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APPENDICES

Appendix A Specification of Untreated Activated Carbon

Table A1 Specification of untreated activated carbon from Carbokarn

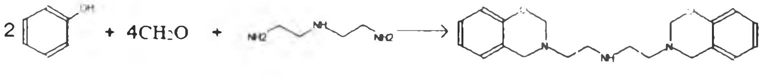
TECHNICAL SPECIFICATION		
Granular Activated Coconut Shell Based Carbon Grade : PHO 60 x 200		
PHYSICAL PROPERTIES		SPECIFICATION
Particle Size Distribution	+ 60 (0.25 mm.)	MAX. 5 %
(ASTM MESH/MM.)	60 x 200 (0.25 – 0.075 mm.)	MIN. 90 %
	- 200 (0.075 mm.)	MAX. 5 %
Apparent Density (g / cc)		MIN. 0.45
Moisture (% w/w)		MAX. 5
Ash (% w/w)		MAX. 3.5
pH		9 – 11
Surface Area (m2/ g) (Calculated)		MIN. 1100
Iodine Number (mg / g)		MIN. 1050
Hardness Number (%)		MIN. 98

Appendix B Calculation for Benzoxazine Synthesis Ratio

From the synthesis method that was modified from the work of Su and Chang (2003), briefly, phenol: formaldehyde: amine in the mole ratio of 2:4:1 convert to benzoxazine one mole and the target is 20 g of benzoxazine in each batch.

Molecular weight of phenol	= 94.11
Molecular weight of formaldehyde	= 30.03
Molecular weight of DETA	= 103.17
Molecular weight of PEHA	= 232.37
Density of formaldehyde	= 1.09 g/mL
Density of DETA	= 0.955 g/mL
Density of PEHA	= 0.95 g/mL

Amine: DETA



Molecular weight of benzoxazine $= (20\times C) + (3\times N) + (2\times O) + (25\times H)$

$= (20\times 12) + (3\times 14) + (2\times 16) + (25\times 1)$

$= 339$

Benzoxazine 339 g = 1 mol

20 g = 0.06 mol

Phenol $= 0.06\times 2 = 0.12$ mol

Formaldehyde $= 0.06\times 4 = 0.24$ mol

DETA $= 0.06\times 1 = 0.06$ mol

Use in gram:

Phenol $= 0.12\times 94.11$ = <u>11.29 g</u>

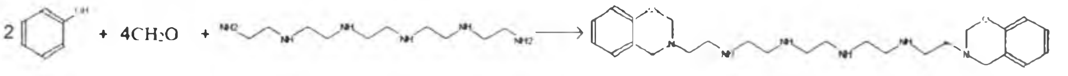
Use in mL:

Formaldehyde $= 0.24\times 30.03 = 7.21$ g

But formaldehyde 37wt% $= (7.21\times 100) \div (37\times 1.09)$ = <u>17.87 mL</u>

DETA $= 0.06\times 103.17 \div 0.955$ = <u>6.48 mL</u>

Amine: PEHA



Molecular weight of benzoxazine = (26×C) + (6×N) + (2×O) + (40×H)

= (26×12) + (6×14) + (2×16) + (40×1)

= 468

Benzoxazine	468 g	= 1 mol
	20 g	= 0.043 mol
Phenol	= 0.043×2	= 0.086 mol
Formaldehyde	= 0.043×4	= 0.172 mol
DETA	= 0.043×1	= 0.043 mol

Use in gram:

Phenol = 0.086×94.11 = <u>8.09 g</u>

Use in mL:

Formaldehyde = 0.172×30.03 = 5.16 g

But formaldehyde 37wt% = (5.16×100) ÷ (37×1.09) = <u>12.81 mL</u>

DETA = 0.0043×232.37÷0.95 = <u>10.52 mL</u>

Appendix C Decomposition of All Adsorbents

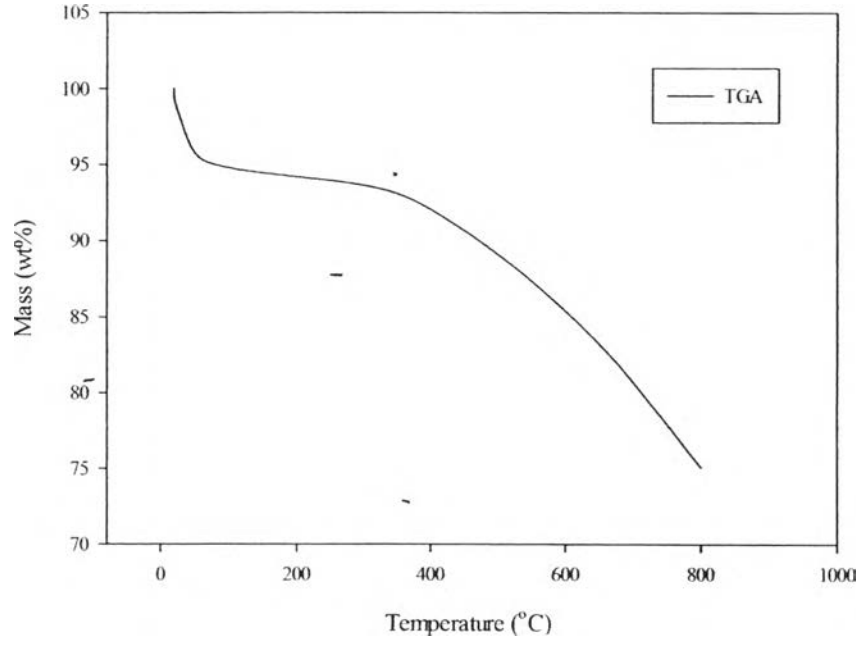


Figure C1 Decomposition of untreated activated carbon.

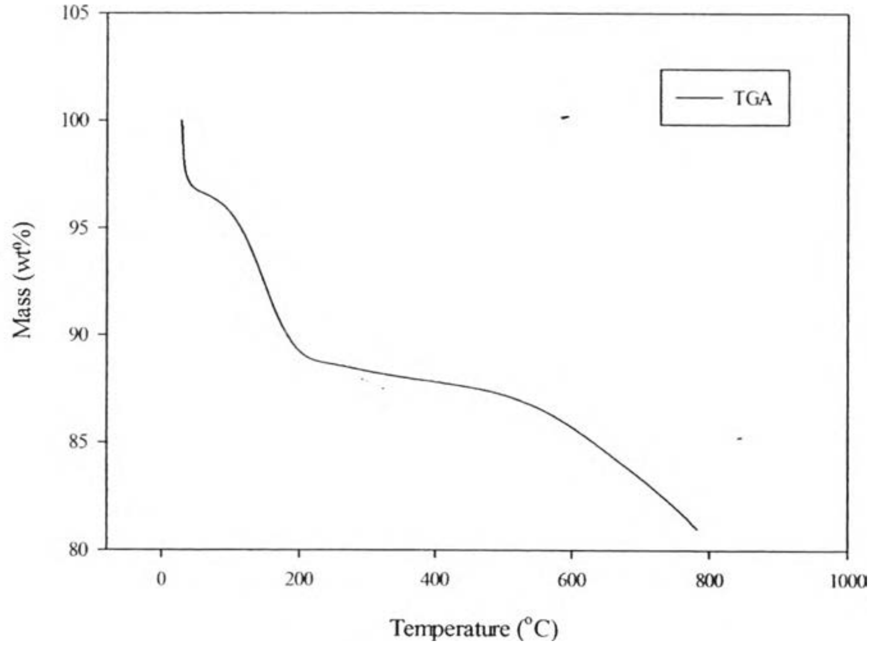


Figure C2 Decomposition of 1wt% of DETA-derived polybenzoxazine impregnating on activated carbon.

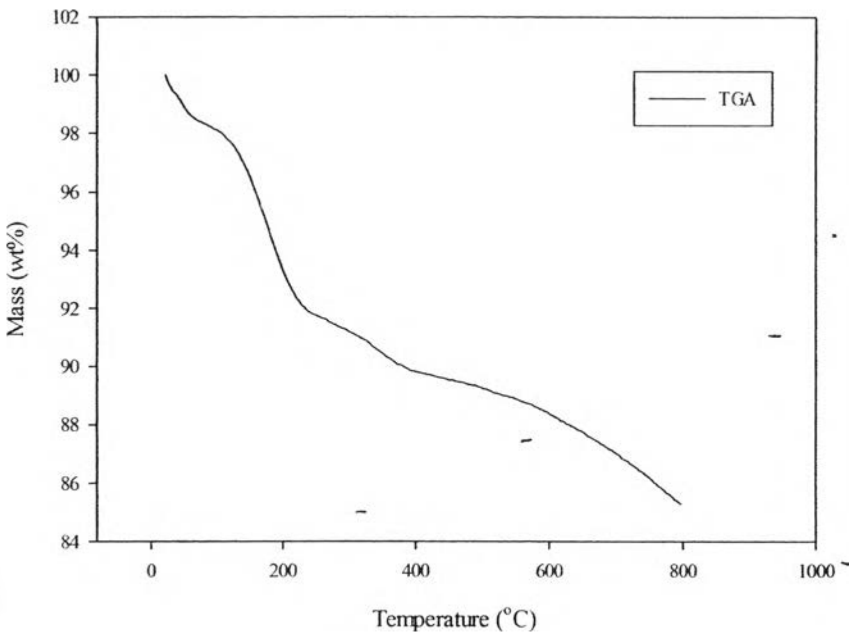


Figure C3 Decomposition of 5wt% of DETA-derived polybenzoxazine impregnating on activated carbon.

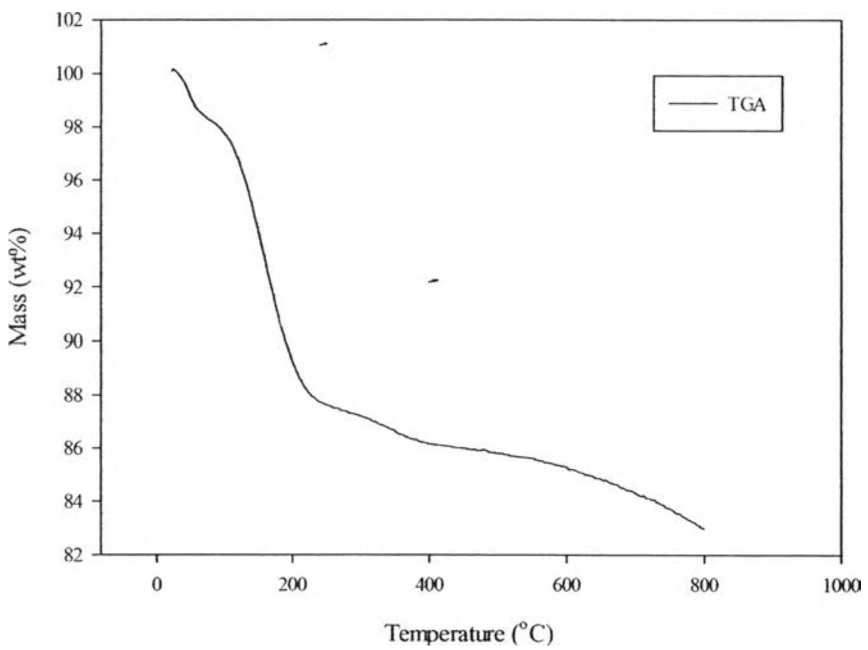


Figure C4 Decomposition of 10wt% of DETA-derived polybenzoxazine impregnating on activated carbon.

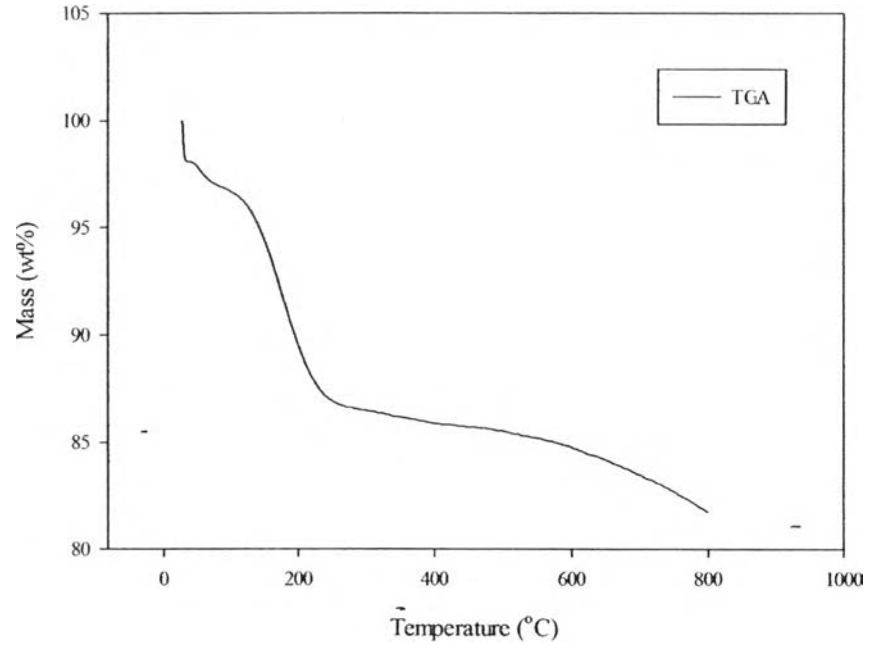


Figure C5 Decomposition of 1wt% of PEHA-derived polybenzoxazine impregnating on activated carbon.

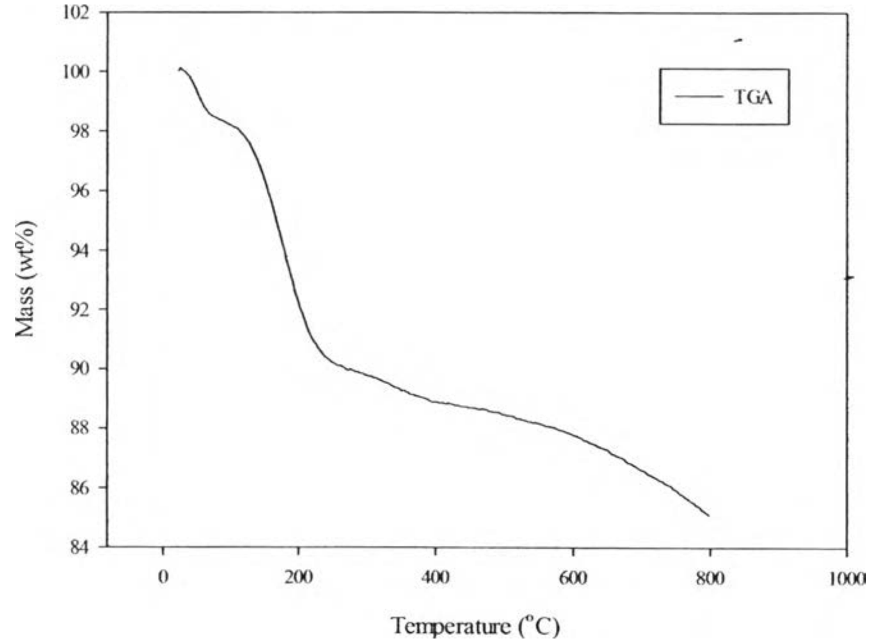


Figure C6 Decomposition of 5wt% of PEHA-derived polybenzoxazine impregnating on activated carbon.

