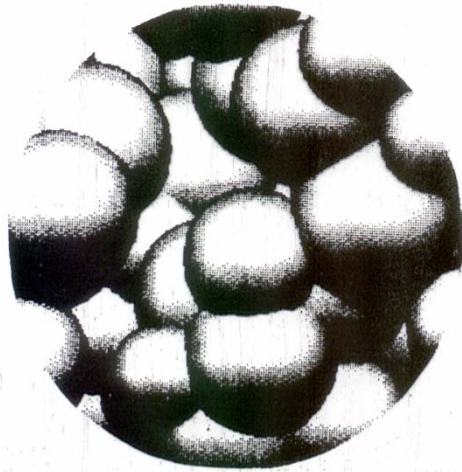


POROZNI MATERIALI

Teksturalne osobine

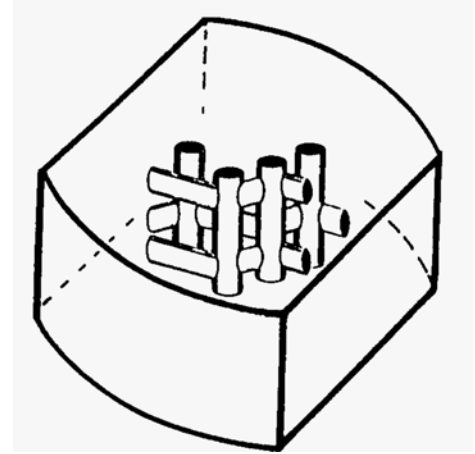
200mm



Silica



Carbon



Zeolite

Važne osobine poroznih sistema su:

- Površina – određuje se BET-metodom
- Struktura pora
- Hemijski sastav površine

Tehnike kojima se ispituje sastav površine:

- IR i Raman
- X-ray fluorescentna (XRF)
- Difrakcija elektrona niske energije (LEED)
- X-ray fotoelektronska spektroskopija (ESCA)
- Ožeova elektronska spektroskopija (AES)

Tekstura i morfologija poroznih sistema

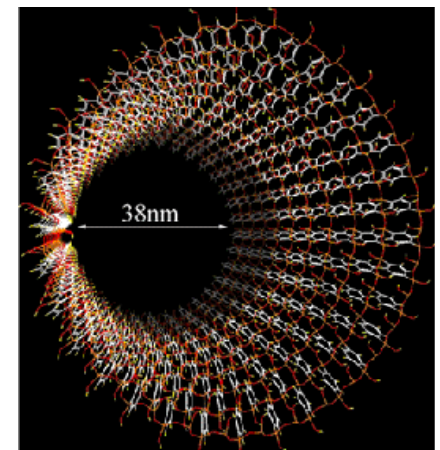
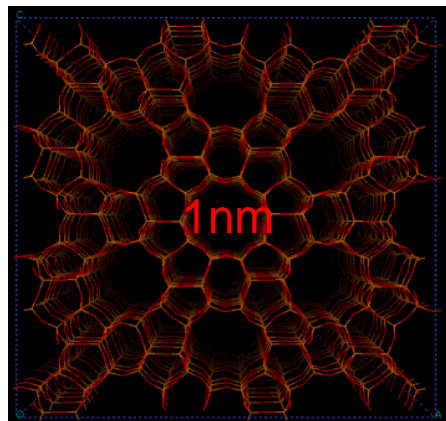
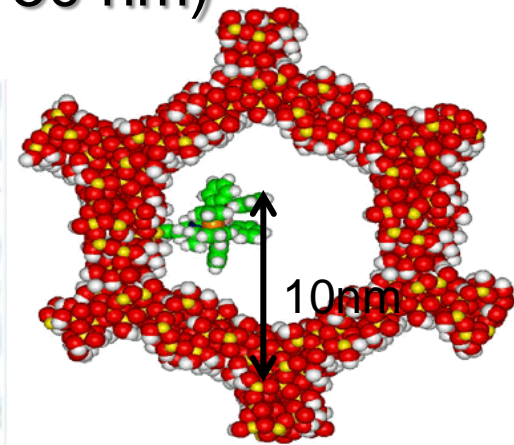
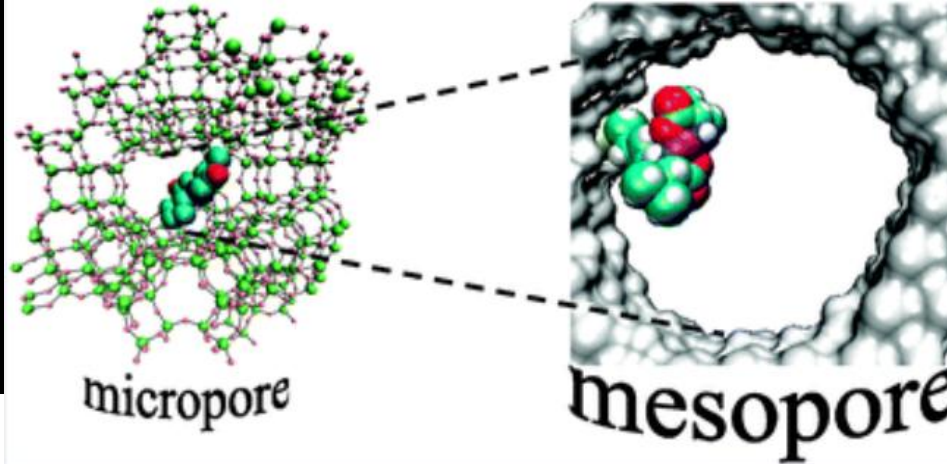
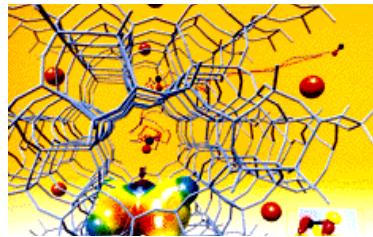
- Veličina pora
- Oblik pora
- Distribucija pora po veličini
- Zapremina pora
- Specifična površina adsorbenta

