REFERENCES

1. Thomson, T. Polyurethane as Specialty Chemicals. Florida: CRC Press, 2005.
2. Stevens, M. P. Polymer Chemistry, an Introduction. New York: Oxford University Press, 1999.
3. Odian, G. Principles of polymerization. New York: John Wiley & Sons, 1993.
4. Dysons, R. W. Specialty Polymers. New York: Chapman and Hall, 1987.
5. Frisch, K. C. Recycling of Polyurethanes. Pennsylvania: Technomic, 1999.
6. Genge, K. Polyurethanes. Chichester: John Wiley & Sons, 1987.
7. Jayakumar, R.; Lee, Y. S.; Rajkumar, M. and Nanjundan, S. Synthesis, characterization and antibacterial activity of metal-containing polyurethanes. J. Appl. Polym. Sci. 91 (2004): 288-295.
8. Chantarasiri, N.; Damrongkosit, T.; Jangwong, W.; Sridaeng, D. and Suebphan, R. Synthesis, characterization and thermal properties of metal-containing polyurethane-ureas from hexadentate Schiff base metal complexes. Eur. Polym. J. 40 (2004): 1867-1874.
9. Nanjundan. S.; Prasath, R. A.; Pakula, T. and Klapper, M. Thermal and dynamic mechanical behaviour of calcium containing co-polyurethane. Polymer. Degrad. Stab. 85 (2004): 911-923.
10. Jayakumar, R.; Lee, Y. S. and Nanjundan, S. Studies on calcium-containing poly(urethane ether)s. J. Polym. Sci. A: Polym. Chem. 41 (2003): 2865-2878.
11. Issam, A. M. and Ismail, J. Improvement of thermal stability of new heteroaromatic poly(azomethine urethane)s. J. Appl. Polym. Sci. 100 (2006): 1198-1204.
12. Behniafar, H.; Haghighat, S. and Farzaneh, S. Direct synthesis of soluble and thermally stable poly(urethane-imide)s from a new triimide-dicarbonylazide. Polym. J. 46 (2005): 4627-4634.
13. 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.

14. 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.

15. 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.

16. 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.

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

18. Nanjundan, S.; Prasath, R. A. and Vijayanand, P. S. Studies on polyurethanes and polyurethane-ureas derived from divalent metal salts of mono(hydroxyl)hexolate. Polym. Int. 49 (2002): 1464-1472.

19. Nanjundan, S. and Prasath, R. A. Synthesis and characterization of metal-containing polyurethanes and polyurethane-ureas. Eur. Polym. J. 35 (1999): 1939-1948.

20. Nanjundan, S.; Lee, Y. S. and Jaryakumar, R. Studied on metal-containing copolyurethanes. React. Funct. Polym. 55 (2003): 267-276.

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

22. Jayakumar, R.; Prasart, R. A.; Radhakrishnan. and Nanjundan, S. Studies on zinc-containing polyurethanes and polyurethane-ureas. J. Macromol. Sci Pure. Appl. Chem. A. 39 (2002): 853-877.

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

24. Jayakumar, R.; Nunjundan, S. and Radhakrishnan, S. Studies on poly(urethane-urea)s base on zinc salt of mono(hydroxyl ethoxyethyl)phthalate. React. Funct. Polym. 57 (2003): 23-31.

25. Jayakumar, R.; Lee, Y. S. and Nanjundan, S. Synthesis and coating characteristics of novel calcium-containing poly(urethane ethers). J. Appl. Polym. Sci. 92 (2004): 710-721.

26. Prasath, R. A.; Nanjundan, S., Pakula, T. and Klapper, M. Synthesis and characterization of calcium containing poly(urethane-ether)s. Eur. Polym. J. 40 (2004): 1767-1778.

27. Jayakumar, R and Nanjundan, S. Synthesis of zinc-containing poly (urethane-ether)s based-on zinc salt of mono(hydroxypentyl) phthalate. Eur. Polym. J. 41 (2005): 1623-1629.

28. Khamma, N. Synthesis of metal-containing polyurethane-ureas from 4,4'-dihydroxysaltrien metal complexes. Master's thesis, Department of Chemistry, Chulalongkorn University, 2004.

29. Krisiri, D. Synthesis of polyurethane-ureas containing nickel and zinc 4,4'-dihydroxysaltrien metal complexes. Master's thesis, Program of Petrochemistry and Polymer Science, Chulalongkorn University, 2005.

30. Annakutty, K. S.; Kishore, K. A novel approach to structure-flammability correlation in polyphosphate esters. Polym. J. 29 (1998): 1273-1276.