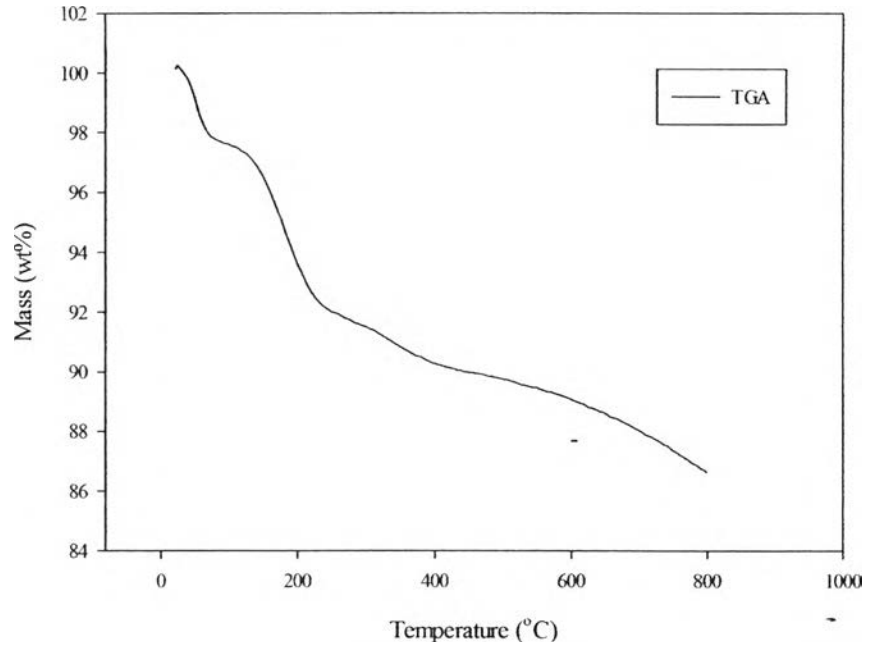


Figure C7 Decomposition of 10wt% of PEHA-derived polybenzoxazine impregnating on activated carbon.

Appendix D XPS Spectra of All Adsorbents

Activated carbon

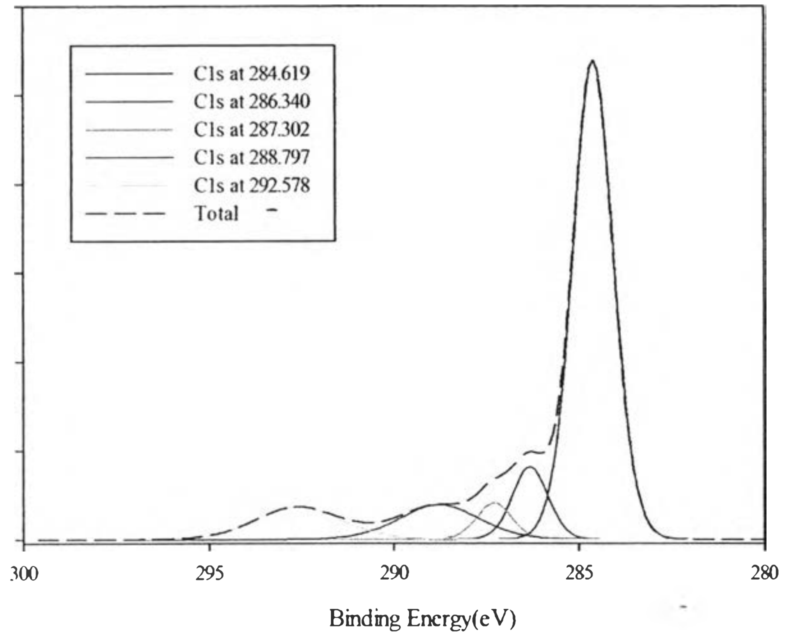


Figure D1 C1s XPS spectra of activated carbon.

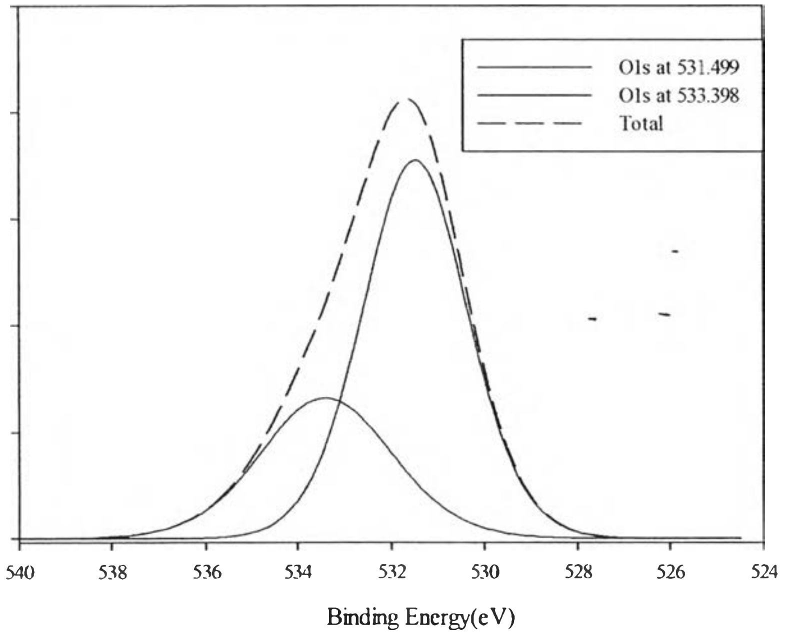


Figure D2 O1s XPS spectra of activated carbon.

Activated carbon with 1wt% PBZ derived from DETA

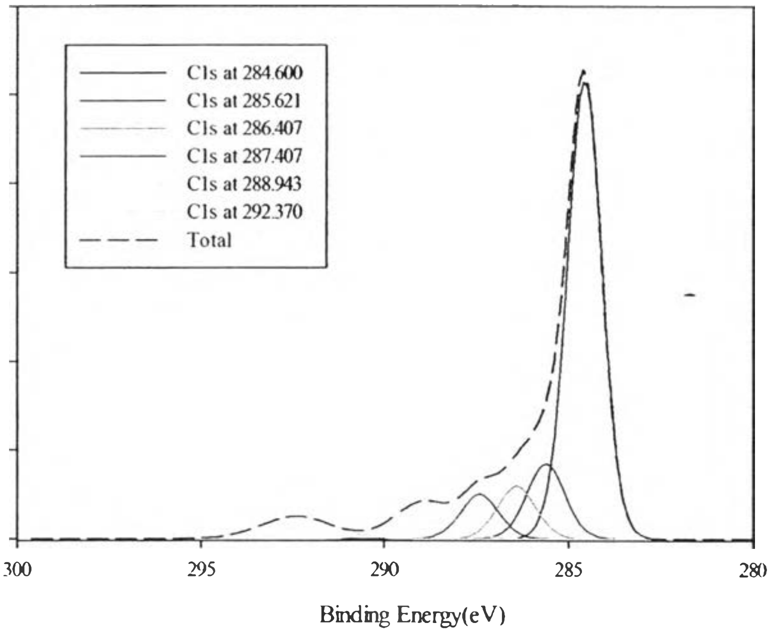


Figure D3 C1s XPS spectra of 1wt% PBZ derived from DETA impregnating on activated carbon.

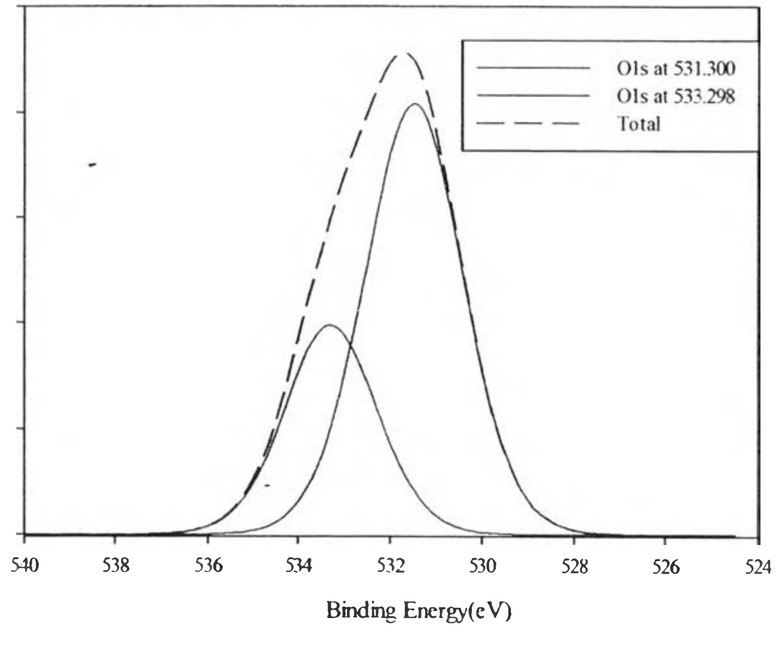


Figure D4 O1s XPS spectra of 1wt% PBZ derived from DETA impregnating on activated carbon.

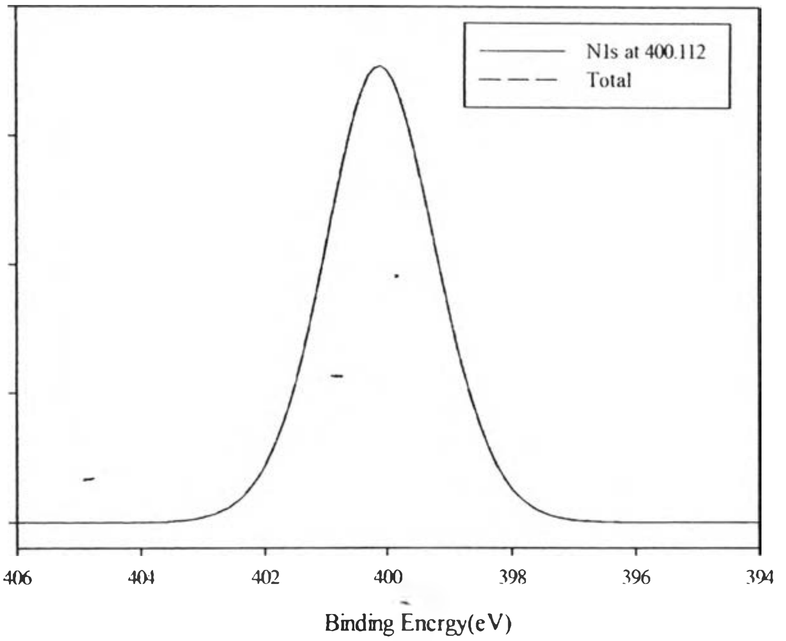


Figure D5 N1s XPS spectra of 1wt% PBZ derived from DETA impregnating on activated carbon.

Activated carbon with 5wt% PBZ derived from DETA

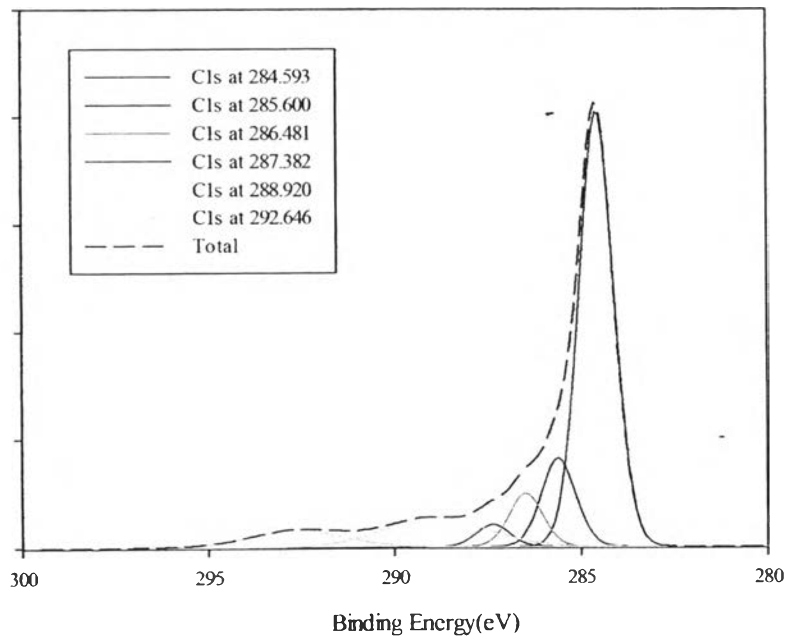


Figure D6 C1s XPS spectra of 5wt% PBZ derived from DETA impregnating on activated carbon.

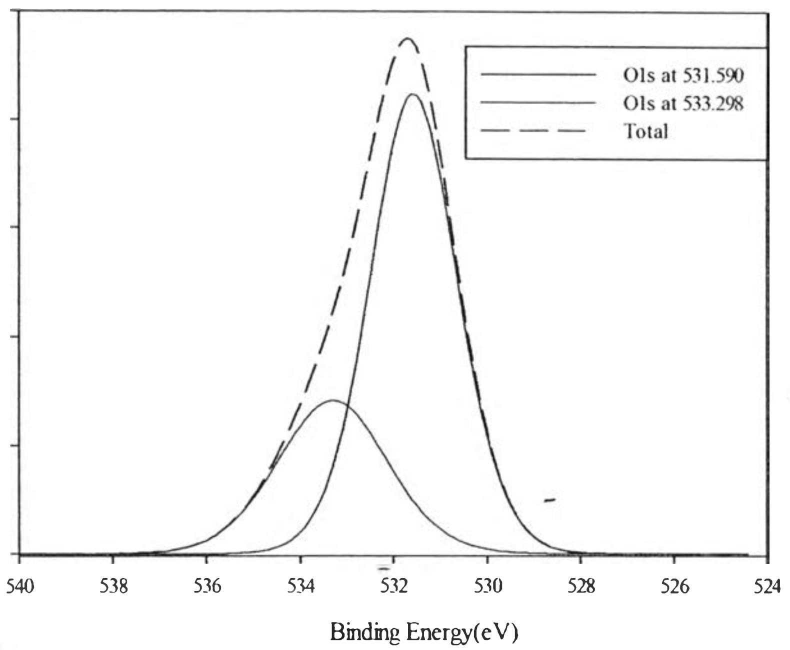


Figure D7 O1s XPS spectra of 5wt% PBZ derived from DETA impregnating on activated carbon.

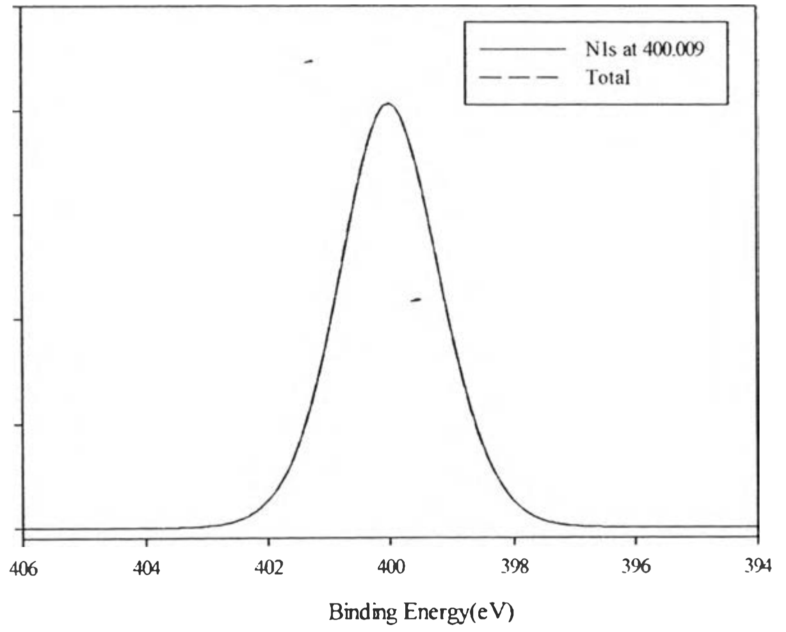


Figure D8 N1s XPS spectra of 5wt% PBZ derived from DETA impregnating on activated carbon.