Pore se formiraju u procesu sinteze datog materijala. Pore su dostupne željenom adsorbatu onda kada su prazne što se postiže aktiviranjem, najčešće zagrevanjem na određenoj temperaturi i u vakuumu.

Veličina i oblik pora

Dijametar pora

- mikropore (< 2 nm)
- mezopore (2 - 50 nm)
- makropore (> 50 nm)



Aktivni ugalj se sastoji od:

1. Mikro pora radijusa manjeg od 1 nm
2. Mezo pora radijusa 1-25 nm
3. Makropora radijusa većeg od 25 nm

Velike pore služe da transportuju adsorbat u mezo- i mikro- pore.

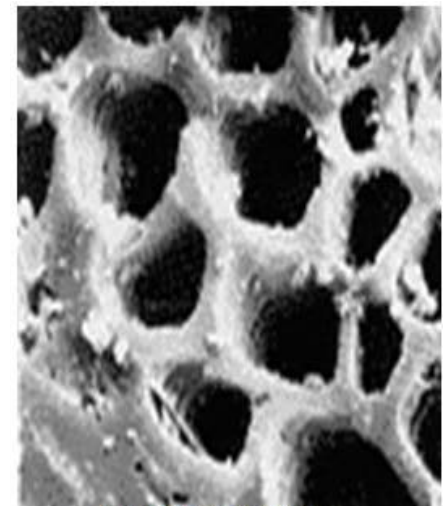
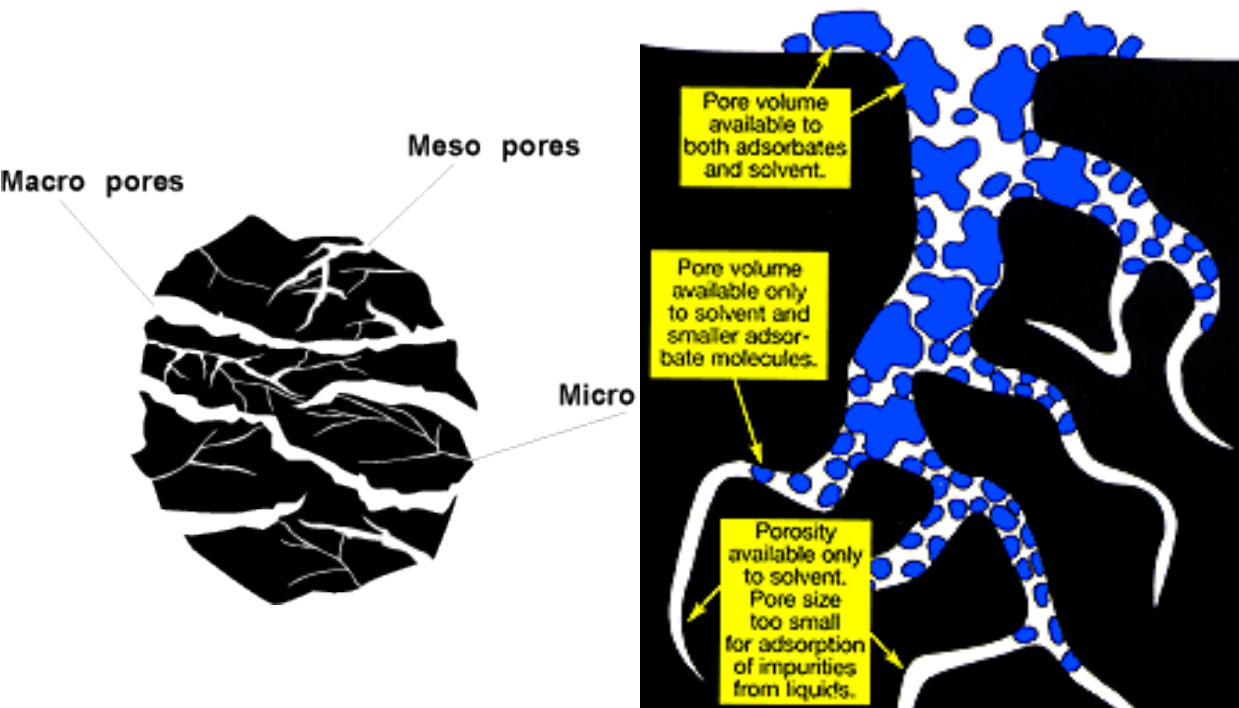
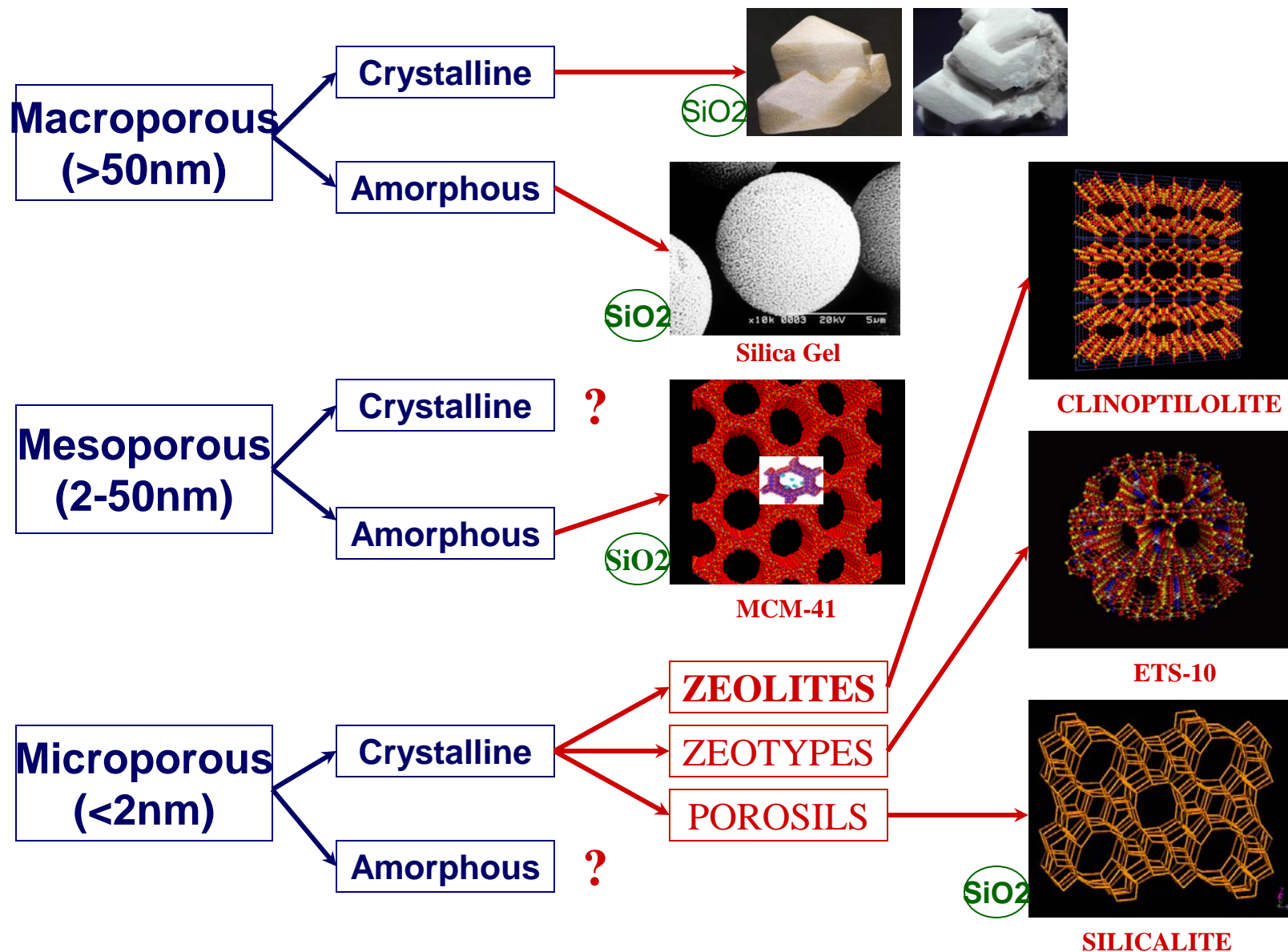
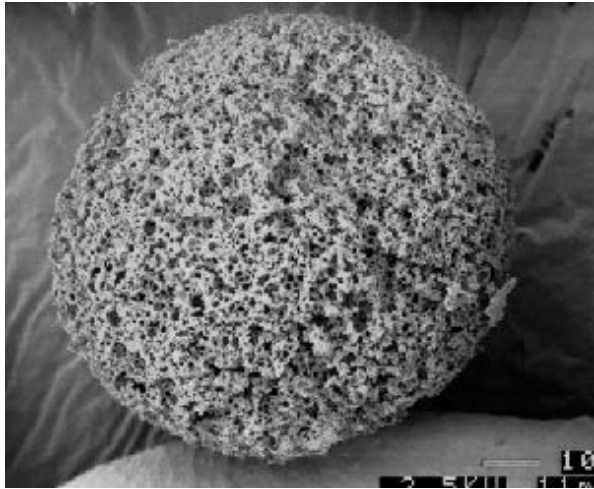


Fig.2 Coconut carbon

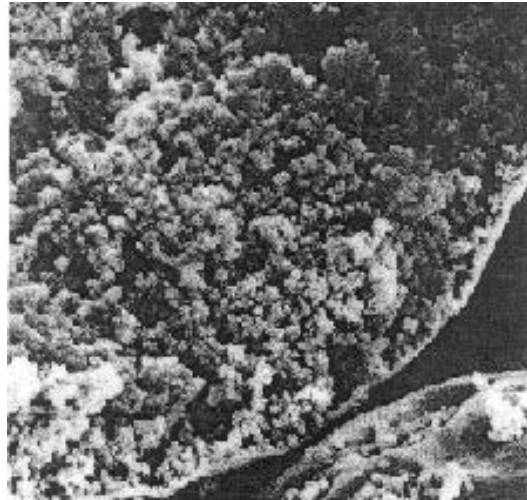
SILICATE / ALUMINOSILICATE POROUS MATERIALS