APPENDICES

APPENDIX A

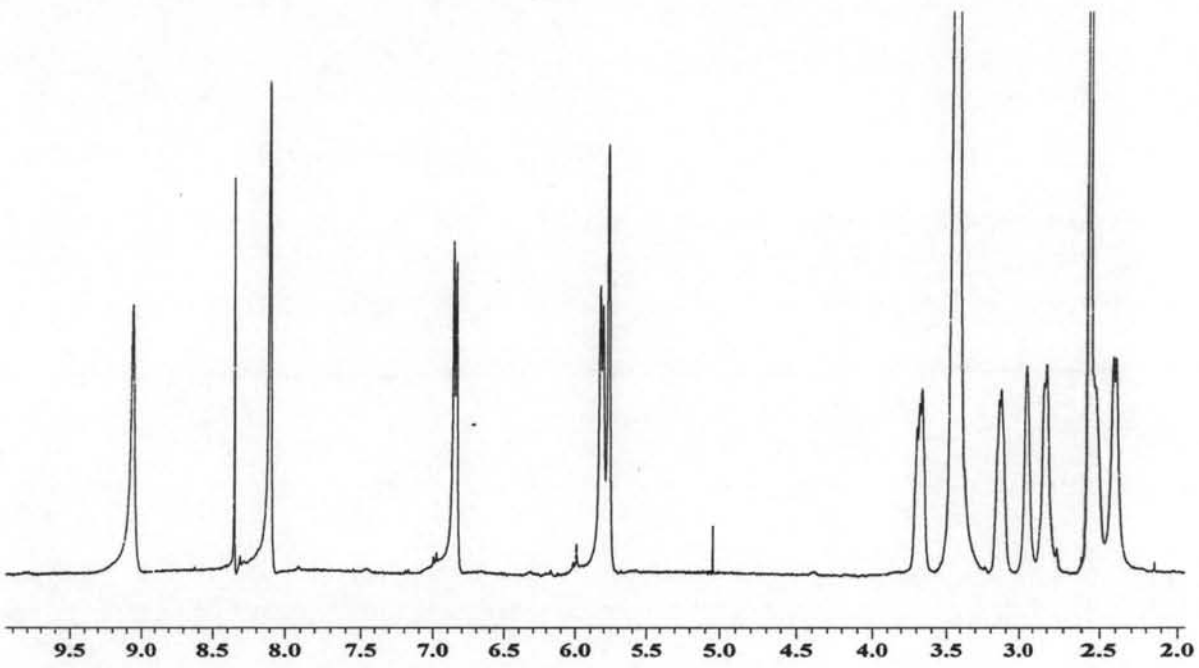


Figure A.1 ^{1}H NMR spectrum of ZnL in DMSO-d_6 + $CDCl_3$

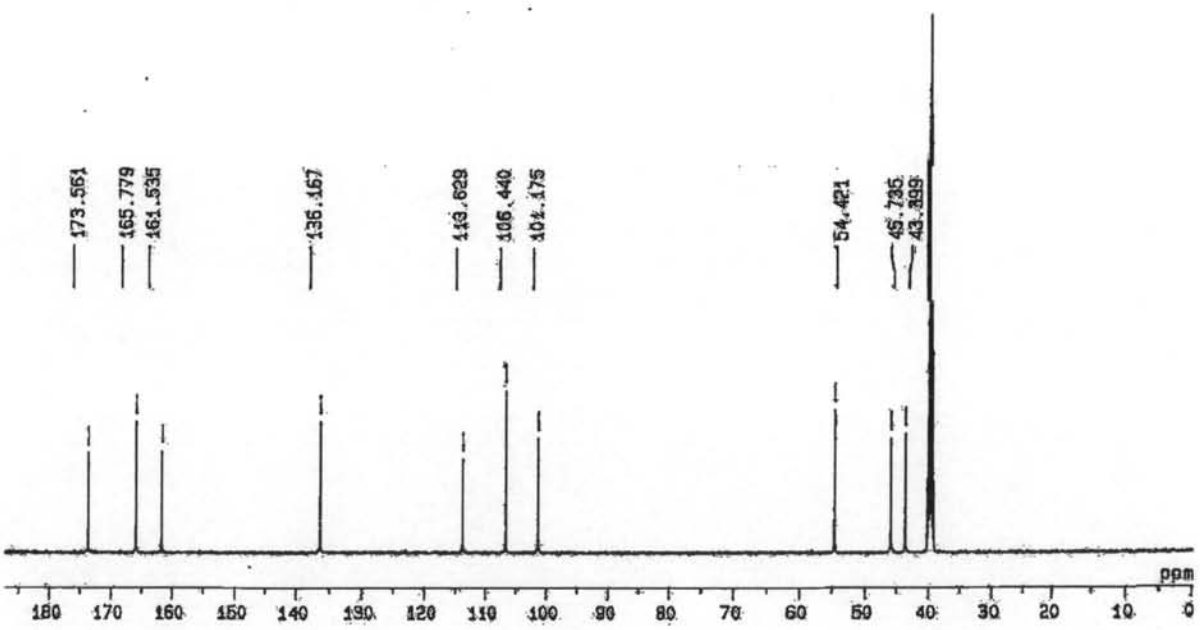


Figure A.2 ^{13}C-NMR spectum of ZnL in DMSO-d_6

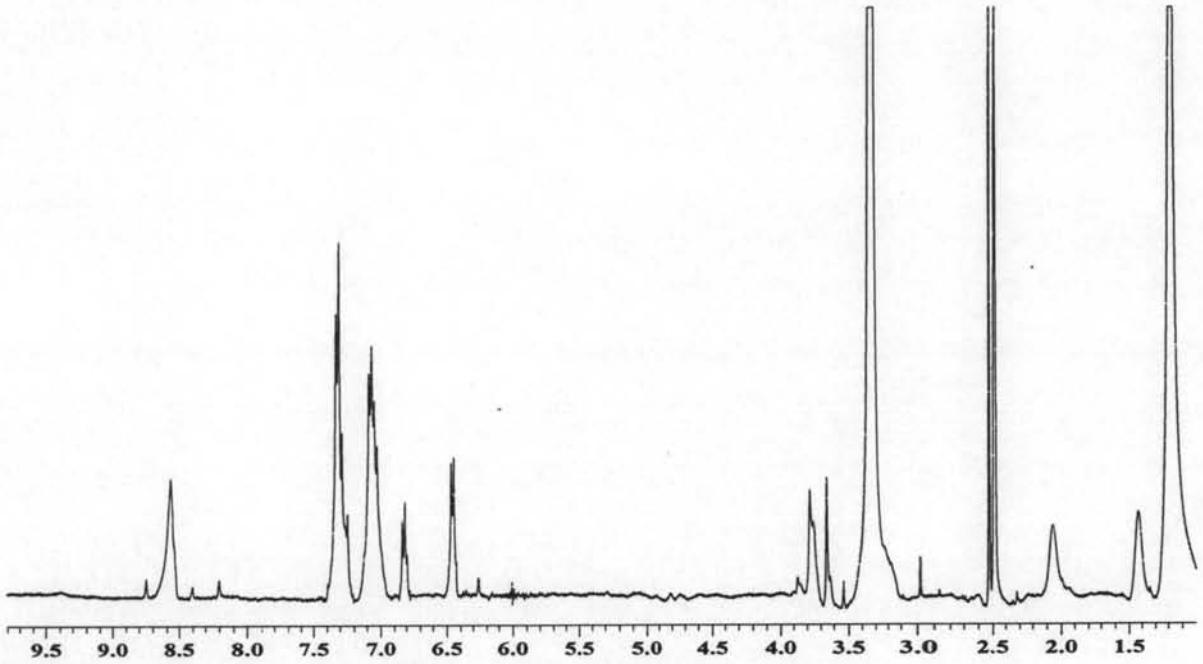


Figure A.3 ^{1}H NMR spectrum of ZnL-MDI (1:2) in DMSO-d_6

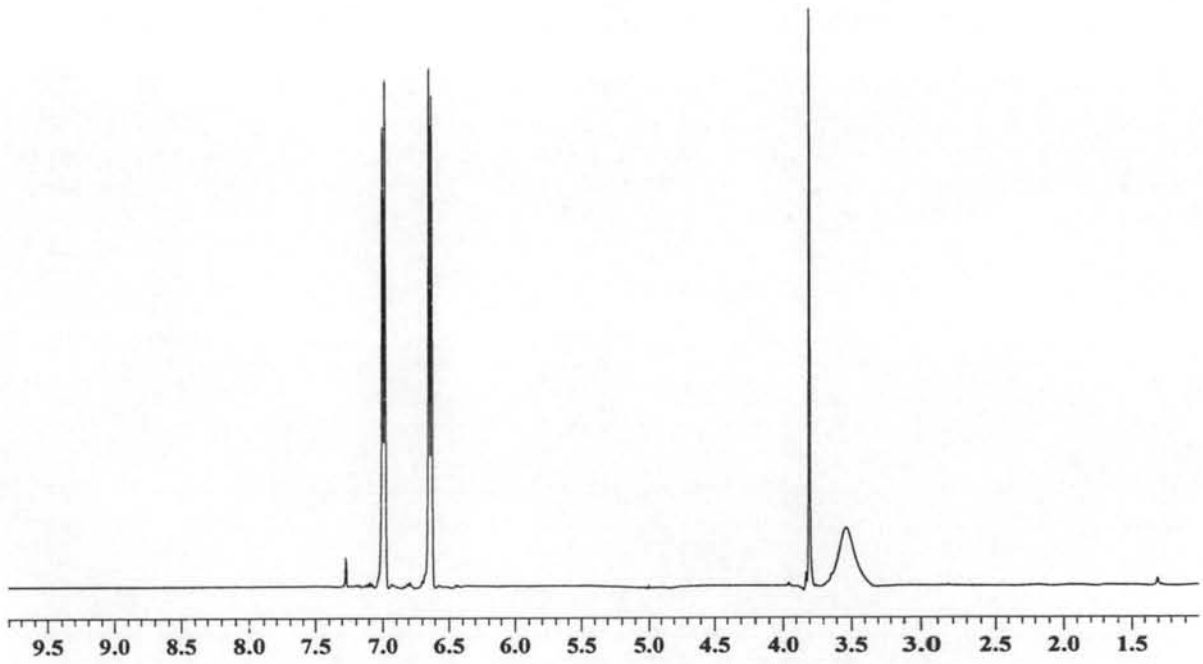


Figure A.4 ^{1}H NMR spectraum of MTDA in DMSO-d_6 + $CDCl_3$

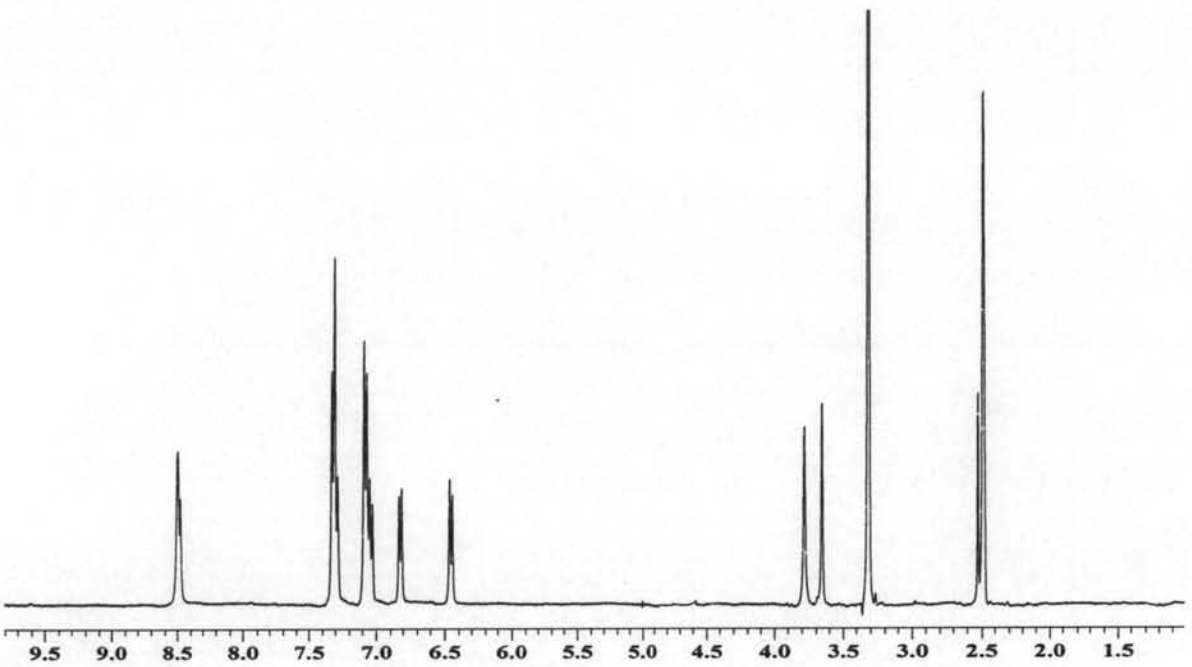


Figure A.5 ^{1}H NMR spectrum of MDI-MTDA (1:1) in DMSO-d_6

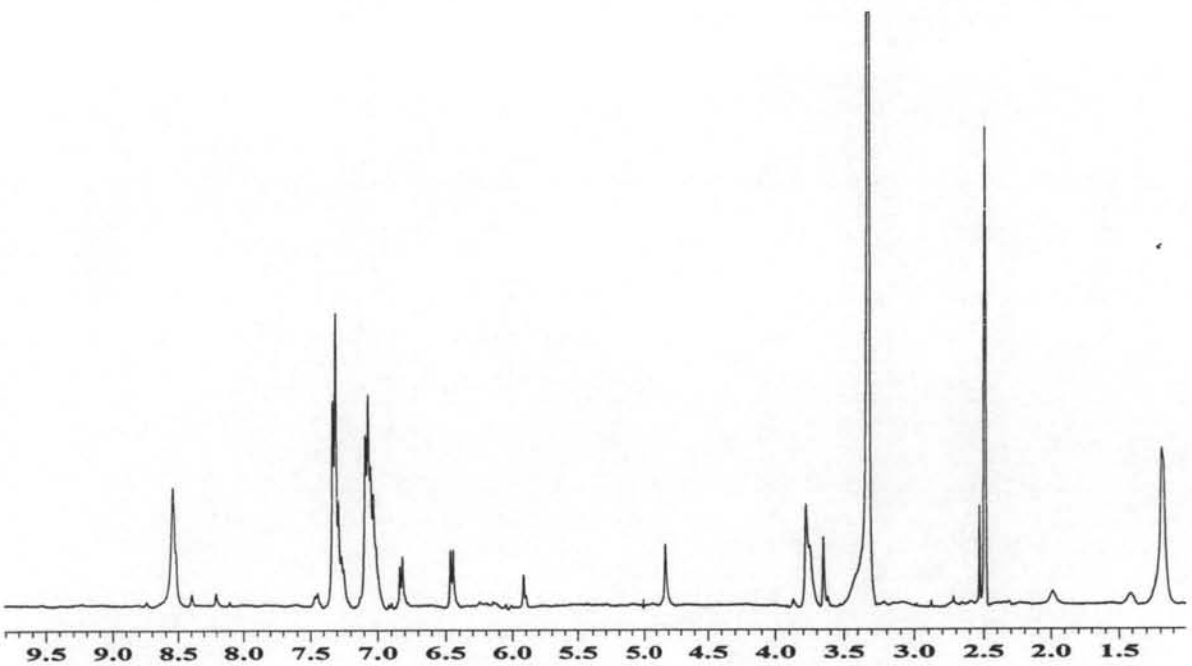