Activated carbon with 10wt% PBZ derived from DETA

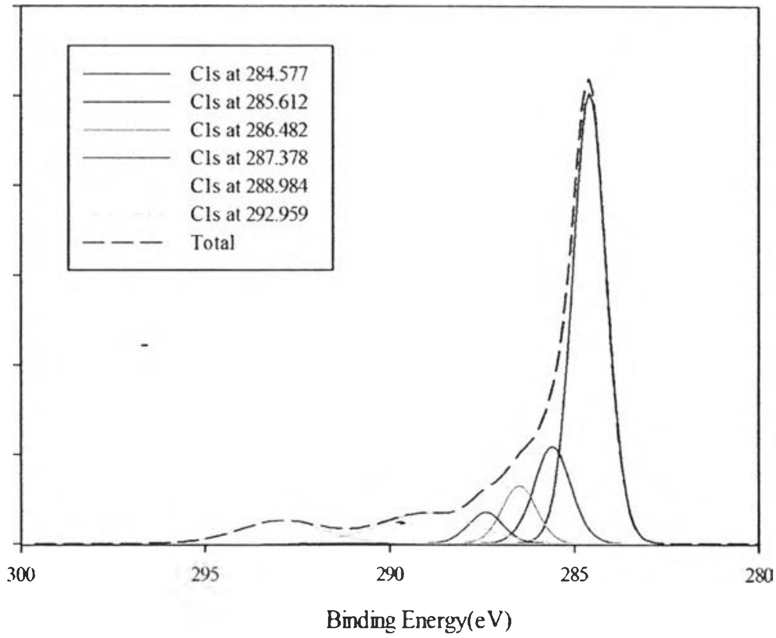


Figure D9 C1s XPS spectra of 10wt% PBZ derived from DETA impregnating on activated carbon.

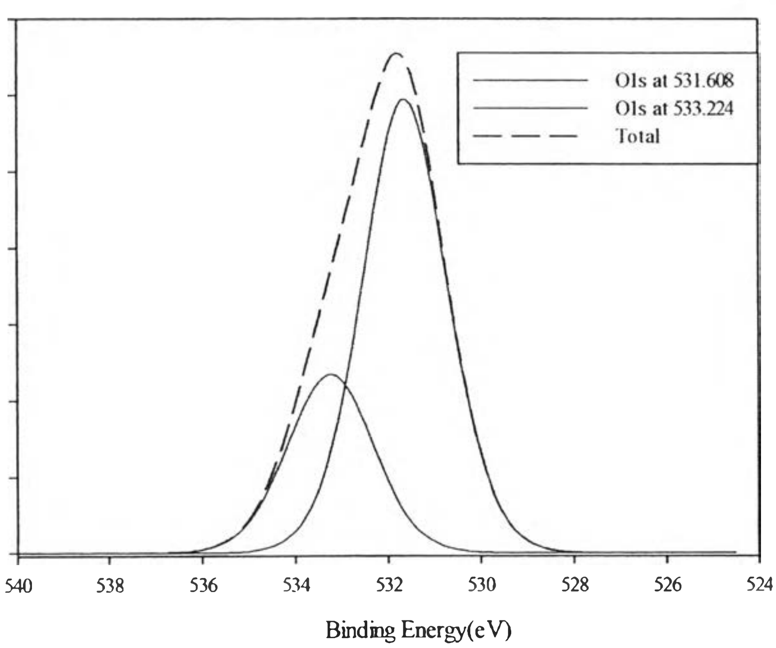


Figure D10 O1s XPS spectra of 10wt% PBZ derived from DETA impregnating on activated carbon.

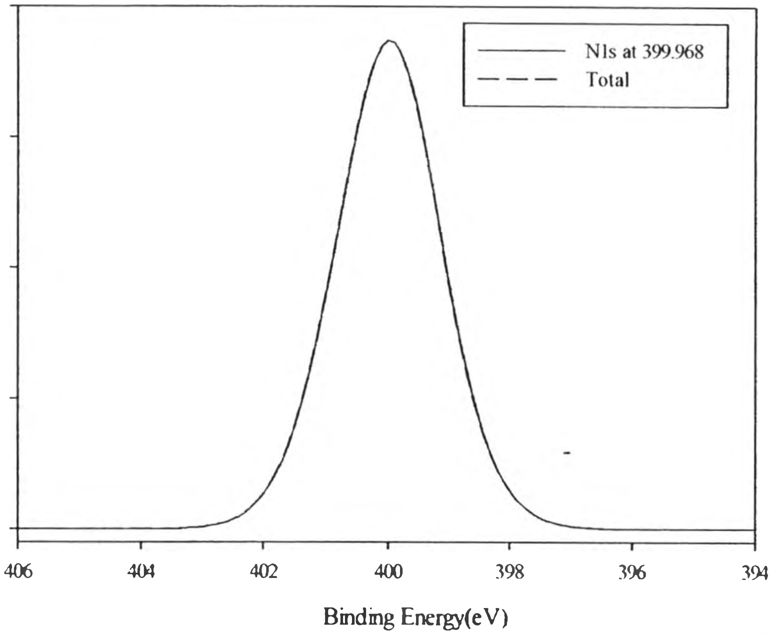


Figure D11 N1s XPS spectra of 10wt% PBZ derived from DETA impregnating on activated carbon.

Activated carbon with 1wt% PBZ derived from PEHA

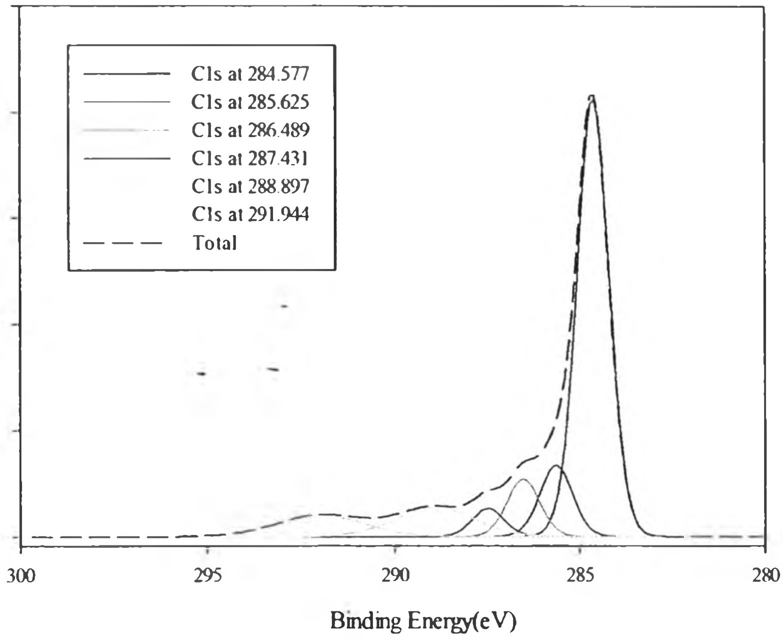


Figure D12 C1s XPS spectra of 1wt% PBZ derived from PEHA impregnating on activated carbon.

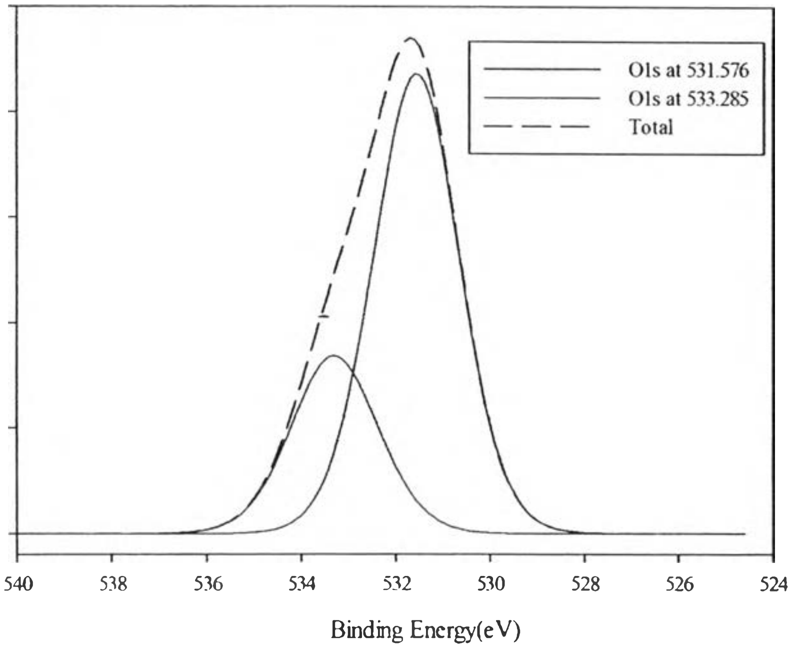


Figure D13 O1s XPS spectra of 1wt% PBZ derived from PEHA impregnating on activated carbon.

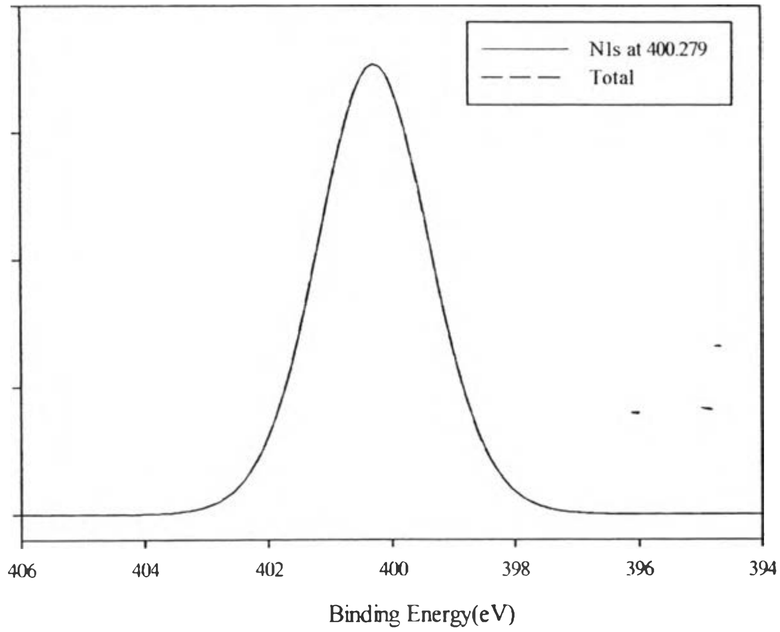


Figure D14 N1s XPS spectra of 1wt% PBZ derived from PEHA impregnating on activated carbon.

Activated carbon with 5wt% PBZ derived from PEHA

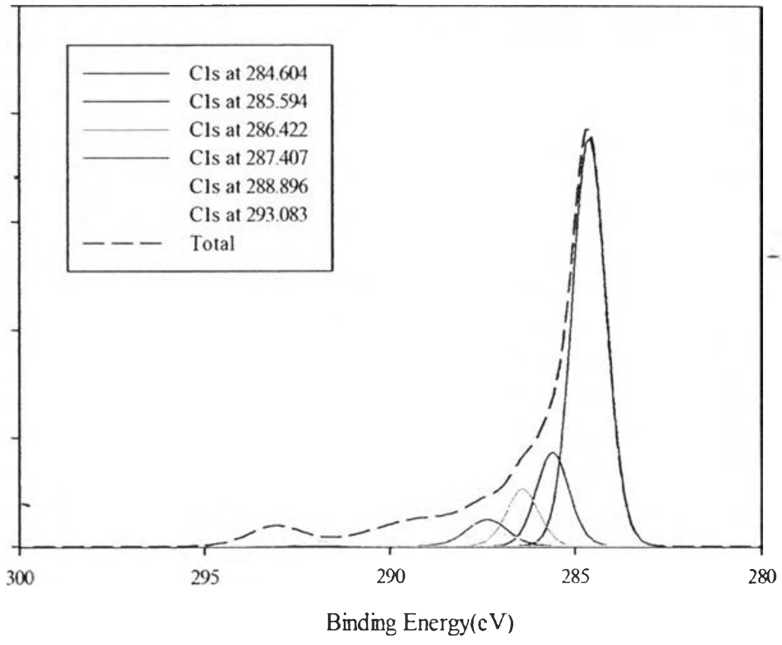


Figure D15 C1s XPS spectra of 5wt% PBZ derived from PEHA impregnating on activated carbon.

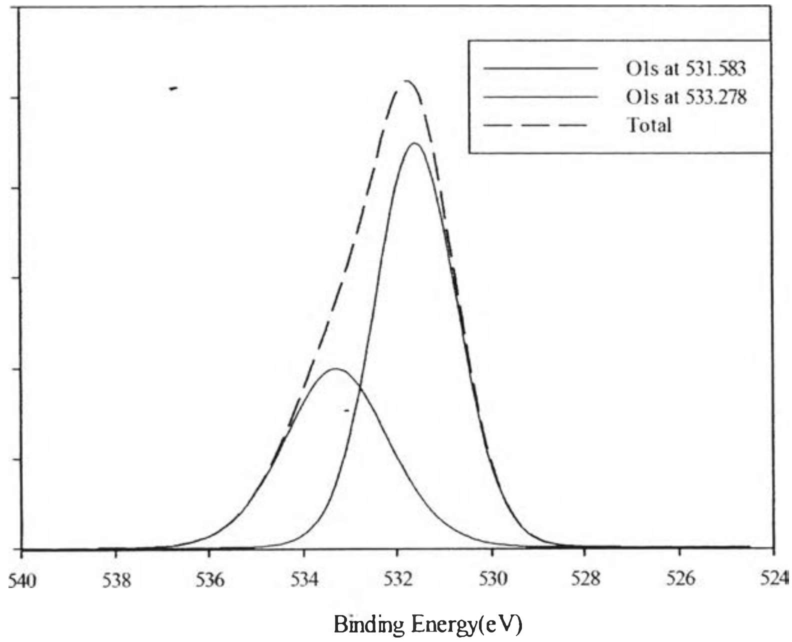


Figure D16 O1s XPS spectra of 5wt% PBZ derived from PEHA impregnating on activated carbon.

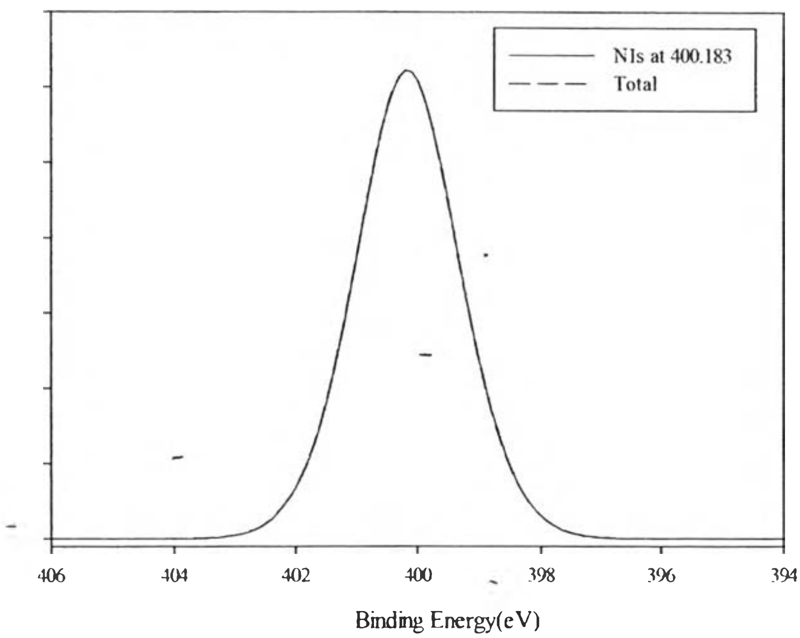


Figure D17 N1s XPS spectra of 5wt% PBZ derived from PEHA impregnating on activated carbon.

