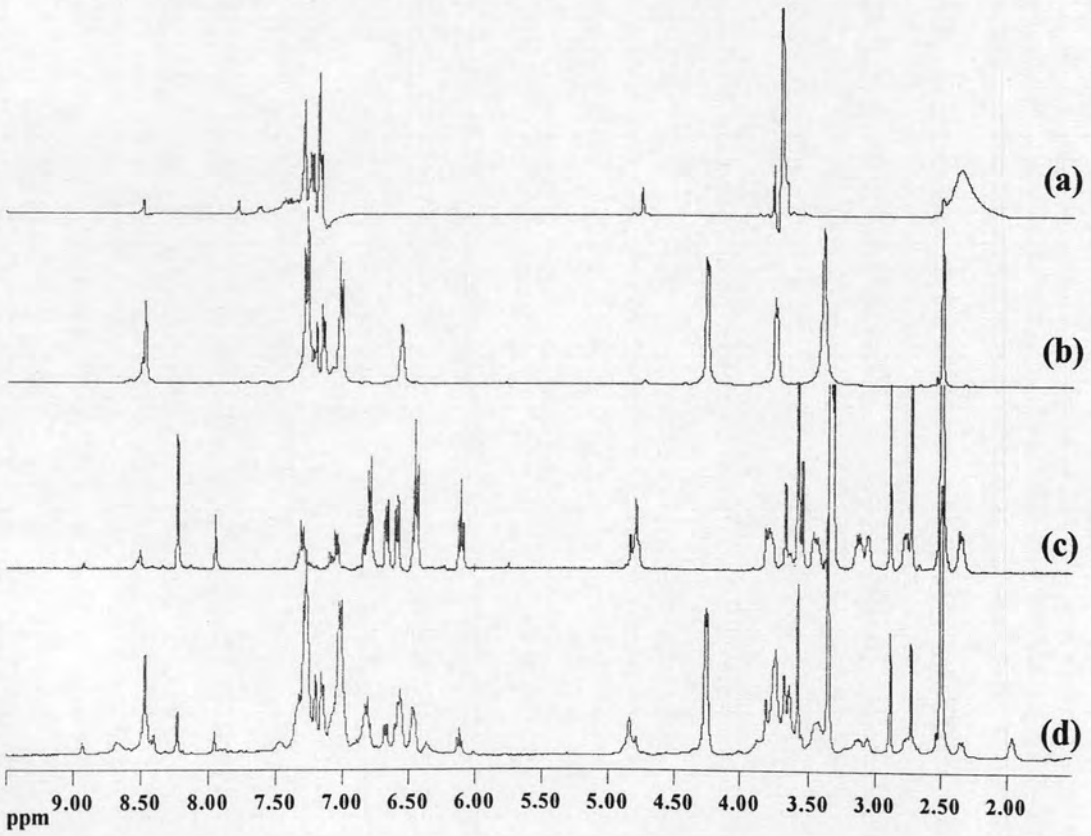

Figure A.32 ^{1}H NMR spectra of (a) XDA; (b) MDI-XDA; (c) ZnSalOMe$_2$trien-MDI; (d) ZnSalOMe$_2$trien-MDI-XDA