Figure A.6 ^{1}H NMR spectrum of ZnL-MDI-MTDA (1:3:1) in DMSO-d_6

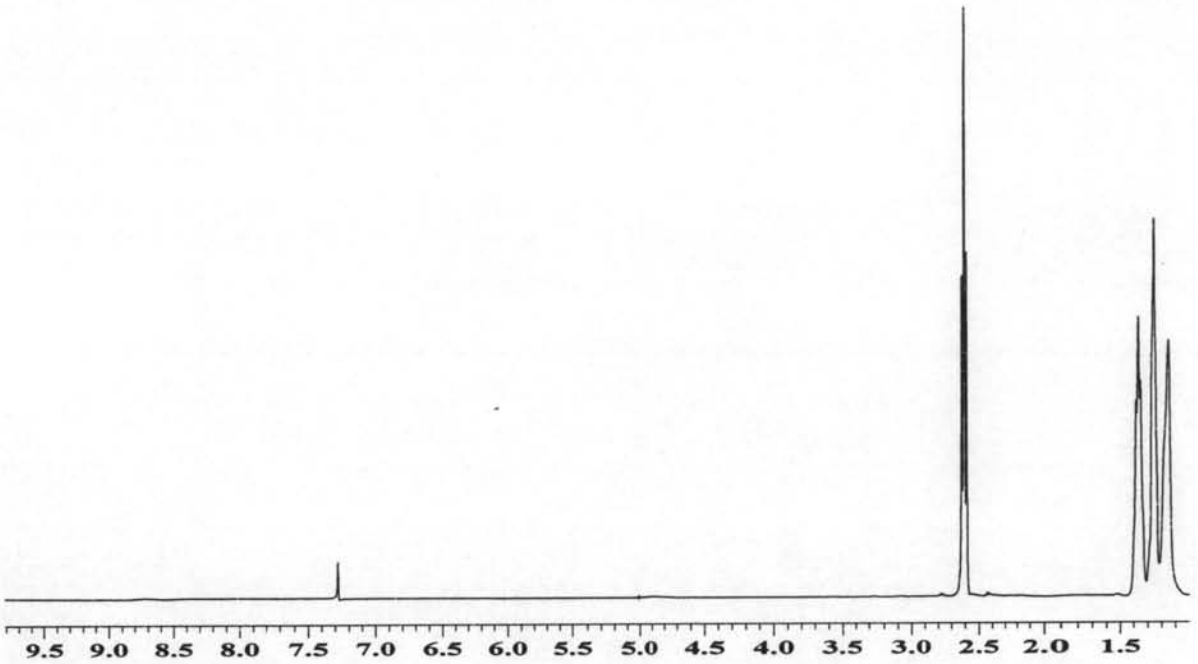


Figure A.7 ^{1}H NMR spectrum of HMDA in DMSO-d_6 + $CDCl_3$

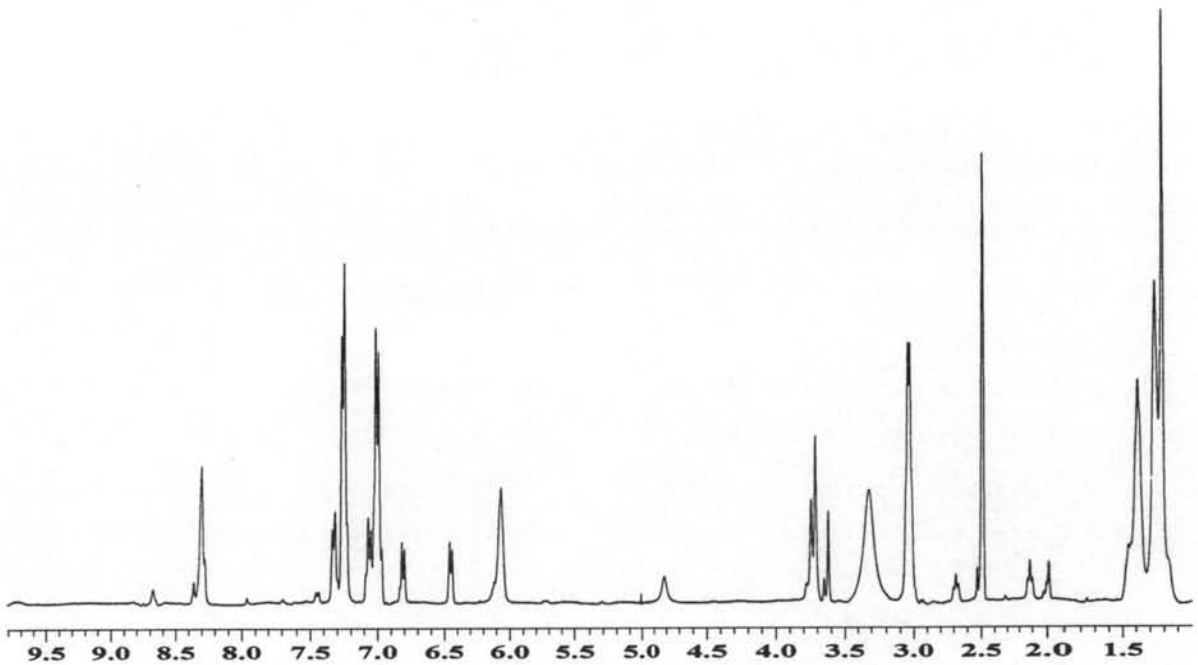


Figure A.8 ^{1}H NMR spectrum of MDI-HMDA (1:1) in DMSO-d_6

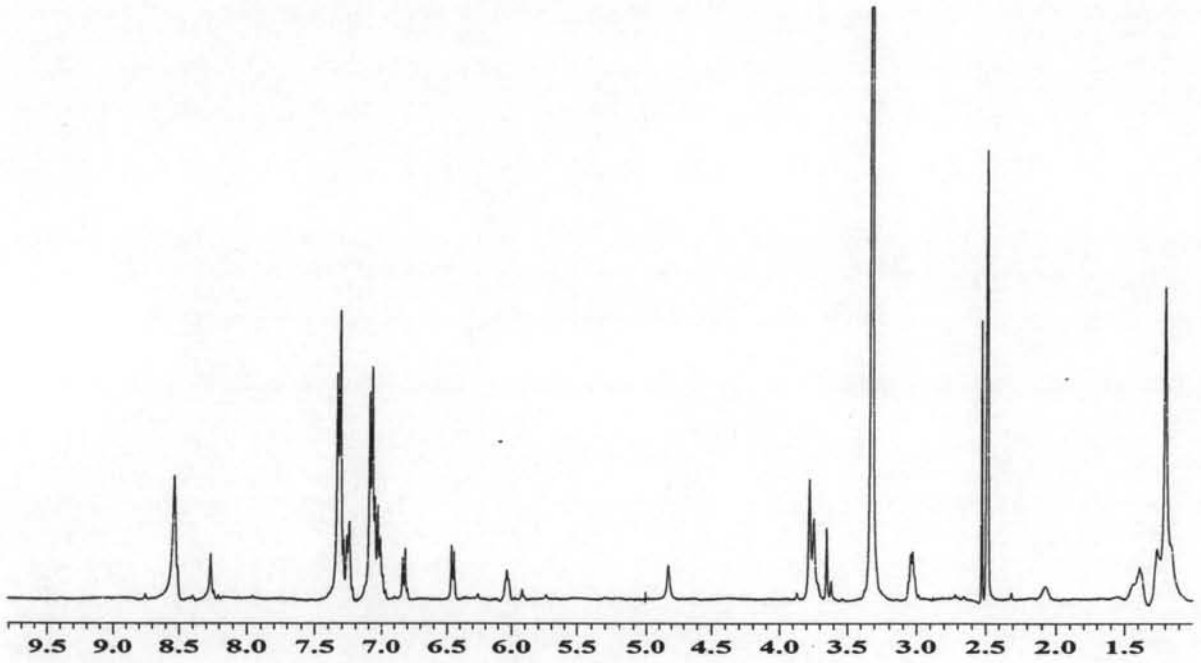


Figure A.9 ^{1}H NMR spectrum of ZnL-MDI-HMDA (1:3:1) in DMSO-d_6

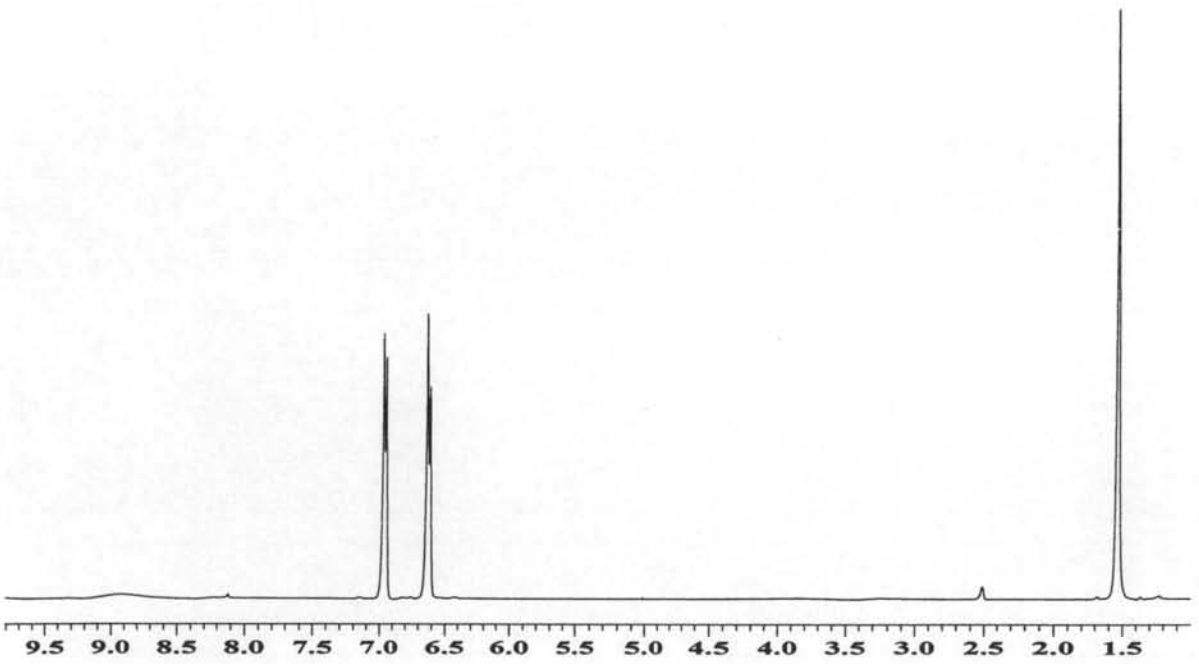


Figure A.10 ^{1}H NMR spectrum of BA in DMSO-d_6 + $CDCl_3$

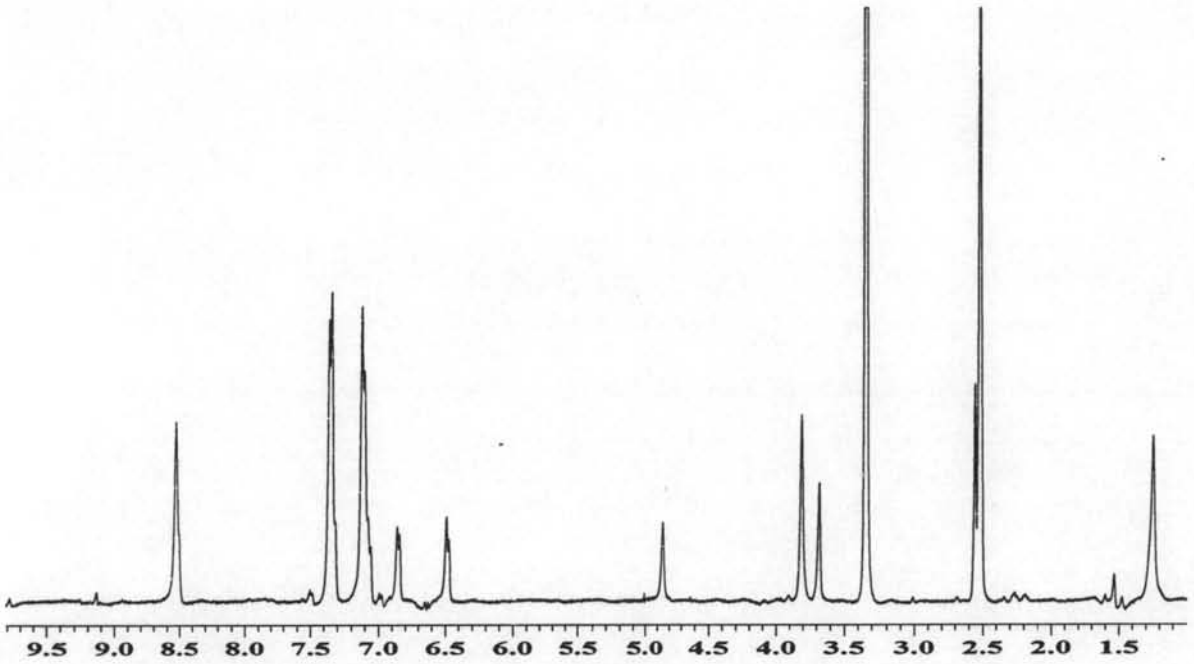


Figure A.11 ^{1}H NMR spectrum of MDI-BA (1:1) in DMSO-d_6

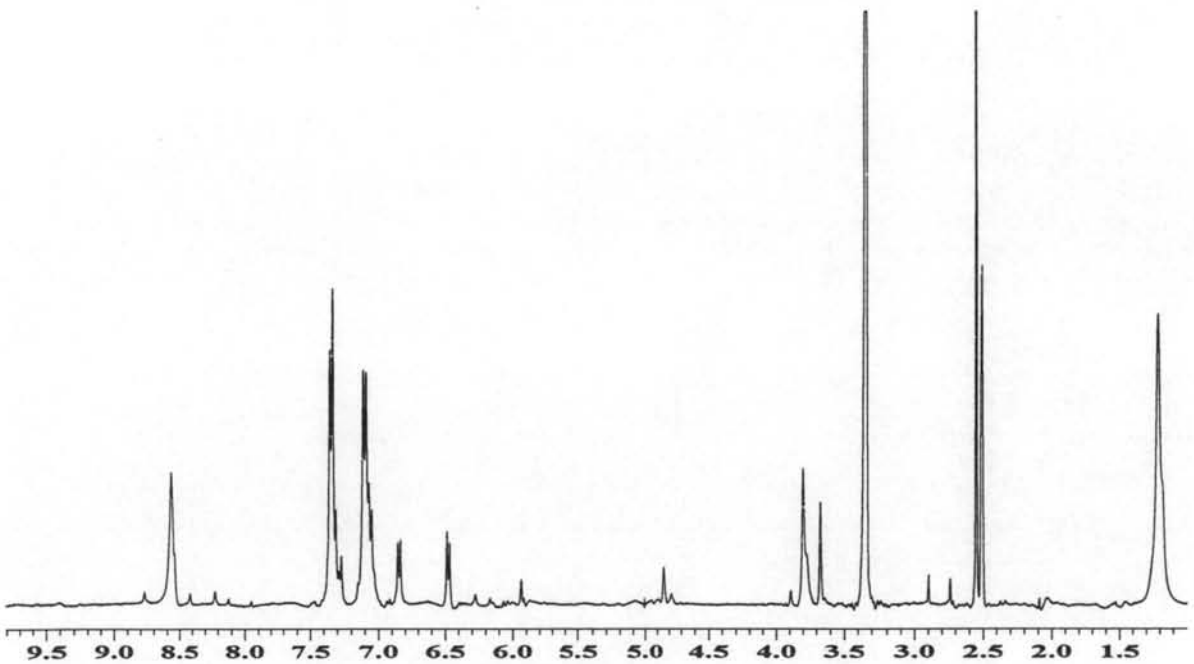