Activated carbon with 10wt% PBZ derived from PEHA

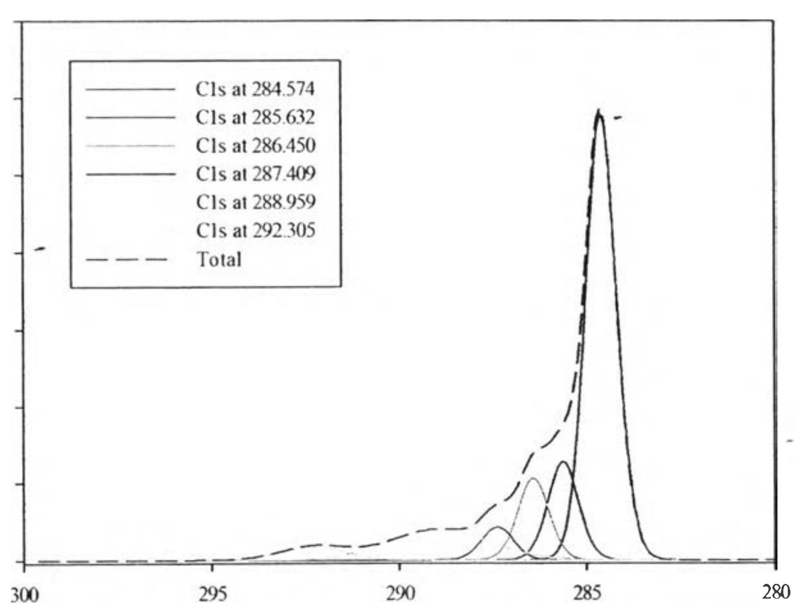


Figure D18 C1s XPS spectra of 10wt% PBZ derived from PEHA impregnating on activated carbon.

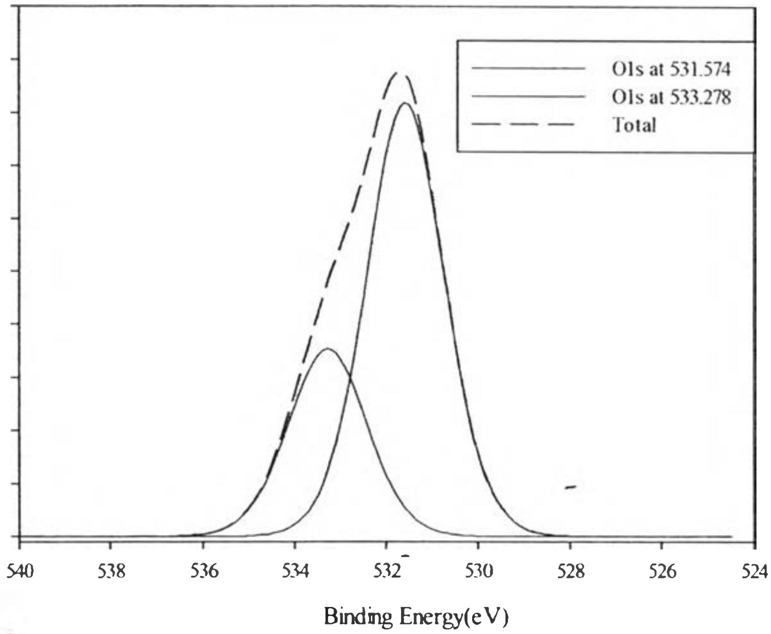


Figure D19 O1s XPS spectra of 10wt% PBZ derived from PEHA impregnating on activated carbon.

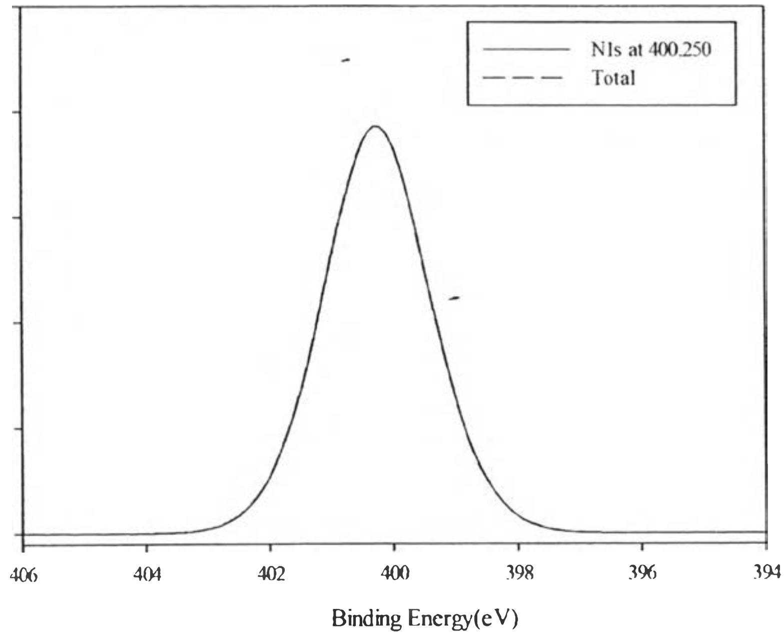


Figure D20 N1s XPS spectra of 10wt% PBZ derived from PEHA impregnating on activated carbon.

Polybenzoxazine derived from DETA

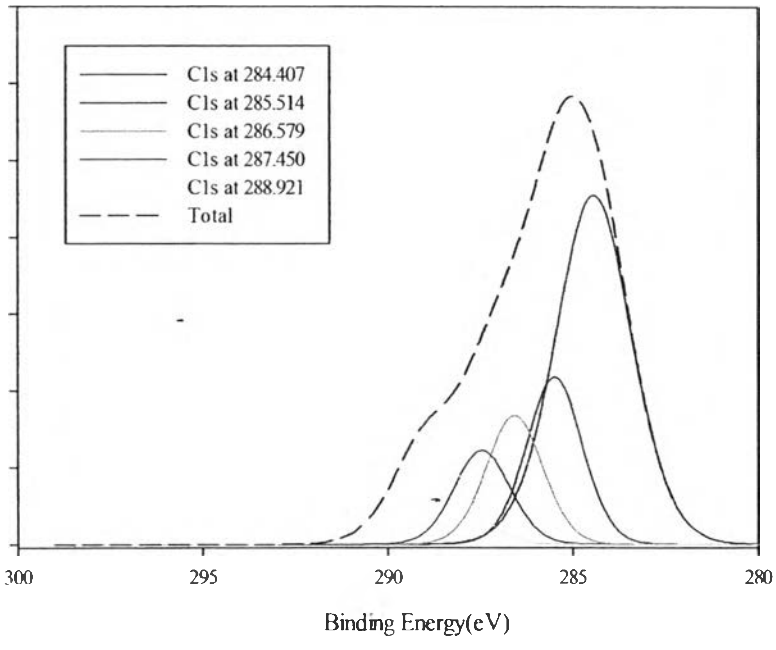


Figure D21 C1s XPS spectra of polybenzoxazine derived from DETA.

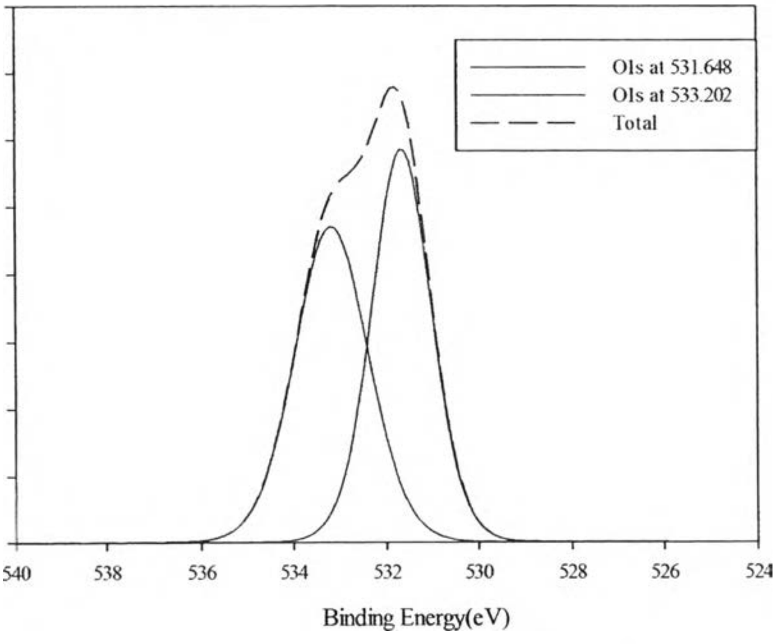


Figure D22 O1s XPS spectra of polybenzoxazine derived from DETA.

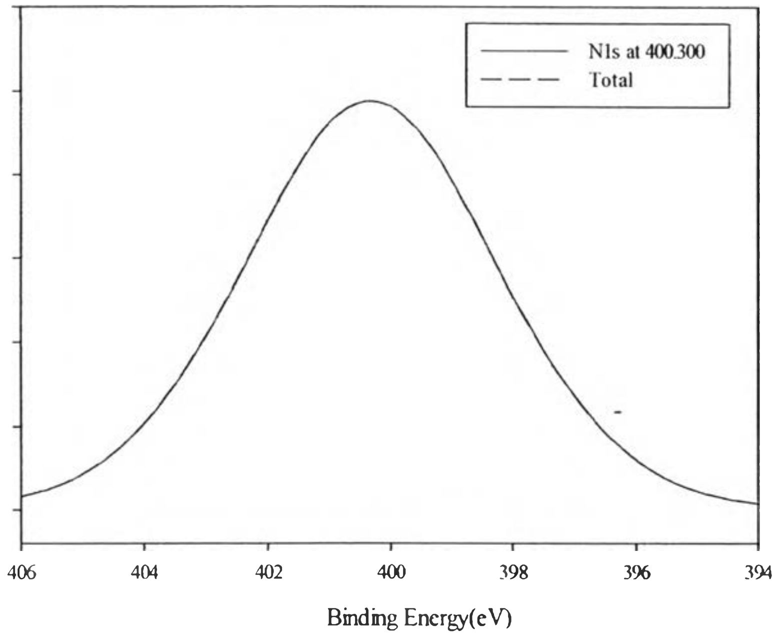


Figure D23 N1s XPS spectra of polybenzoxazine derived from DETA.

Polybenzoxazine derived from PEHA

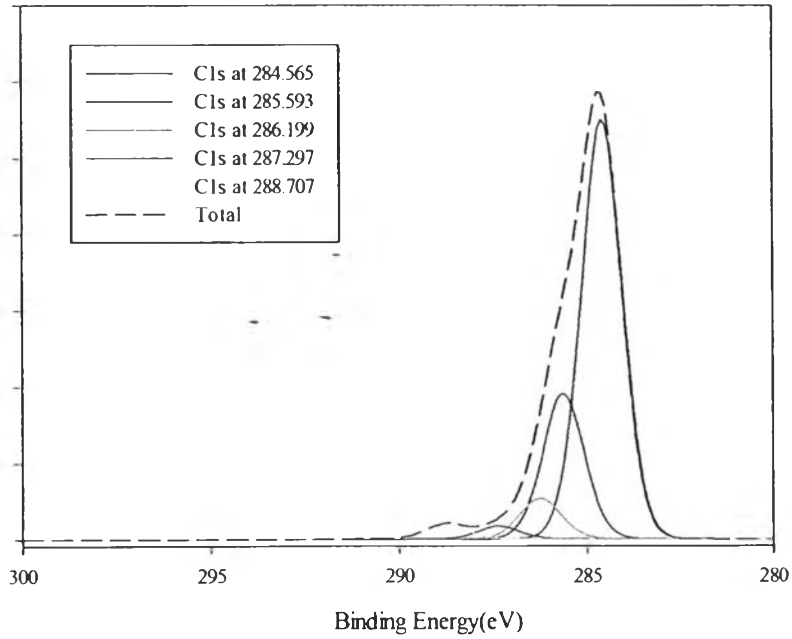


Figure D24 C1s XPS spectra of polybenzoxazine derived from PEHA.

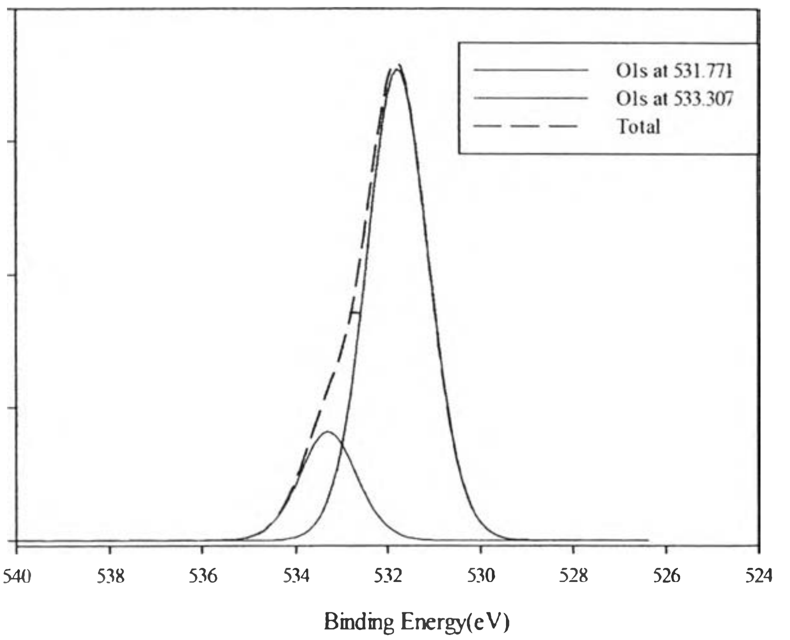


Figure D25 O1s XPS spectra of polybenzoxazine derived from PEHA.

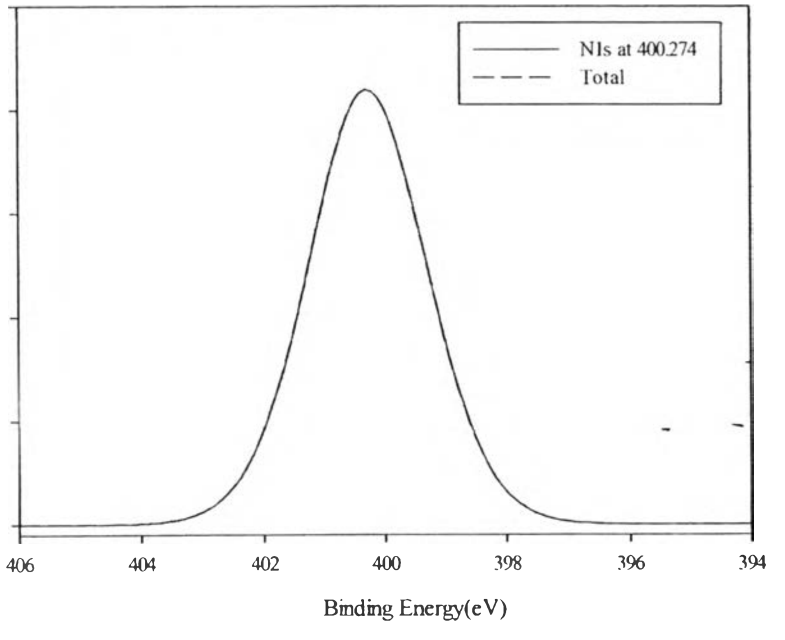


Figure D26 N1s XPS spectra of polybenzoxazine derived from PEHA.