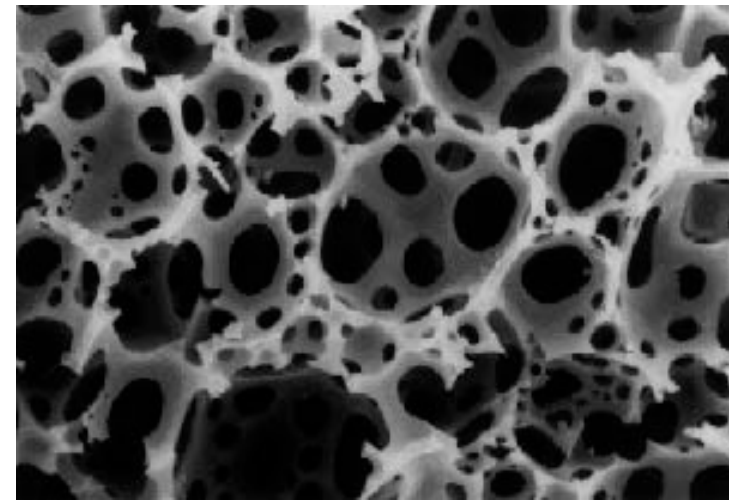
Cavilink polimer SEM



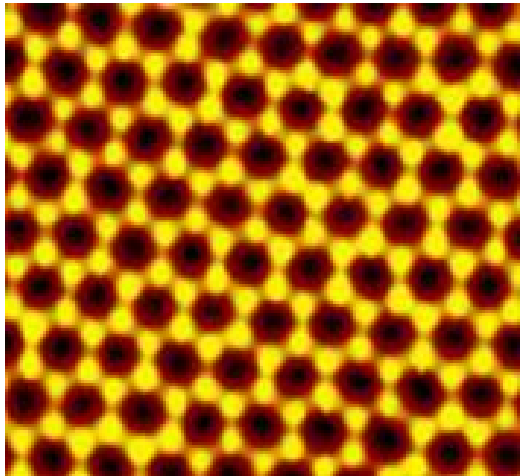
Kuglica Cavilink polimera



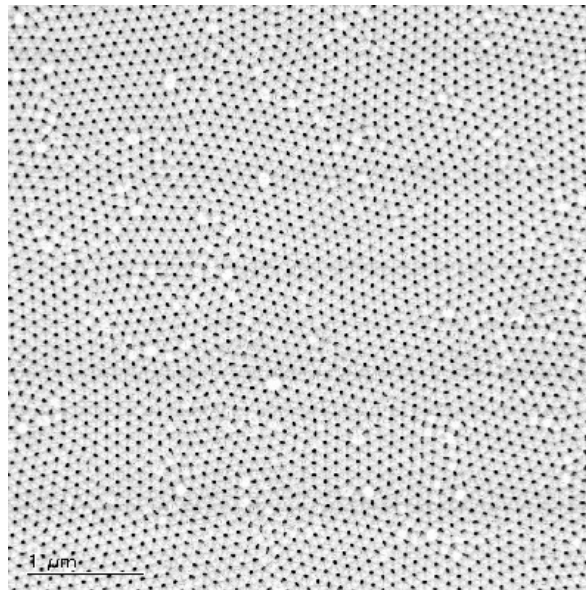
Presek kuglice Cavilink polimera, čestice međusobno povezane



Cavilink polimer sa potpuno otvorenom površinom – interkonekcija pora, kavezi imaju dijametar veći od 10,000 Å.



AFM imidž nanoporoznog aluminijumtriosida, tamne površine pore prečnika s ~50nm)



SEM mikrografija tamne površine pore aluminijum-oksida prečnika ~25nm)

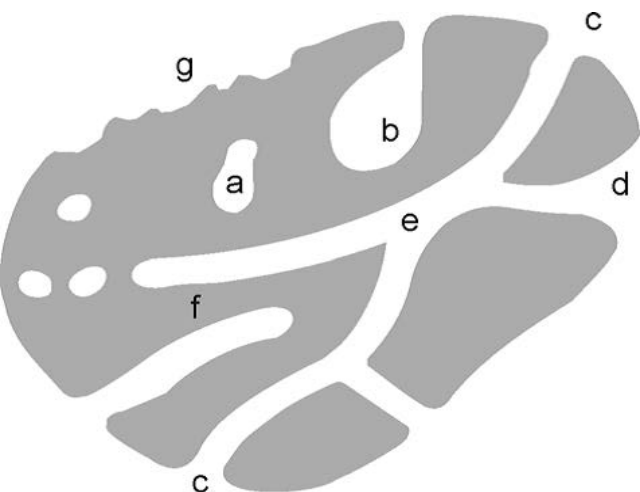
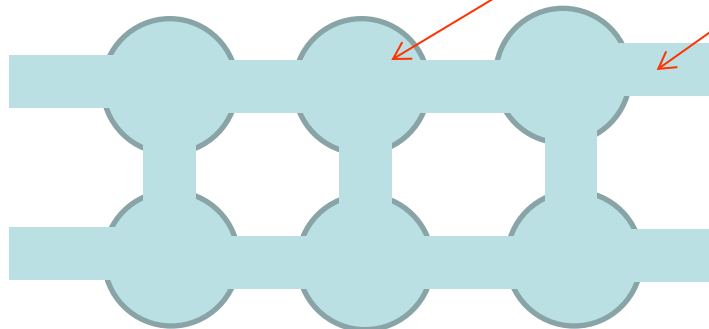
Definicije svojstava poroznih materijala