Figure A.12 ^{1}H NMR spectrum of ZnL-MDI-BA (1:3:1) in DMSO-d_6

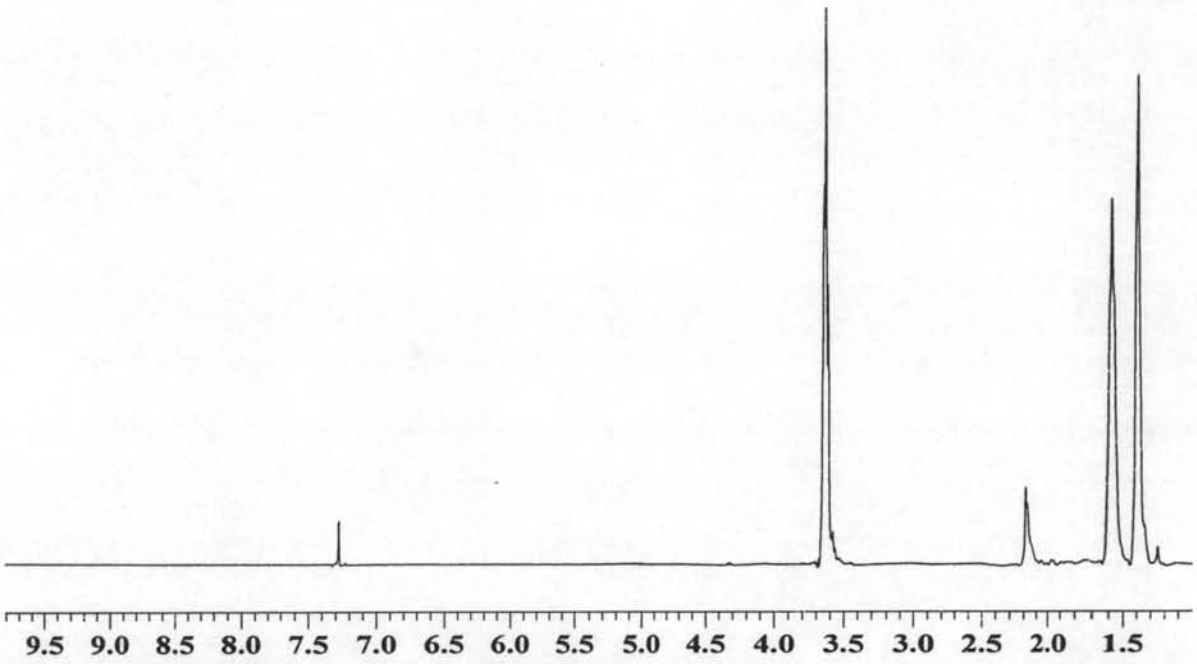


Figure A.13 ^{1}H NMR spectrum of HD in DMSO-d_6 + $CDCl_3$

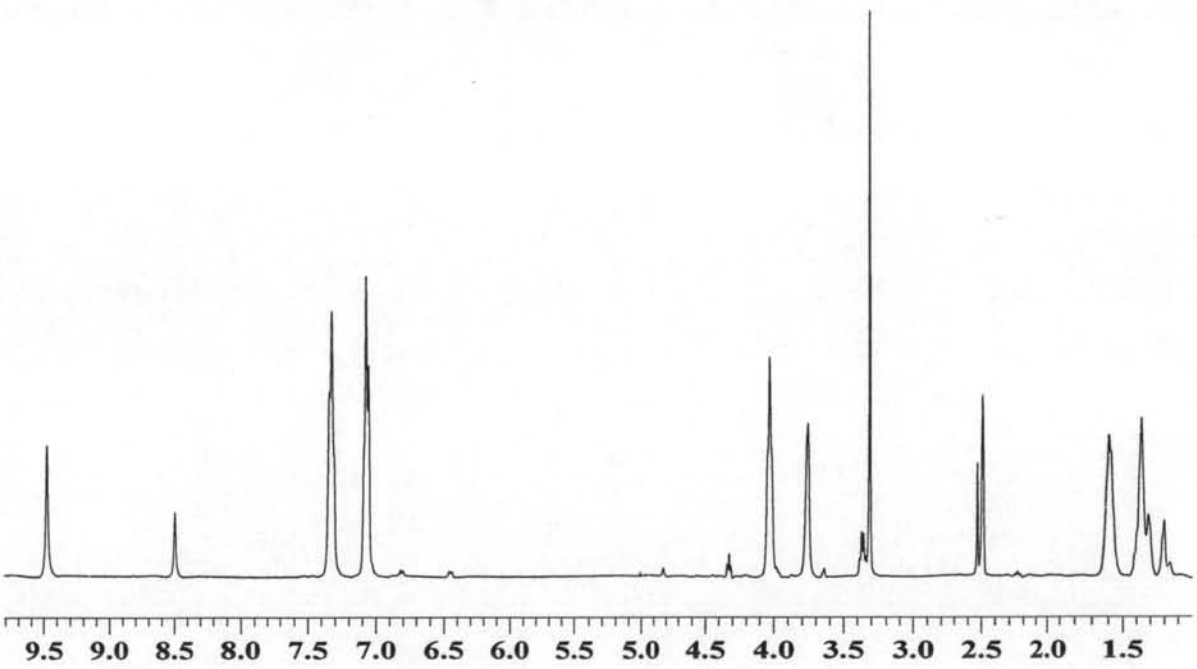


Figure A.14 ^{1}H NMR spectrum of MDI-HD (1:1) in DMSO-d_6

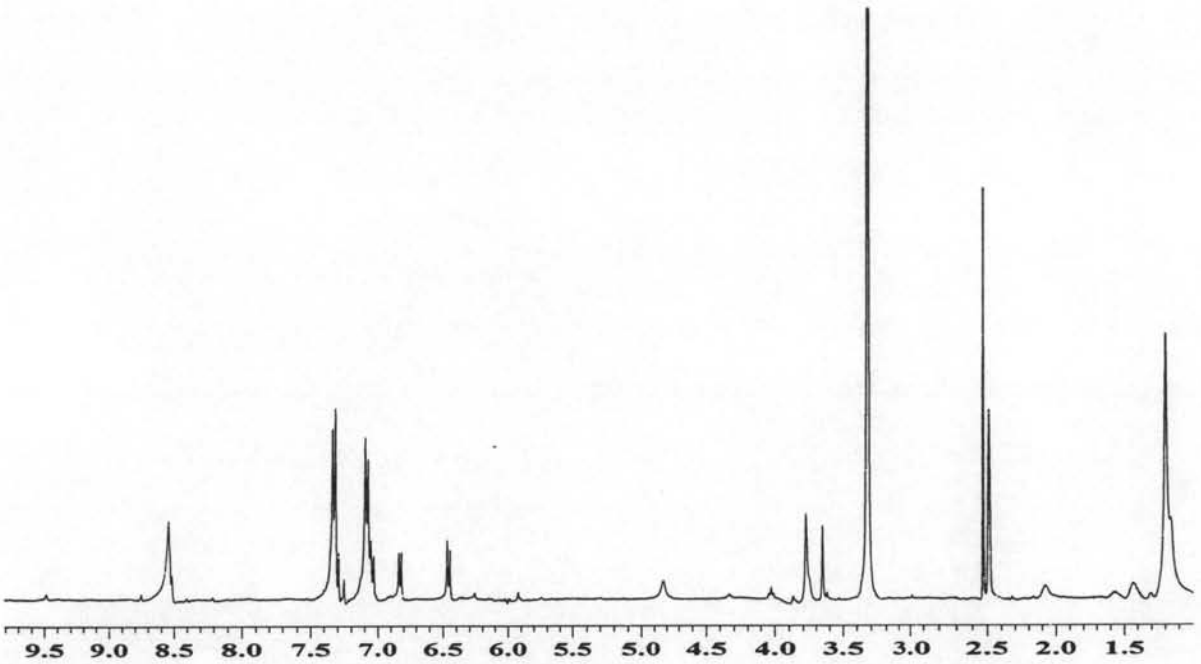


Figure A.15 ^{1}H NMR spectrum of ZnL-MDI-HD (1:3:1) in DMSO-d_6

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

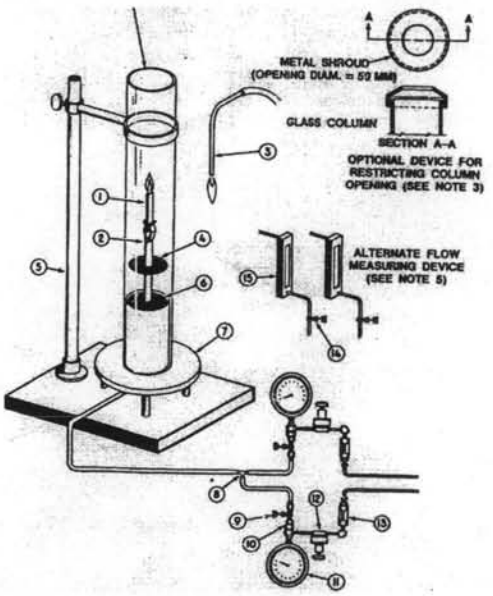
K = 0.01431, t_0 = 98.97 sec, Kt_0 = 1.4163 sec

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.