Activated carbon from DETA-derived polybenzoxazine at 200 °C

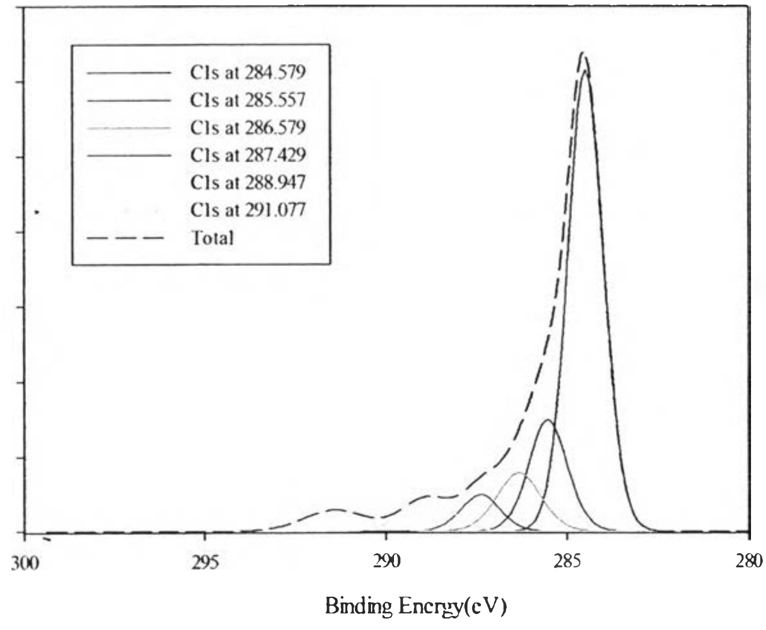


Figure D27 C1s XPS spectra of activated carbon from DETA-derived polybenzoxazine at 200 °C.

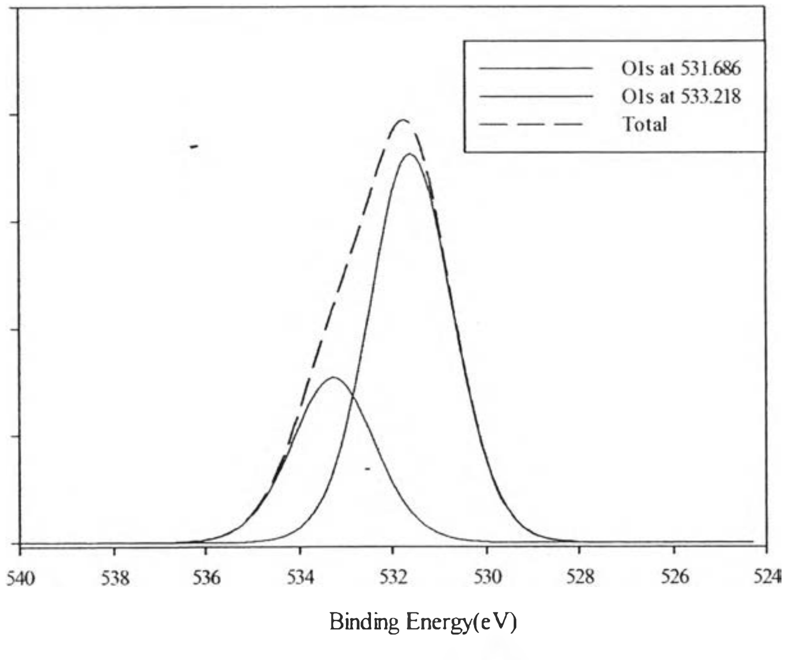


Figure D28 O1s XPS spectra of activated carbon from DETA-derived polybenzoxazine at 200 °C.

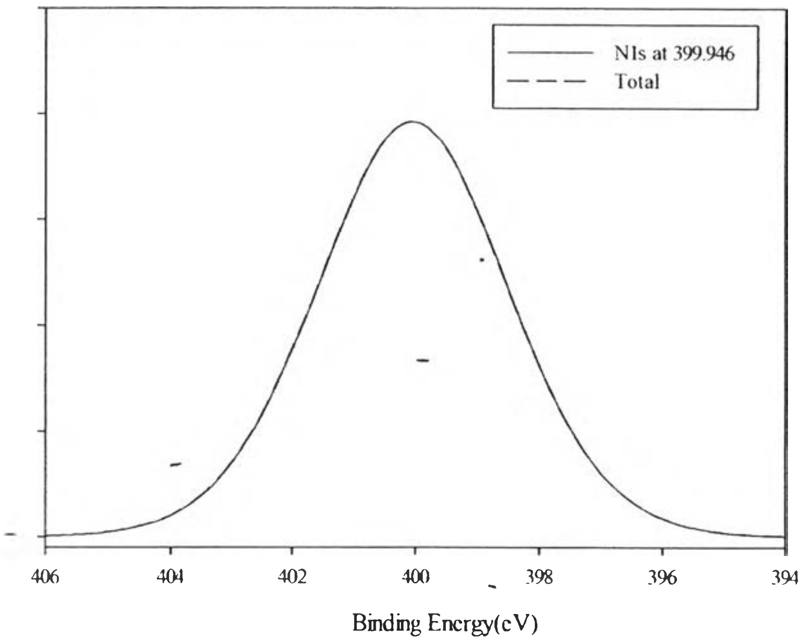


Figure D29 N1s XPS spectra of activated carbon from DETA-derived polybenzoxazine at 200 °C.

Activated carbon from DETA-derived polybenzoxazine at 300 °C

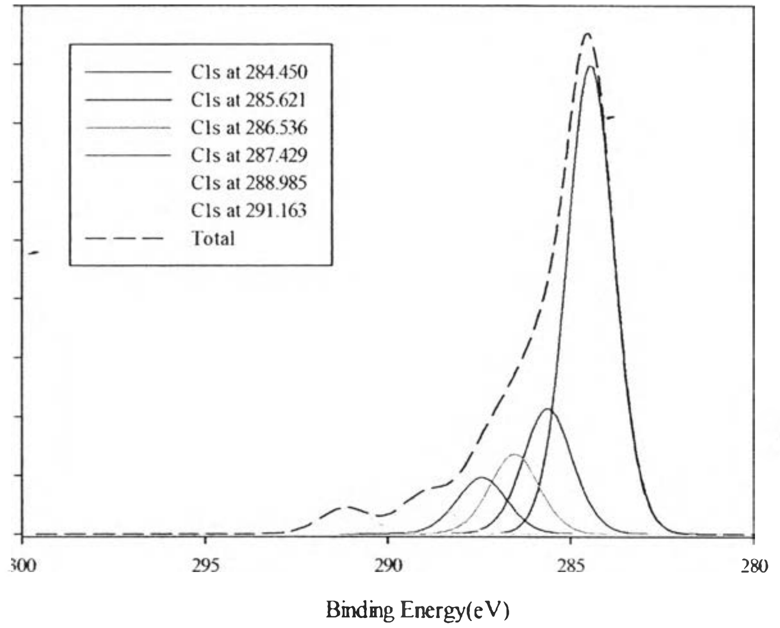


Figure D30 C1s XPS spectra of activated carbon from DETA-derived polybenzoxazine at 300 °C.

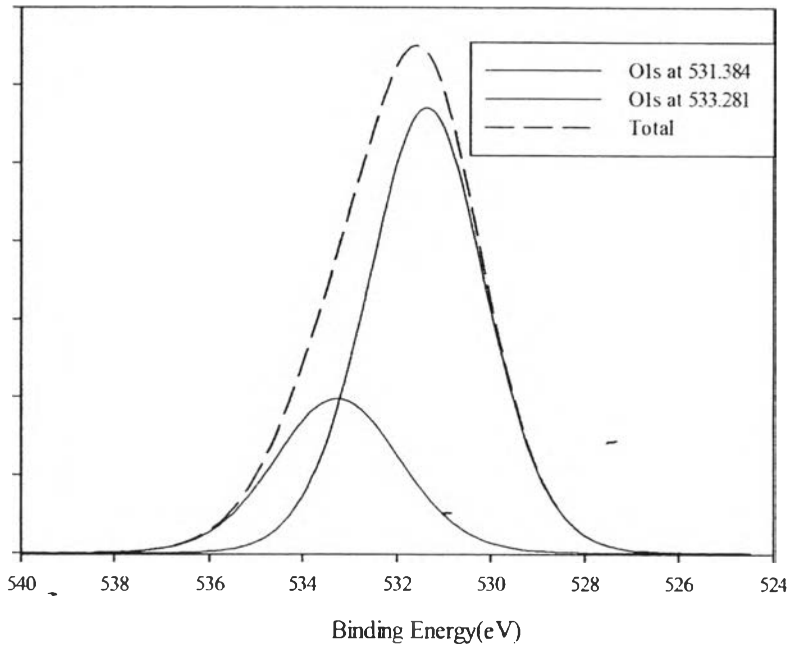


Figure D31 O1s XPS spectra of activated carbon from DETA-derived polybenzoxazine at 300 °C.

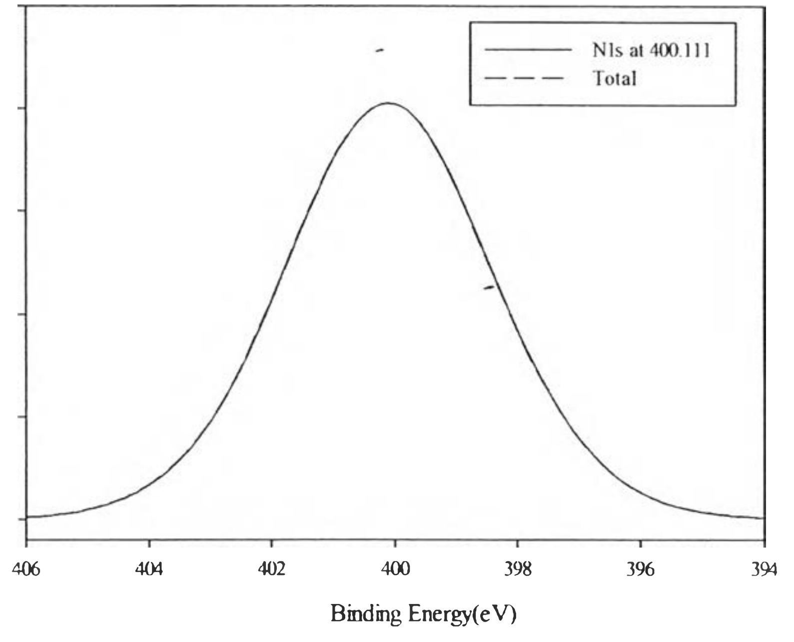


Figure D32 N1s XPS spectra of activated carbon from DETA-derived polybenzoxazine at 300 °C.

Activated carbon from DETA-derived polybenzoxazine at 400 °C

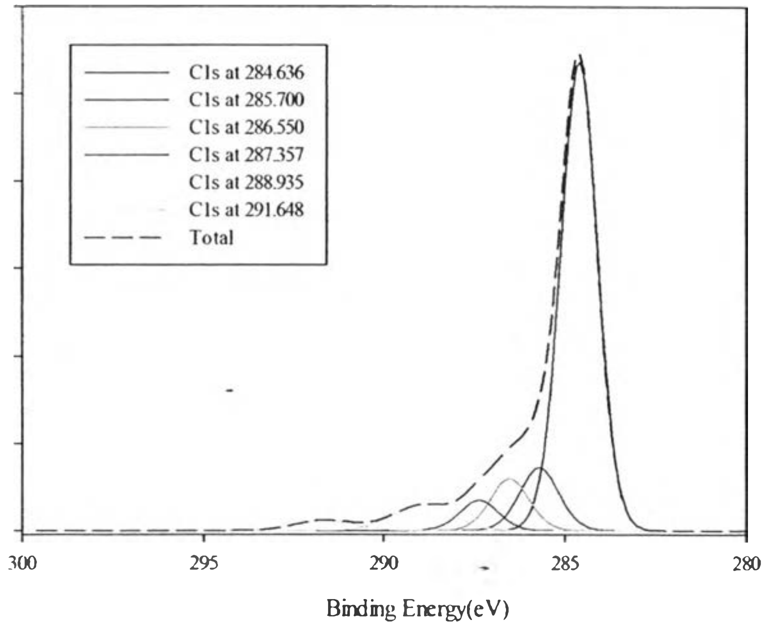


Figure D33 C1s XPS spectra of activated carbon from DETA-derived polybenzoxazine at 400 °C.

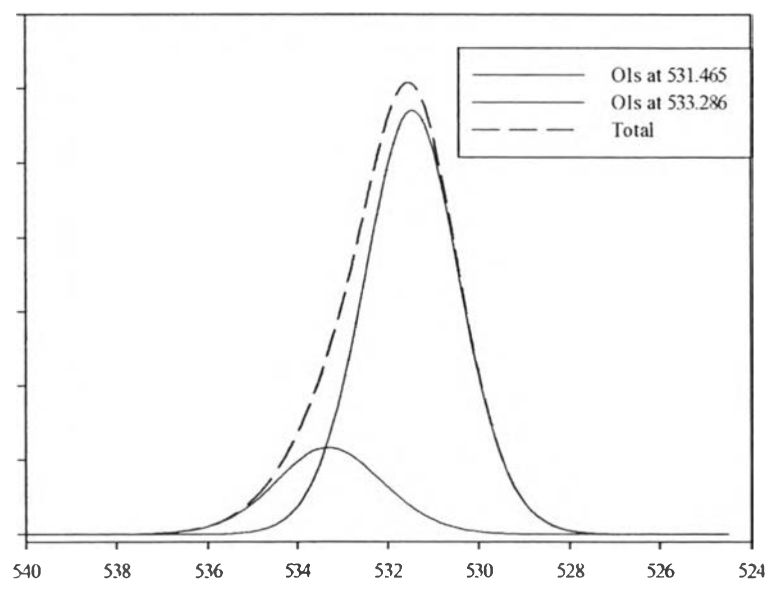


Figure D34 O1s XPS spectra of activated carbon from DETA-derived polybenzoxazine at 400 °C.

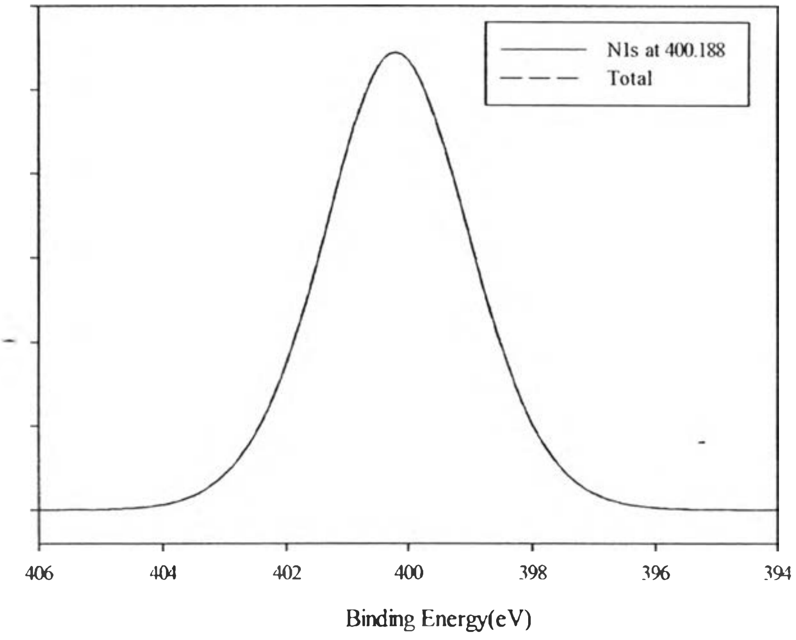


Figure D35 N1s XPS spectra of activated carbon from DETA-derived polybenzoxazine at 400 °C.