- **Porozni materijal** materijal sa kavezima i kanalima koji su dubilji nego širi
- **Otvor pore** kavez ili kanal sa otvorom na površini
- **Povezujuće pore** pore koje koje su međusobno povezane-adsorbat ostvaruje komunikaciju između njih
- **Slepa pora (mrtva)** Pora koja se nalazi na površini i nije povezana sa drugim porama
- **Zatvorena pora** Kavez koji nije povezan sa površinom
- **Void** Prazan prostor između čestica
- **Mikropora** Pora manje od 2 **nm**
- **Mezopora** Pora veličine između 2 i 50 nm
- **Makropora** Pora veličine veće od 50 **nm**

- **Veličina pore** Širina pore (dijametar cilindrične pore, ili rastojanje između zidova)
- **Zapremina pore** Zapremina određena datom metodom
- **Poroznost** Odnos ukupne zapremine pora i prividne gustine čvrste supstance
- **Totalna poroznost** Odnos zapremine praznog prostora između čestica i pora (otvorenih i zatvorenih) i zapremine koju zauzima čvrsta faza
- **Otvorena poroznost** Odnos zapremine slobodnog prostora između čestica i otvorenih pora i zapremine koju zauzima čvrsta faza
- **Površina** Ukupna površina određena nekom metodom pri određenim uslovima
- **Spoljašnja površina** Spoljašnja površina koja ne obuhvata površinu pora
- **Unutrašnja površina** Površina zidova pora
- **Gustina** Gustina čvrste faze, koja ne obuhvata pore i slobodne prostore
- **Prividna gustina** Gustina materijala koja uključuje zatvorene i dostupne pore, određena datim metodom

Poroznost se najčešće definiše kao odnos zapremine pora i zapremine koju zauzima čvrsta faza. Poroznost čine kavezi i kanali koji imaju veću dubinu nego širinu.

U mnogim slučajevima **unutrašnja površina** je mnogo veća od **spoljašnje površine**.



Dostupnost pore

A- zatvorena pora

b,c,d,f otvorena pora

b,f slepa pora

e spoj pora

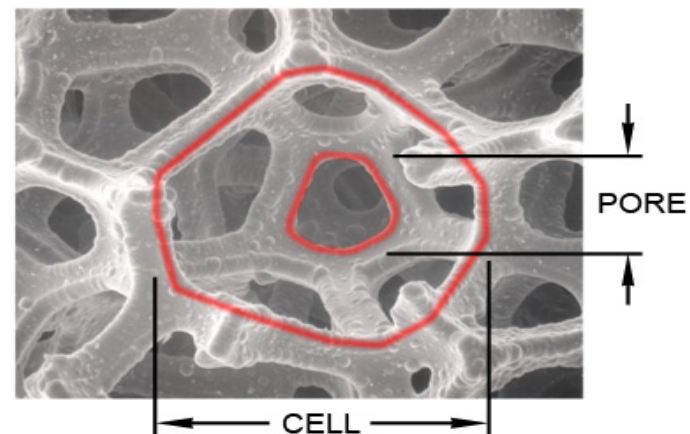
Oblici pora

c- cilindrična

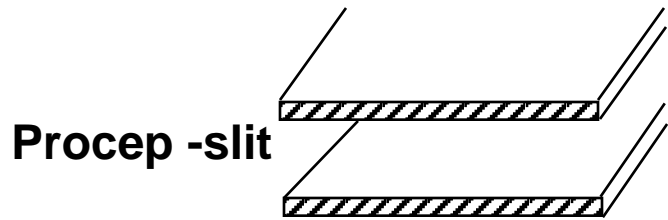
f-cilindrična slepa

d-pora oblika dimnjaka

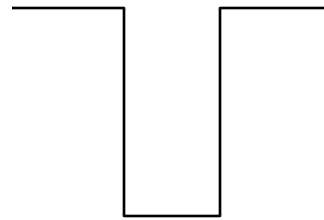
g-hrapavost površine



Oblici pora

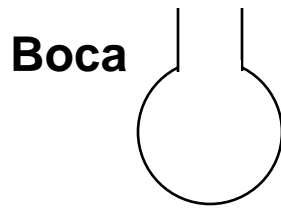


a

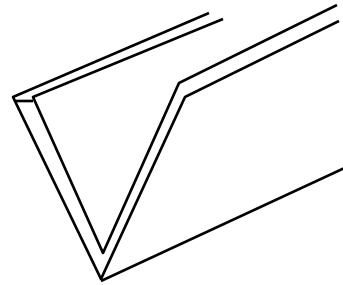


b

Cilindar



c



d

Klin, oluk

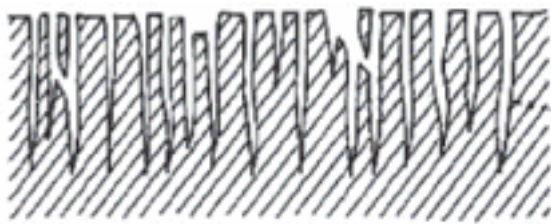


Figure 6. Schematic pore images of activated carbon fiber and activated carbon.