B-2 Limiting Oxygen Index (LOI)

ASTM D2863-70: the minimum concentration of oxygen, expressed as volume percent, in a mixture of oxygen and nitrogen that will just support flaming combustion of a material initially at room temperature. The LOI method used for self-supporting samples has been modified as described below to accommodate the viscous of the powdery samples. The measurement was carried out as follows. About 1 g. of the polymer sample was placed in a glass cup (diameter 20 mm, height 10 mm) fitted to the specimen holder. An external flame of 20 mm length was maintained in contact, for 10 s, with the polymer. The LOI value was taken as the minimum percentages of oxygen required in a nitrogen-oxygen atmosphere, surrounding the sample, to maintain its combustion for at least 30 s after ignition. The LOI value was taken as the average of five experiments each.

Apparatus



11. Burning Specimen	6. Glass Beads in a Bed	1. Pressure Gage
12. Clamp with Rod Support	7. Brass Base	2. Precision Pressure Regulator
13. Igniter	8. Tee	3. Filter
14. Wire Screen	9. Cut-off valve	4. Needle Valve
15. Ring Stand	10. Orifice in Holder	5. Rotameter

Figure A.1 LOI apparatus

Procedure

1. Calibrate the flow-measuring system using a water-sealed rotalin drummter in accordance with Method D 1071.
2. The test shall be conducted at room temperature condition in accordance with Practice D 618.
3. Clamp the specimen vertically in the approximate center of the column.
4. Select the desired initial concentration of oxygen. If the specimen burns rapidly, start at a concentration of about 18 %.
5. Set the flow valves so that desired initial concentration of oxygen in flowing through the column.
6. Allow the gas to flow for 30 s to purge the system.
7. Ignition the entire top of the specimen with the ignition flame so that the specimen is well lighted. Remove the ignition flame and start the timer.
8. Do not adjust the oxygen concentration after ignition the specimen.
9. The concentration of oxygen must be raised if the flaming of the specimen extinguishes before meeting.
10. Adjust the oxygen concentration, insert a new specimen.

VITAE

Name : Miss Prakaywan Tachaprasertporn

Born : March 31st, 1981

Education : 2003 B. Sc. (Chemistry), Srinakarinwirot University, Bangkok, Thailand.

2006 M. Sc. (Petrochemistry and Polymer Science), Chulalongkorn University, Bangkok, Thailand.