Activated carbon from PEHA-derived polybenzoxazine at 300 °C

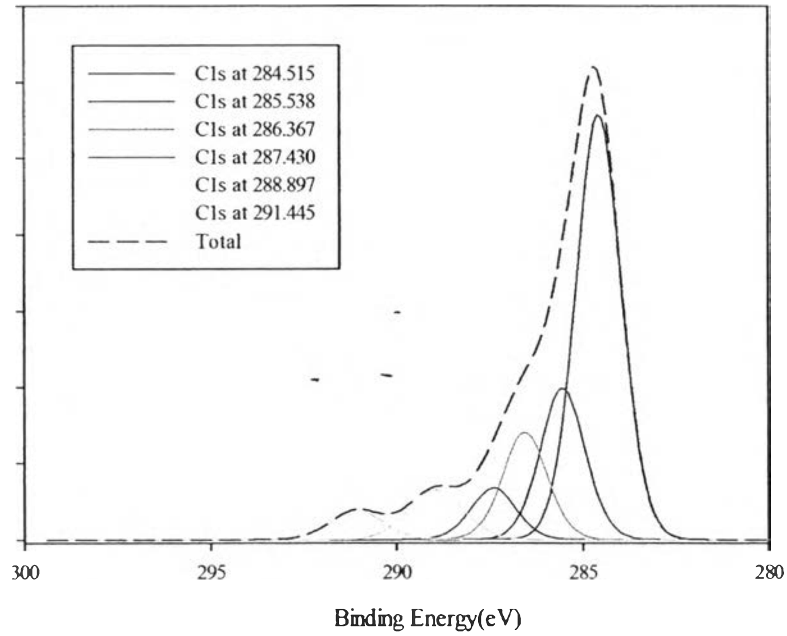


Figure D36 C1s XPS spectra of activated carbon from PEHA-derived polybenzoxazine at 300 °C.

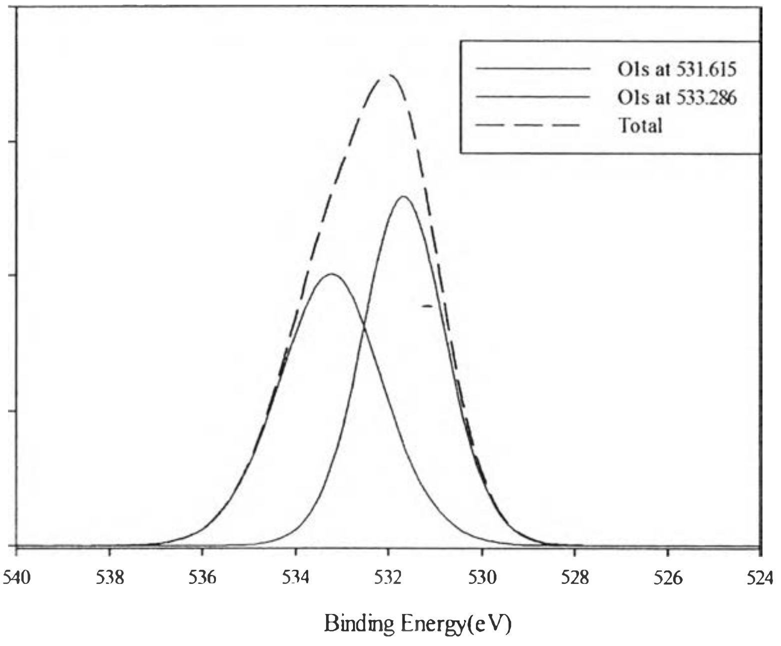


Figure D37 O1s XPS spectra of activated carbon from PEHA-derived polybenzoxazine at 300 °C.

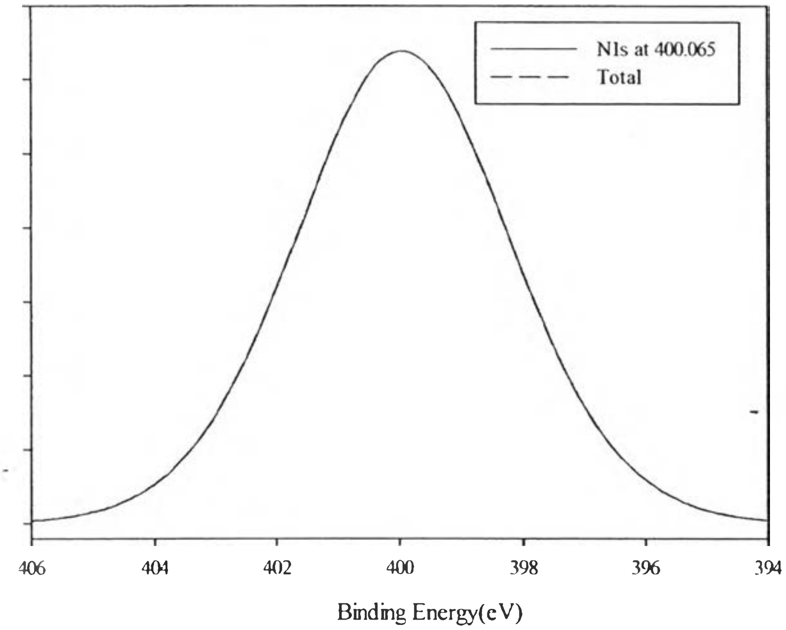


Figure D38 N1s XPS spectra of activated carbon from PEHA-derived polybenzoxazine at 300 °C.

Appendix E %Burn Off of Carbonization and Activation Polybenzoxazines

Table E1 Comparison of %burn off of activated carbon from polybenzoxazine varying carbonization temperature

Carbonization temperature (°C)	%Burn off after carbonization	%Burn off after activation
200	6.40%	70.15%
300	28.41%	70.20%
400	52.73%	70.25%

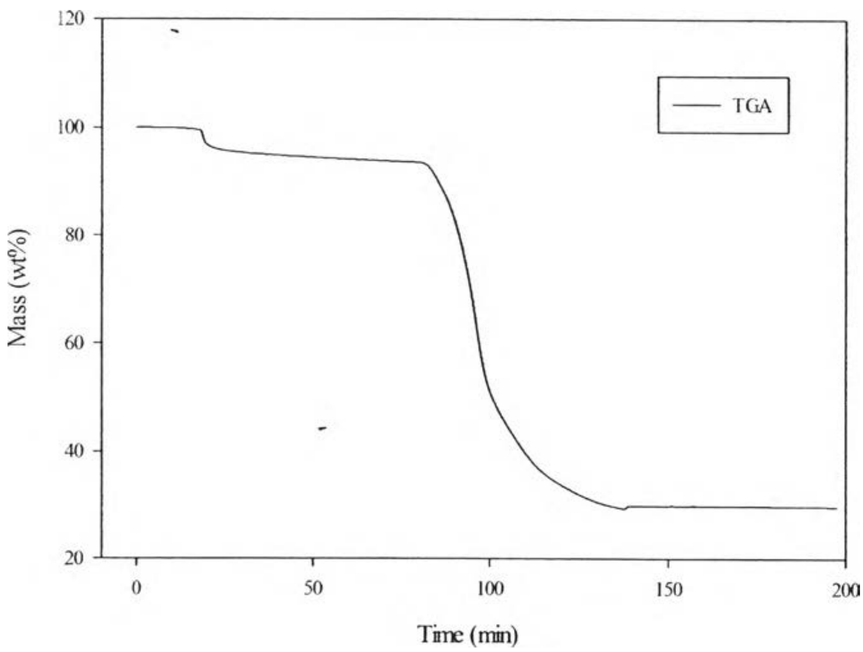


Figure E1 %burn off of activated carbon from polybenzoxazine at 200 °C.

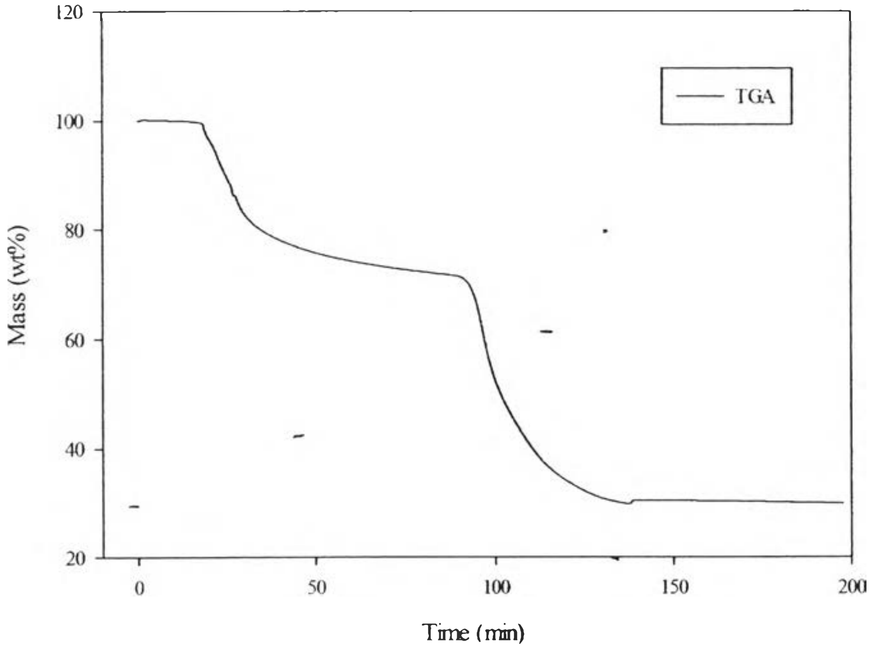


Figure E2 %burn off of activated carbon from polybenzoxazine at 300 °C.

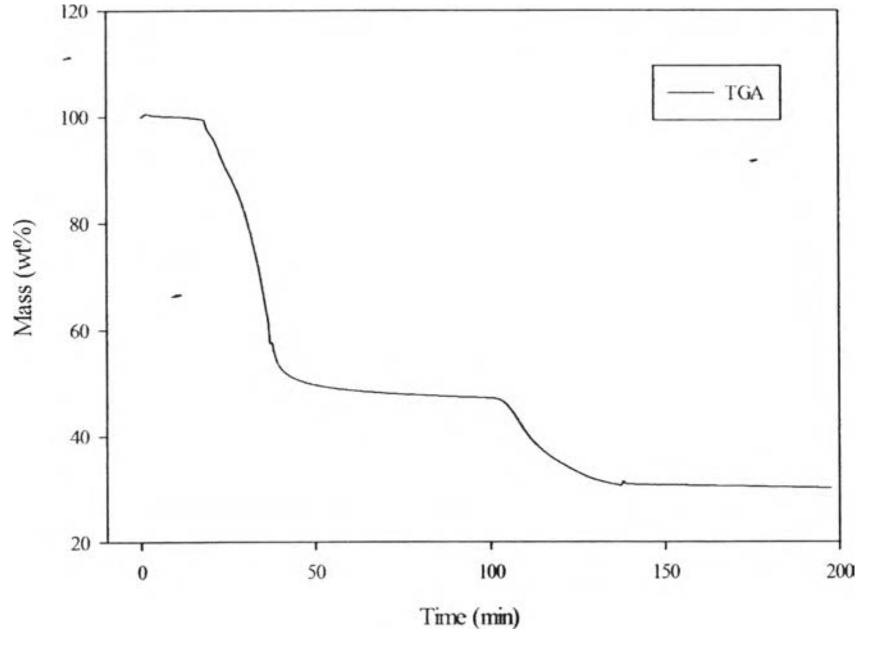


Figure E3 %burn off of activated carbon from polybenzoxazine at 400 °C.

Appendix F Isotherm and HK Pore Size Distribution of All Adsorbents

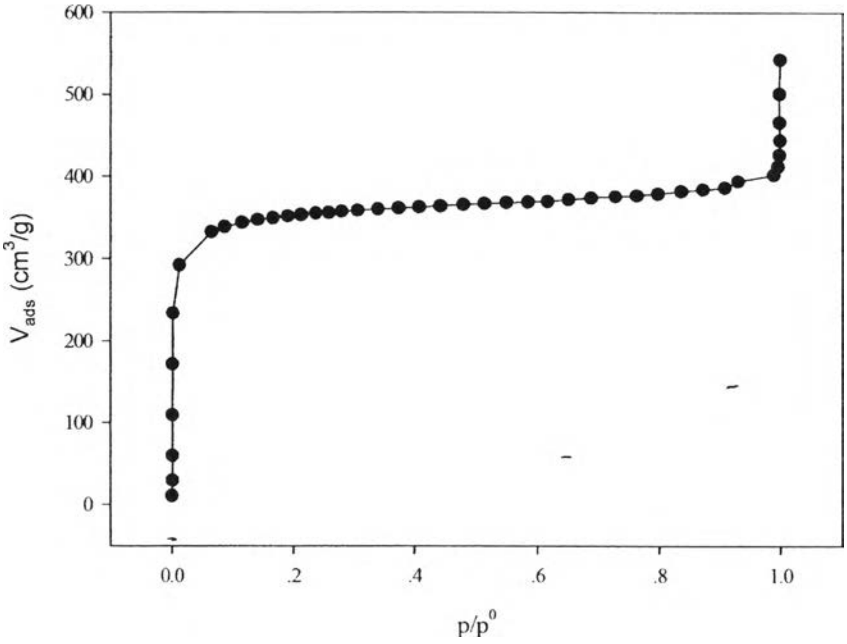


Figure F1 Isotherm of untreated activated carbon.

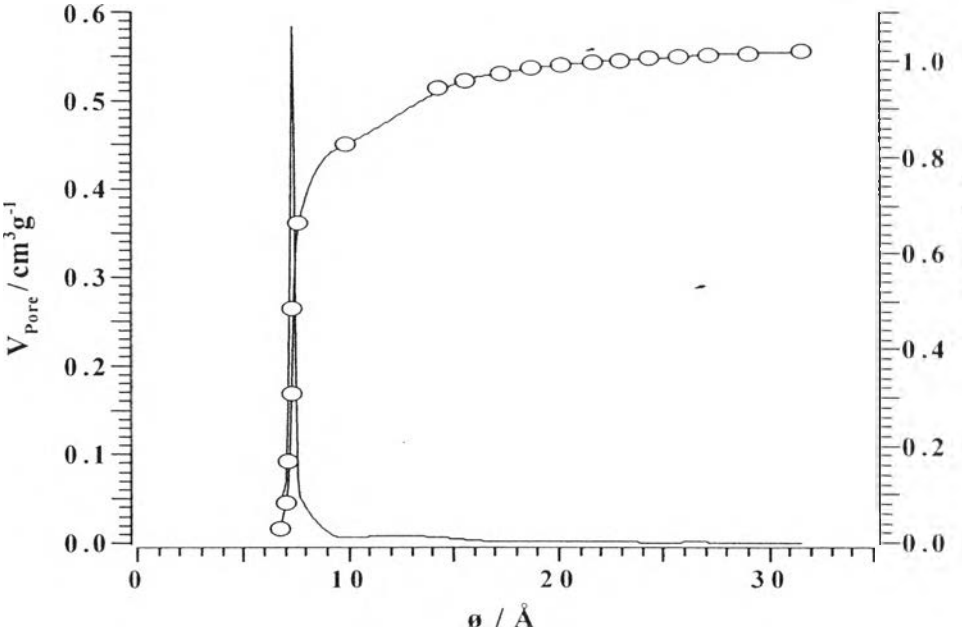


Figure F2 Horvath and Kawazoe pore size distribution of untreated activated carbon.