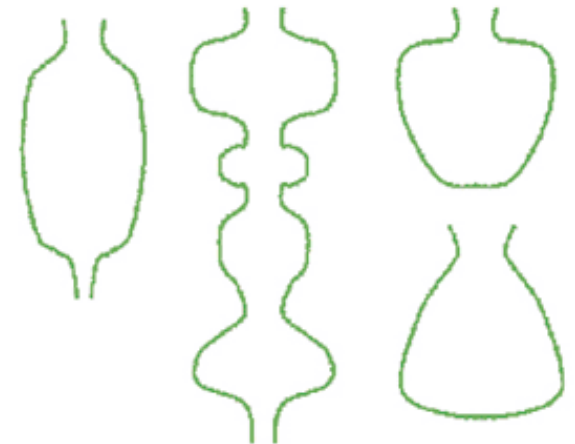
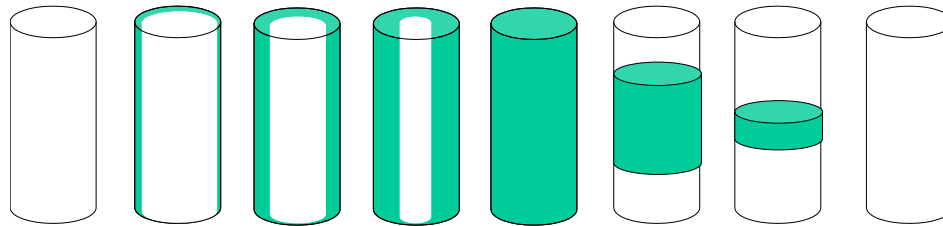
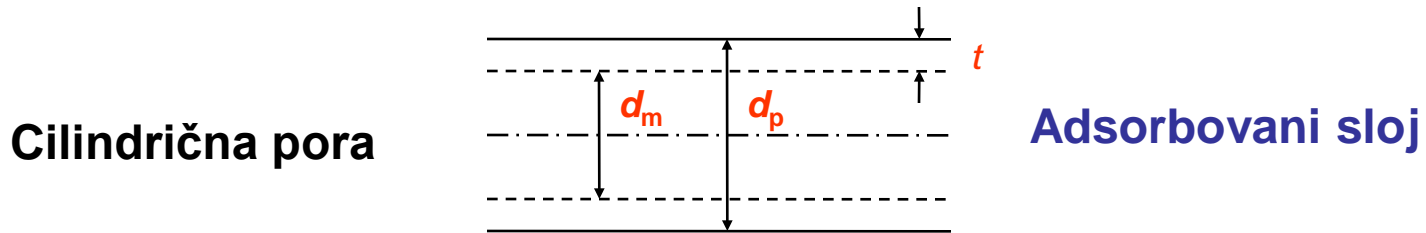
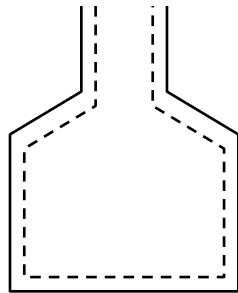


Figure 5. Schematic shapes of pores in activated carbon.

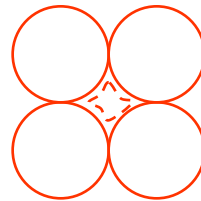
Adsorpcija na zidovima pora



Pora u obliku
boce



Ink-bottle



Pora u međuprostoru između
čestica koje su u gustom
pakovanju

Veličina pora i difuzijski režim

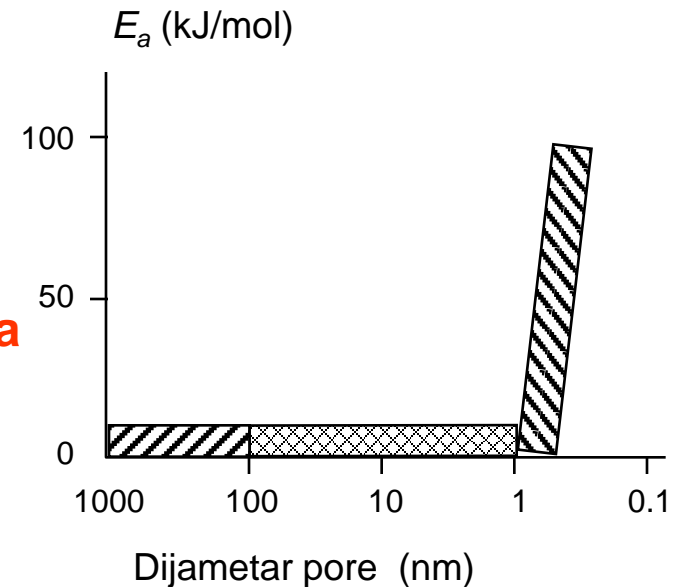
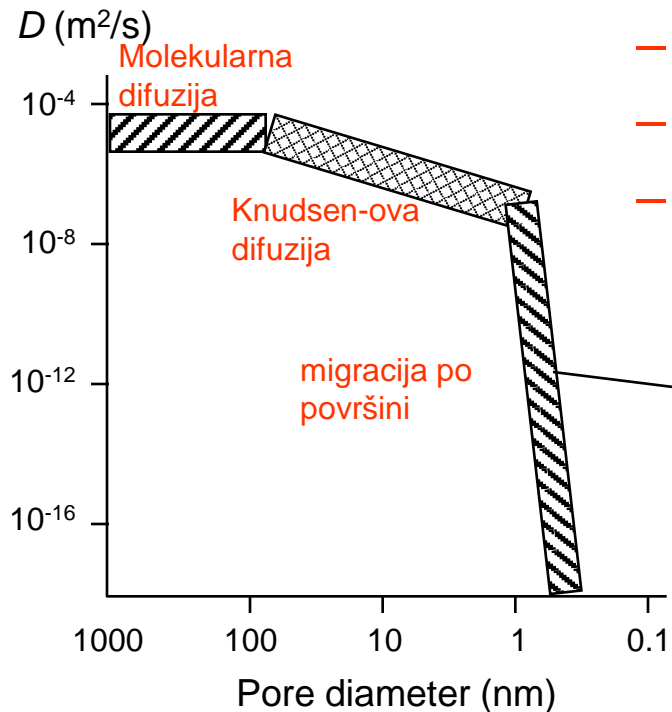
Zašto je ovo važno?