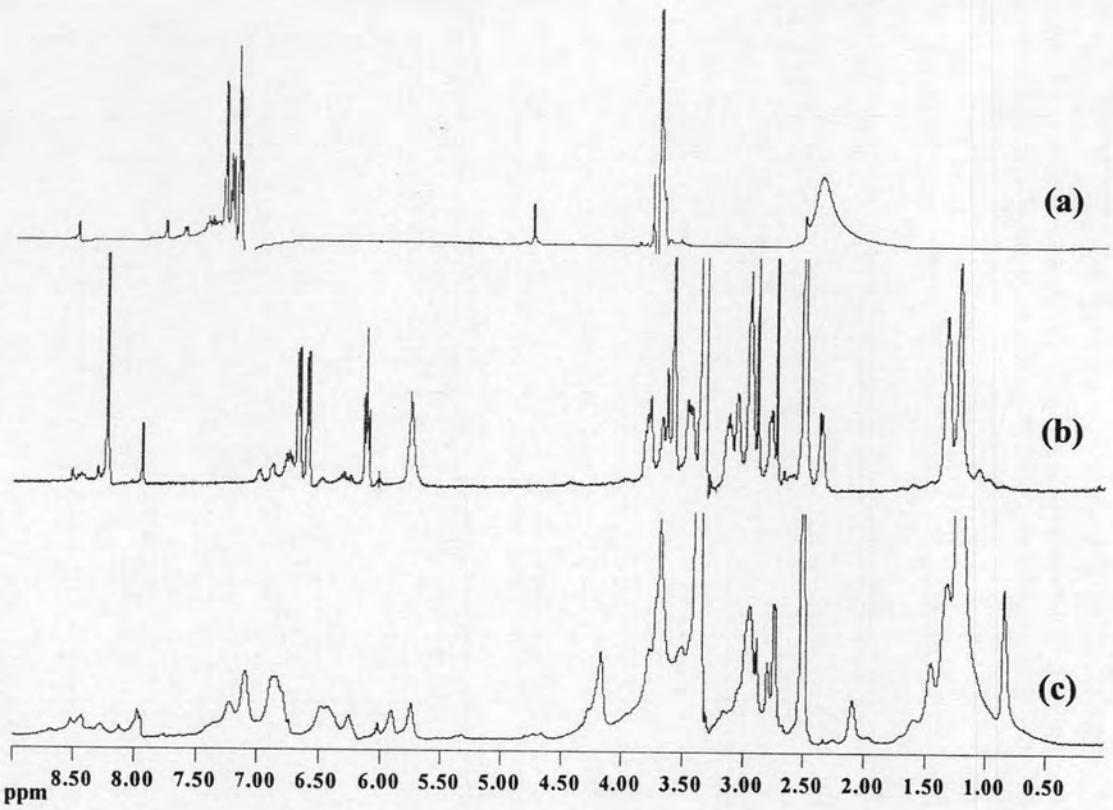

Figure A.33 ^{1}H NMR spectra of (a) XDA; (b) ZnSalOMe$_2$trien-HMDI; (c) ZnSalOMe$_2$trien-HMDI-XDA

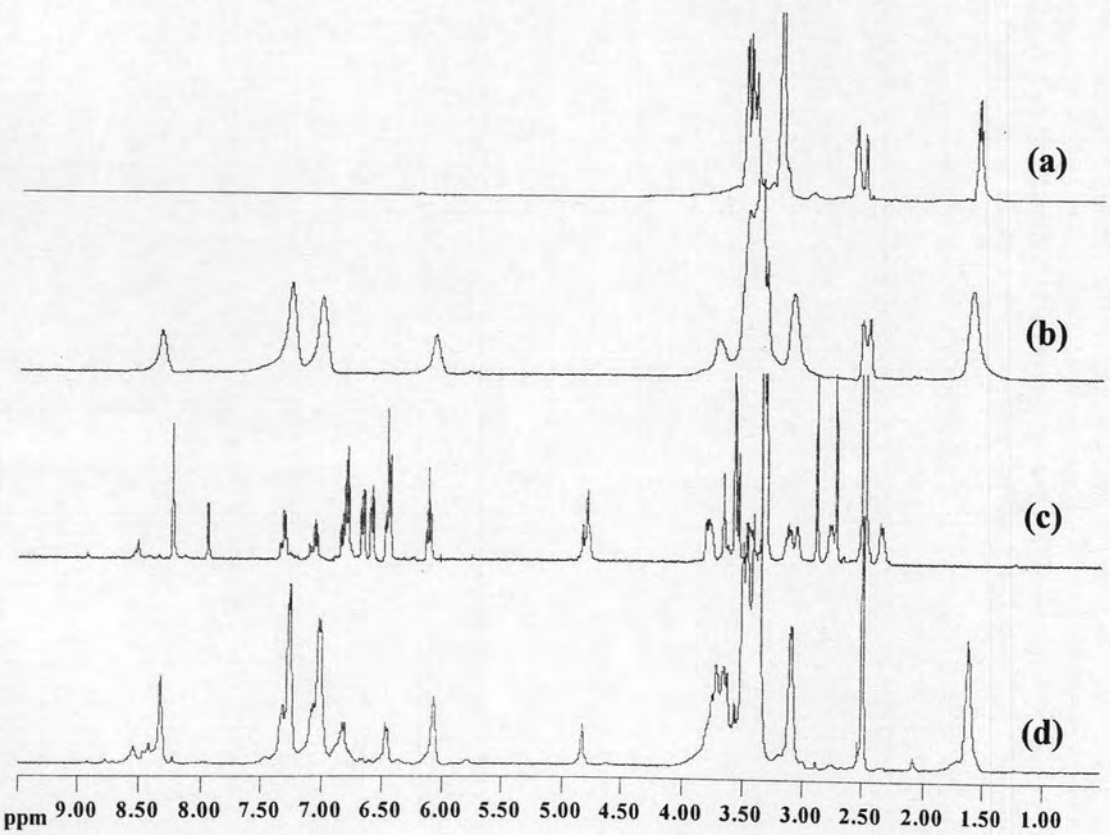

Figure A.34 ^{1}H NMR spectra of (a) TDA; (b) MDI-TDA; (c) ZnSalOMe$_2$trien-MDI; (d) ZnSalOMe$_2$trien-MDI-TDA