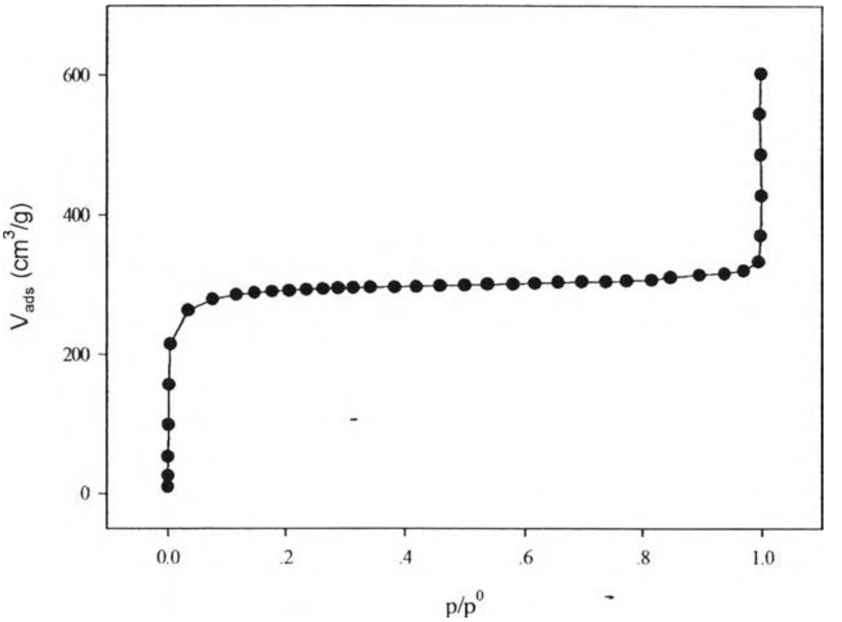


Figure F3 Isotherm of 1wt% PBZ derived from DETA impregnating on activated carbon.

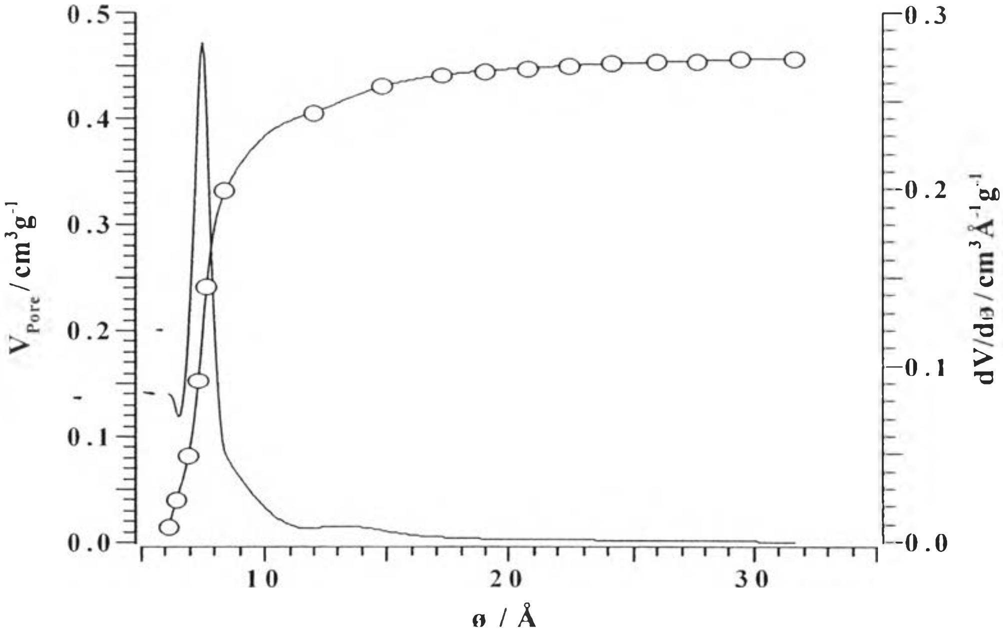


Figure F4 Horvath and Kawazoe pore size distribution of 1wt% PBZ derived from DETA impregnating on activated carbon.

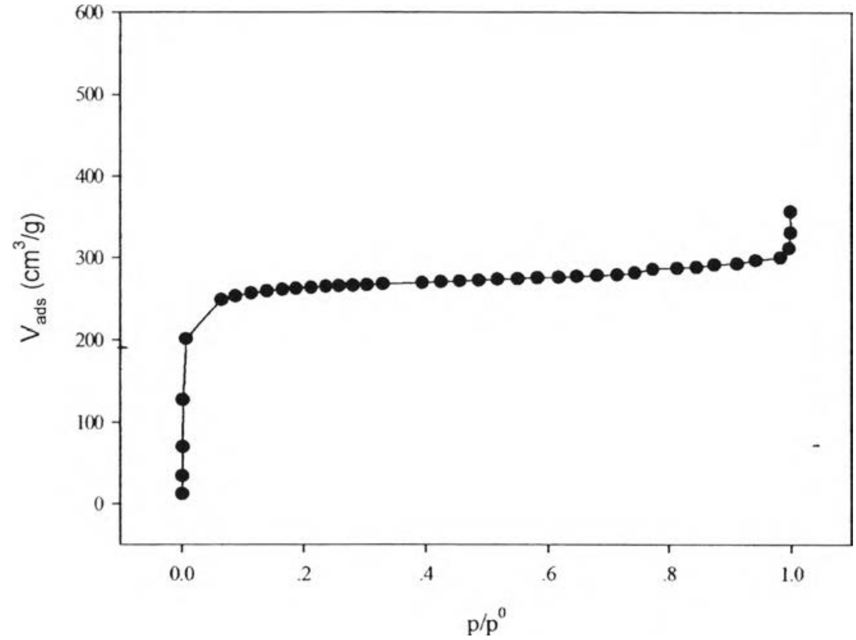


Figure F5 Isotherm of 5wt% PBZ derived from DETA impregnating on activated carbon.

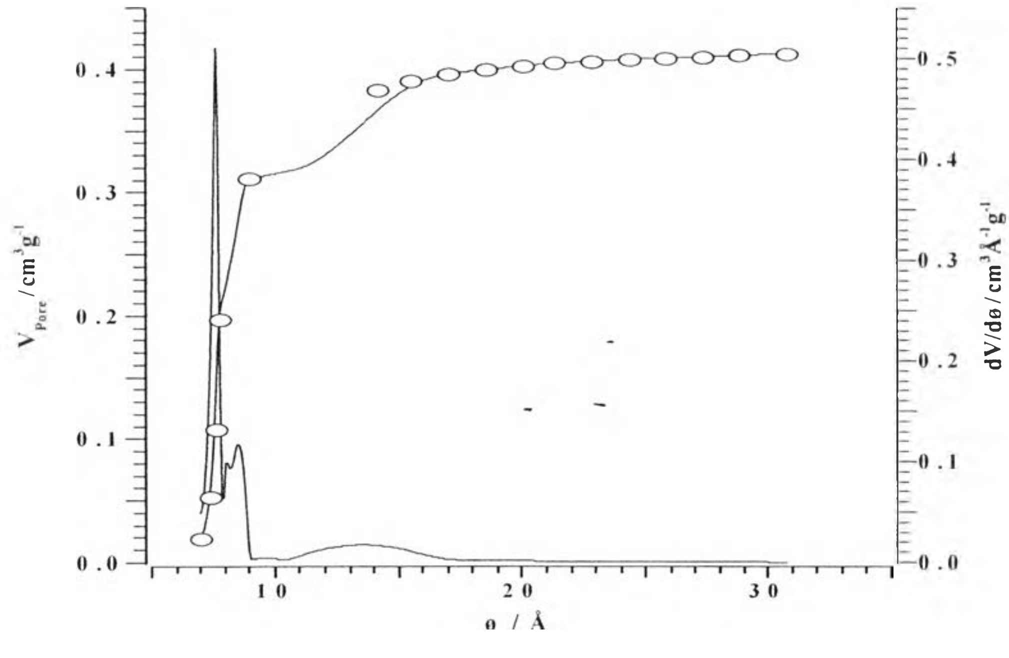


Figure F6 Horvath and Kawazoe pore size distribution of 5wt% PBZ derived from DETA impregnating on activated carbon.

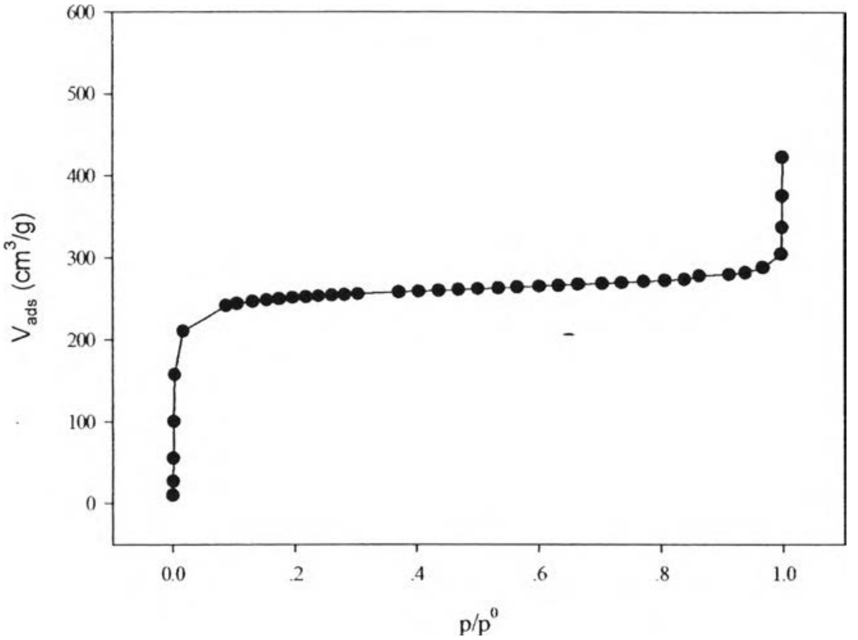


Figure F7 Isotherm of 10wt% PBZ derived from DETA impregnating on activated carbon.

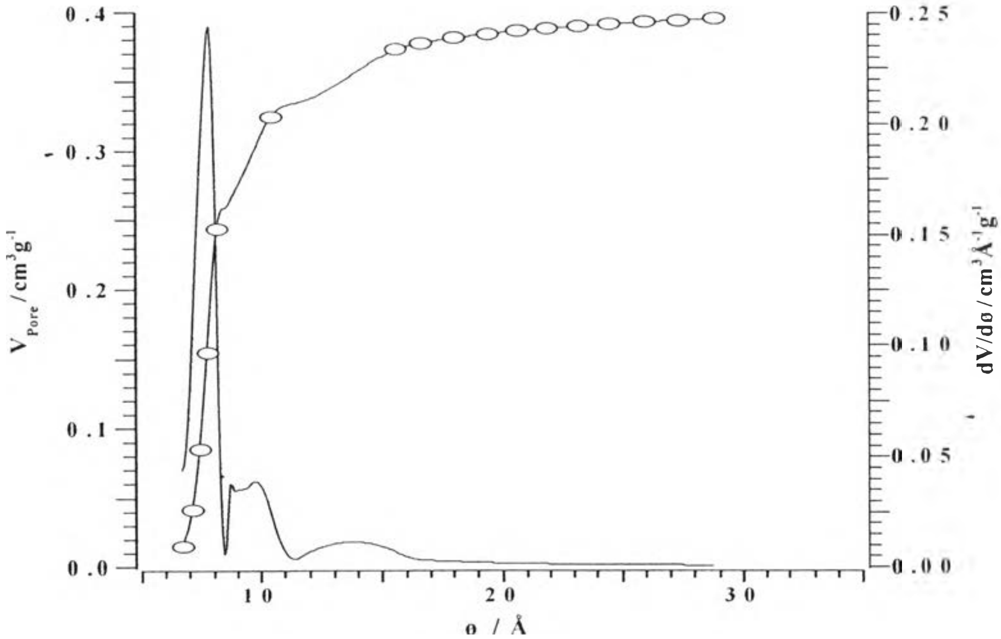


Figure F8 Horvath and Kawazoe pore size distribution of 10wt% PBZ derived from DETA impregnating on activated carbon.

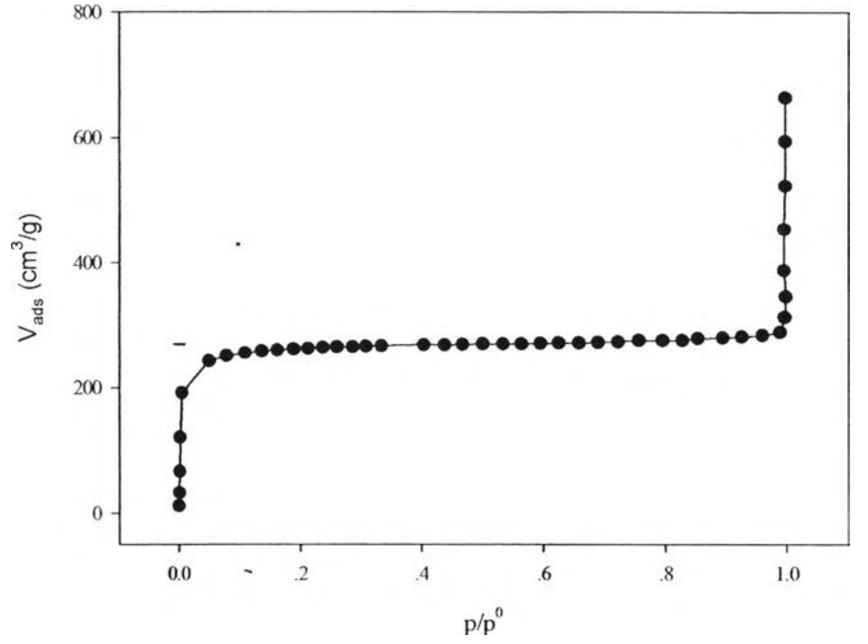


Figure F9 Isotherm of 10wt% PBZ derived from PEHA impregnating on activated carbon.

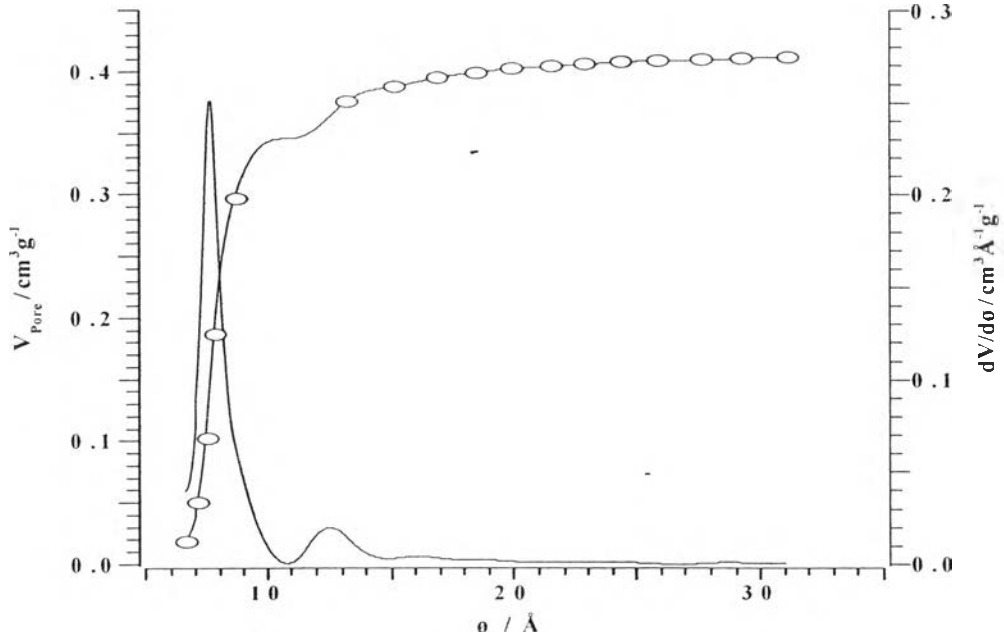


Figure F10 Horvath and Kawazoe pore size distribution of 10wt% PBZ derived from PEHA impregnating on activated carbon.