Veličina pora određuje difuzione procese kroz materijal.

- **Tipovi difuzije**

- **Molekularna**
- **Knudsen-ova**
- **površinska**

Konfiguraciona difuzija migracija po površini



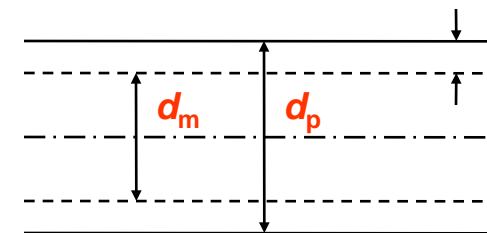
- **Knudsenov broj : $K_n = \lambda/d$**

λ = dužina srednjeg slobodnog puta molekula

d = karakterističan dijametar pore

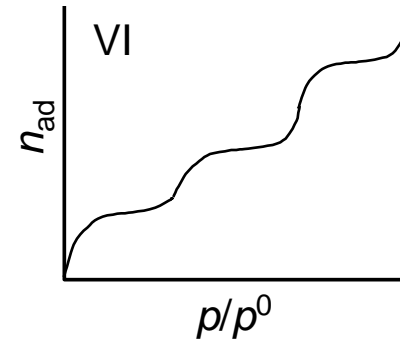
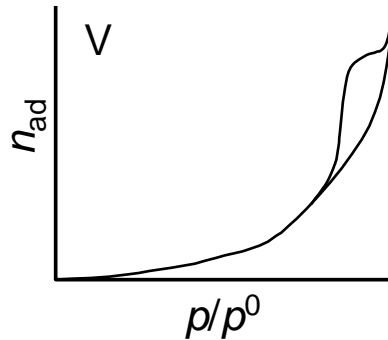
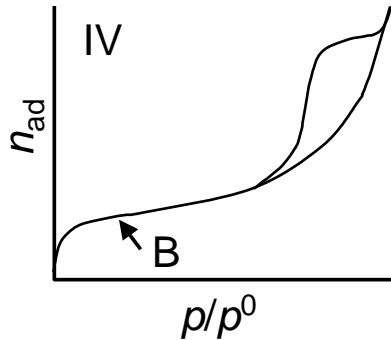
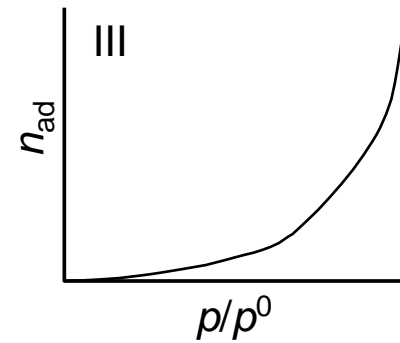
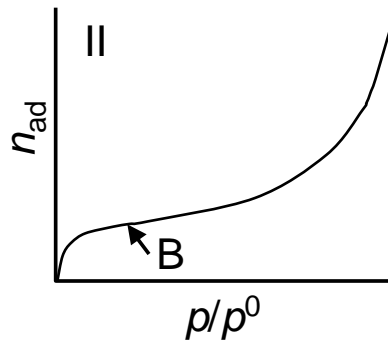
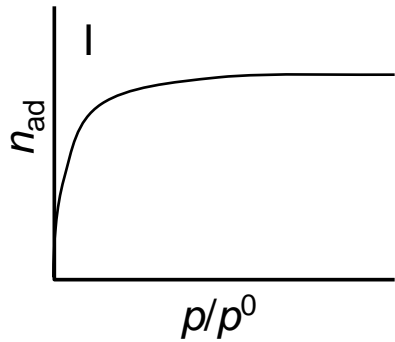
$K_n \ll 1$ bulk difuzija