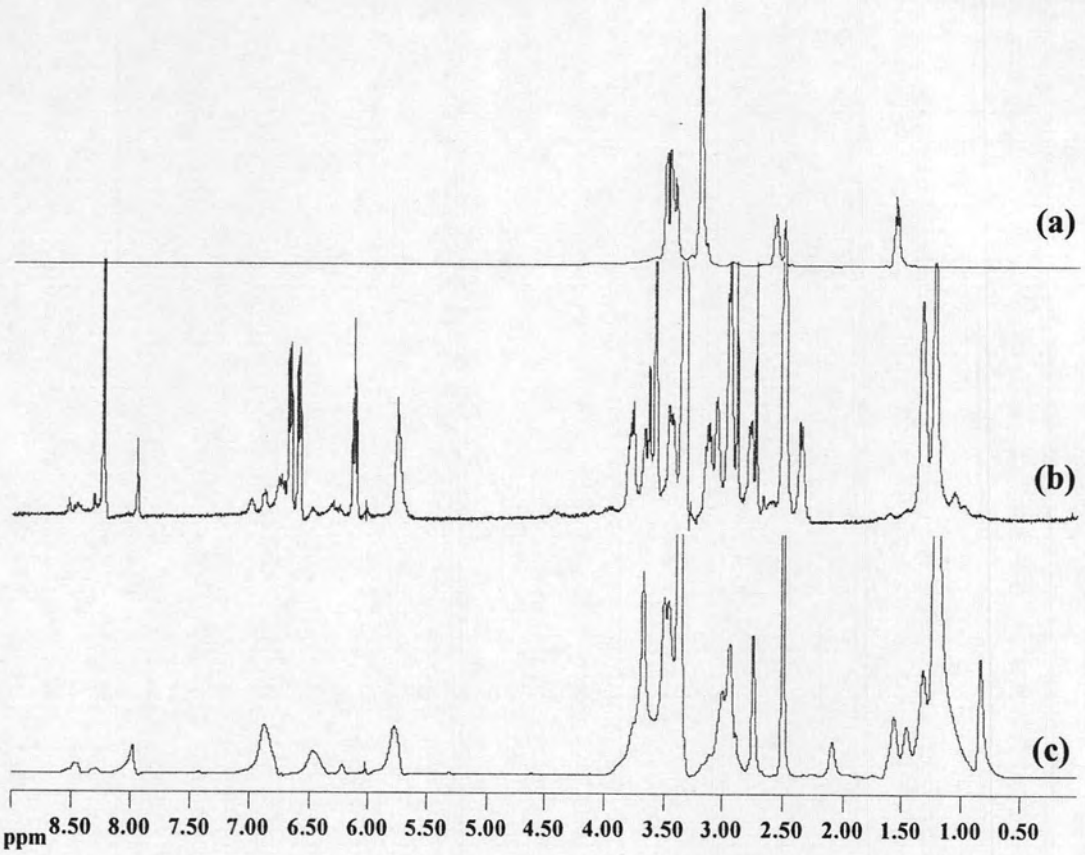

Figure A.35 ^{1}H NMR spectra of (a) TDA; (b) ZnSalOMe$_2$trien-HMDI; (c) ZnSalOMe$_2$trien-HMDI-TDA

APPENDIX B

B-1 DETERMINATION OF INHERENT VISCOSITY

Inherent viscosity [η_{inh}] ASTM D2270: Inherent viscosity is calculated from the dilute solution (1% or less) relative viscosity of the polymer. The inherent viscosity is calculated as:

The relative viscosity is given by:

$$\eta_{rel} = \frac{\text{solution flow time (t), sec}}{\text{solvent flow time } (t_0), \text{ sec}}$$

The inherent viscosity is calculated as:

$$\eta_{inh} = \frac{\eta_{rel}}{C}$$

where

C = concentration of the polymer in grams per 100 ml of solvent; usually, C = 0.5 g/100 mL

$\ln\eta_{rel}$ = natural logarithm of the relative viscosity of the dilute polymer solution

K = 0.008551, t_0 = 169.89 sec, Kt_0 = 1.4527 sec

Relative viscosity can be taken as the ratio of the flow times of a polymer solution and the pure solvent in the same viscometer and at the same temperature. Relative viscosity values generally are used for calculating the intrinsic or inherent viscosity of a polymer. The solvent to be used will depend on the polymer solubility. In general, the solvent should completely dissolve the sample in less than 30 minutes. It is desirable that the polymer be dissolved at room temperature although, heating is permissible if no degradation occurs. Select the viscometer through which the solvent will flow in not less than 100 seconds and not more than 200 seconds.

VITAE

Name: Miss Khwunta Vanitcho

Born: December 22nd, 1982

Education: 2004 B. Sc. (Chemistry), Chulalongkorn University, Bangkok, Thailand.

2008 M. Sc. (Organic Chemistry), Chulalongkorn University, Bangkok, Thailand.