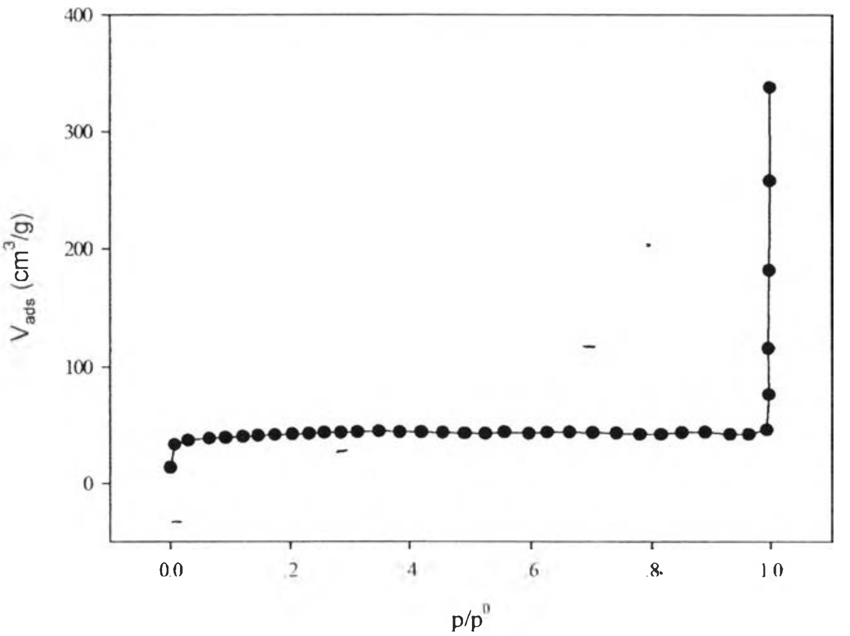


Figure F11 Isotherm of activated carbon from DETA-derived polybenzoxazine at 200 °C.

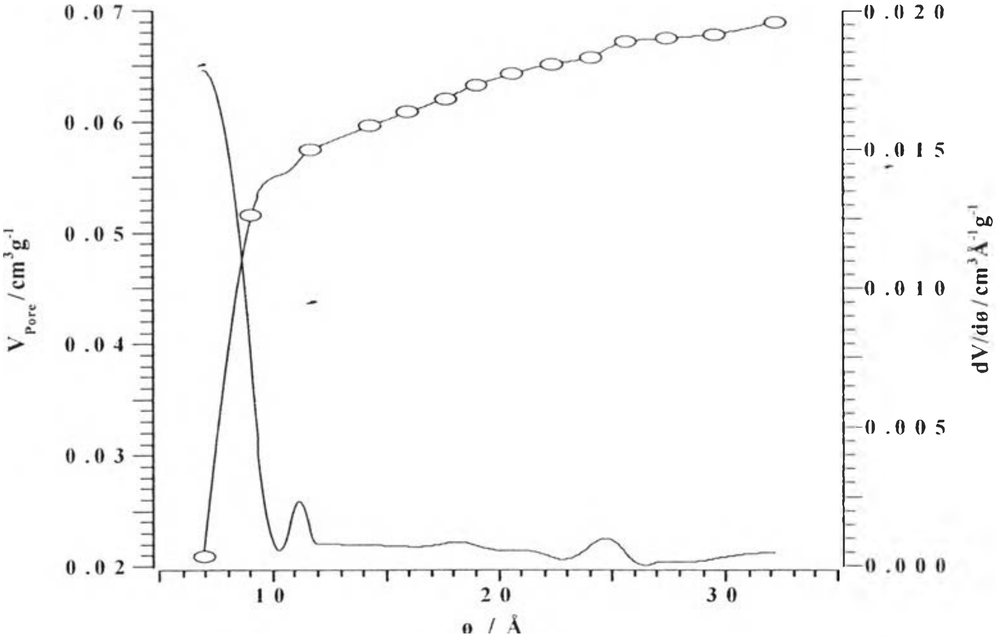


Figure F12 Horvath and Kawazoe pore size distribution of activated carbon from DETA-derived polybenzoxazine at 200 °C.

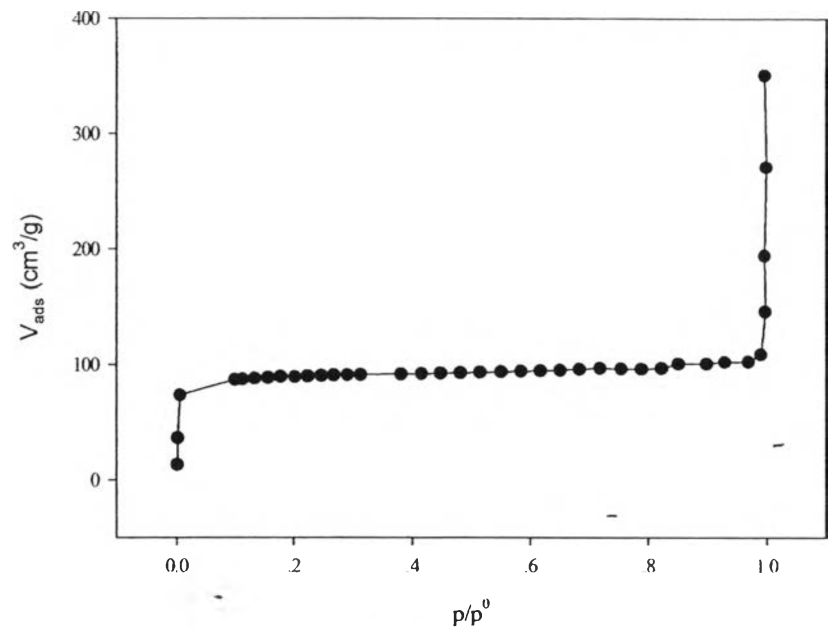


Figure F13 Isotherm of activated carbon from DETA-derived polybenzoxazine at 300 °C.

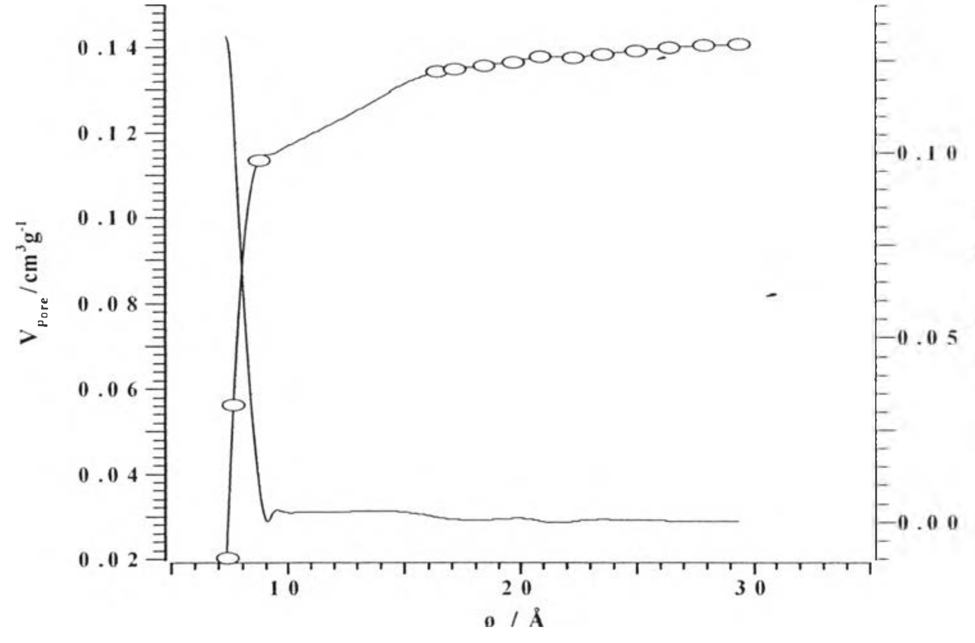


Figure F14 Horvath and Kawazoe pore size distribution of activated carbon from DETA-derived polybenzoxazine at 300 °C.

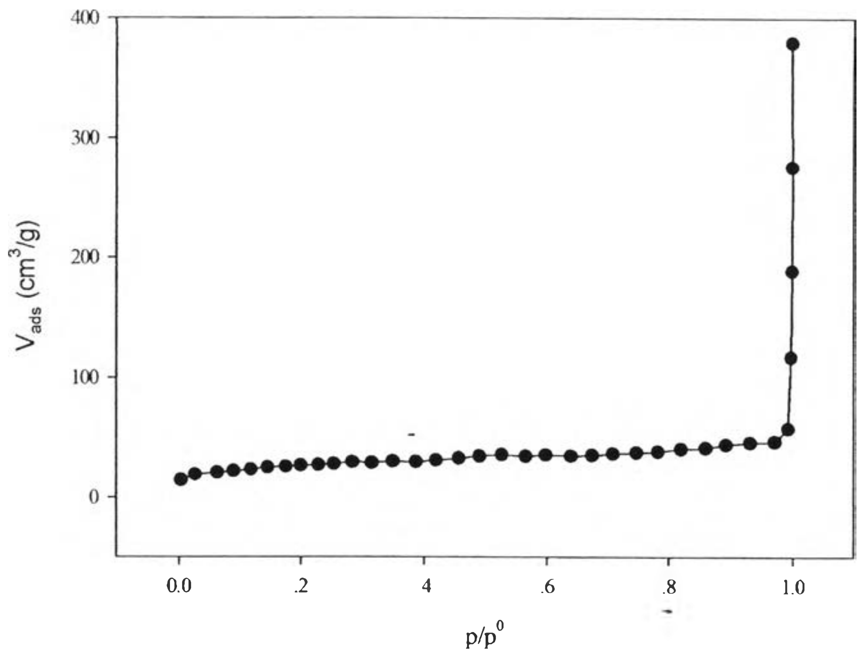


Figure F15 Isotherm of activated carbon from DETA-derived polybenzoxazine at 400 °C.

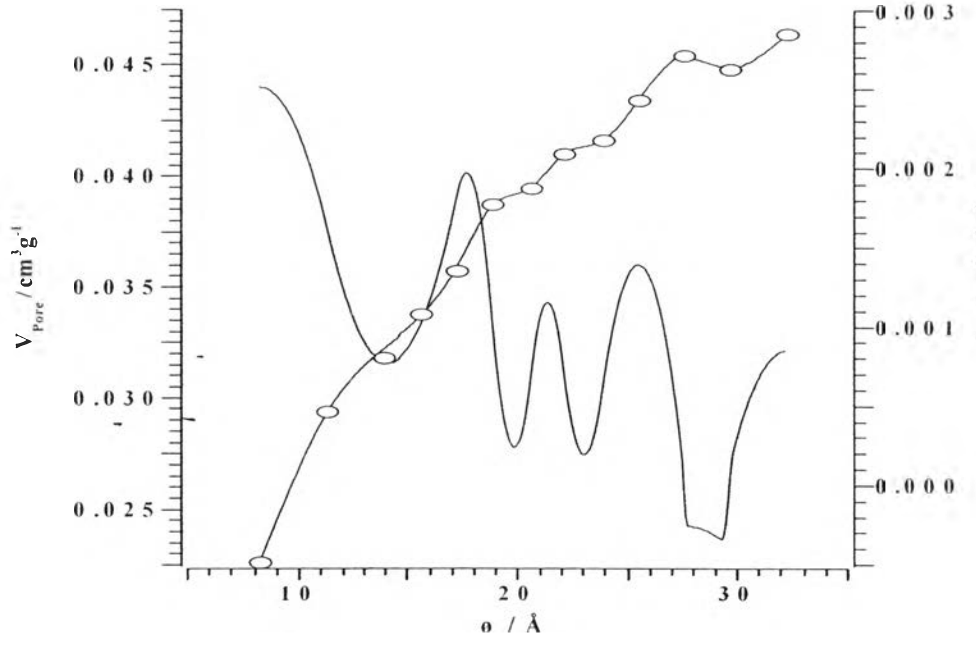


Figure F16 Horvath and Kawazoe pore size distribution of activated carbon from DETA-derived polybenzoxazine at 400 °C.

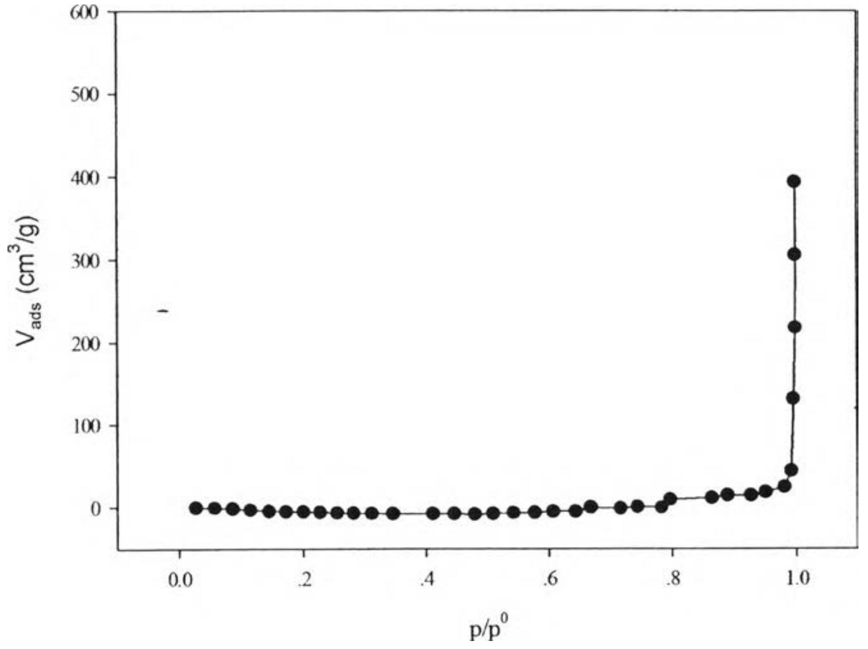


Figure F17 Isotherm of activated carbon from PEHA-derived polybenzoxazine at 300 °C.

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Proceeding:

1. Hirikamol, N.; and Suriyapraphadilok, U. (2014, April 22) Polybenzoxazine Sorbents for CO_2 Capture. Proceedings of The 5th Research Symposium on Petroleum, Petrochemicals and Advanced Materials and The 20th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand.

Presentation:

1. Hirikamol, N.; and Suriyapraphadilok, U. (2014, May 7-8) Polybenzoxazine Sorbents and Its Modified for CO_2 Capture. Paper presented at International Conference on Environment and Renewable Energy, Paris, France.