$K_n \gg 1$ Knudsen-ov difuzija



Cilindrična pora

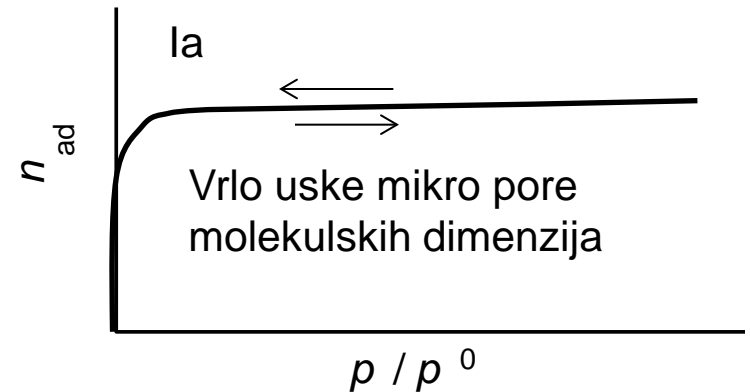
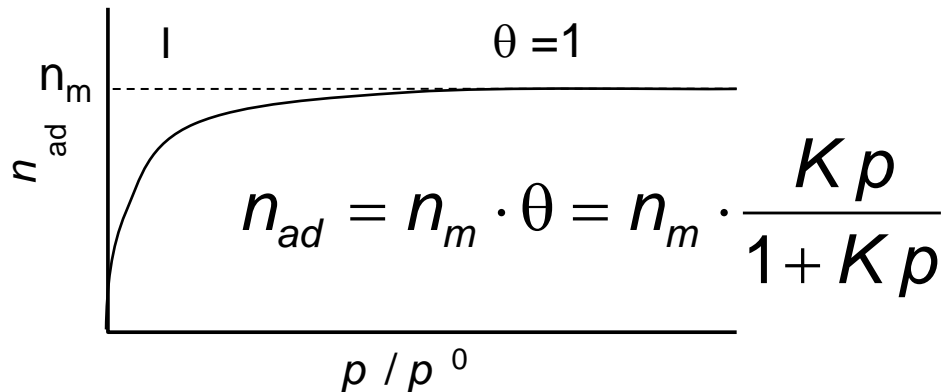
Tipovi adsorpcionih izoterma



p pritisak gasa, p_0 je napon pare na datoj temperaturi, odnosno napon pare na temperaturi ključanja 1 atm na 77 K za N_2

Langmuirova Adsorptionna Izoterma (Tip I)

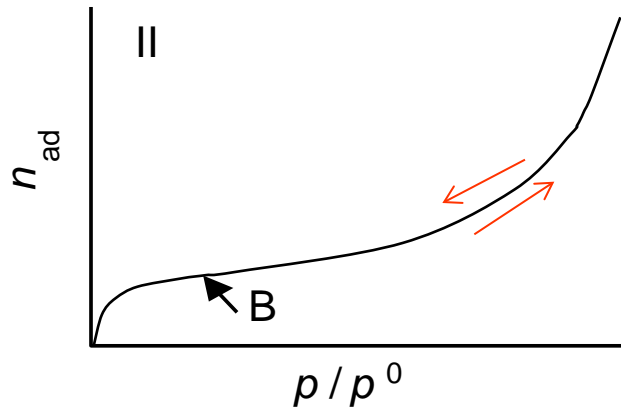
Izoterma tipa I. Mikroporozni materijal sa malom spoljašnjom površinom, količina adsorbovane supstance je limitirana, dostiže se saturacija na vrlo niskoj vrednosti p/p^0 adsorbent i adsorbat interaguju u maloj pori, molekulskih dimenzija.



pretpostavke:

- homogena površina (svi adsorpcioni centri su energetski identični)
- monomolekulska asorpcija
- adsorbat ima osobine idealnog gasa
- adsorbovani molekuli zauzimaju fiksne centre
- nema interakcije između adsorbovanih molekula
- toplota adsorpcije ne zavisi od stepena pokrivenosti.

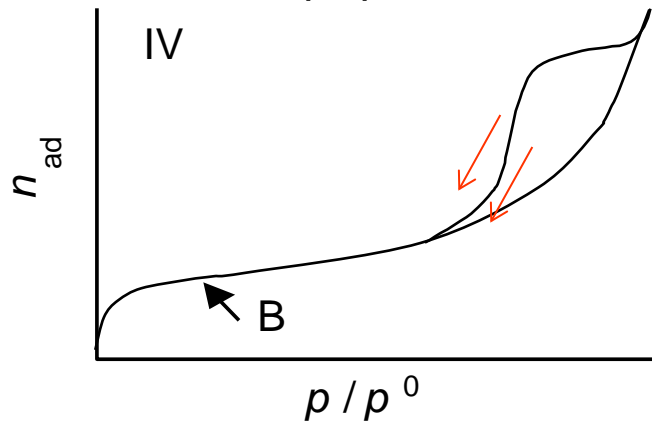
Izoterme tipa II i IV



Multislojna adsorpcija (početak u B)

Karakteristična za nanoporozne materijale i makroporozne materijale, debljina sloja raste bez ograničenja

Kondenzacija u porama

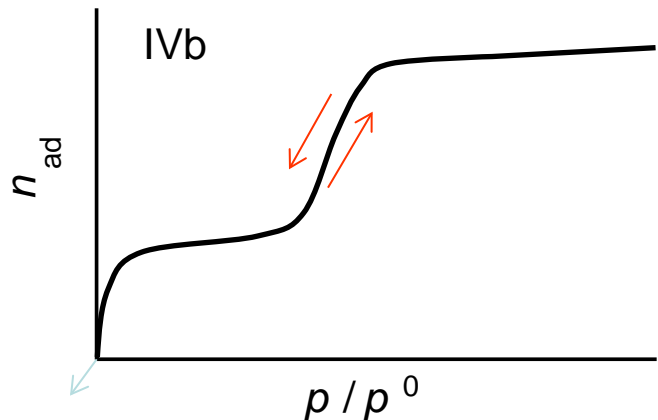


Slična sa tipom II pri malim pritiscima

Kondenzacija pri velikim pritiscima

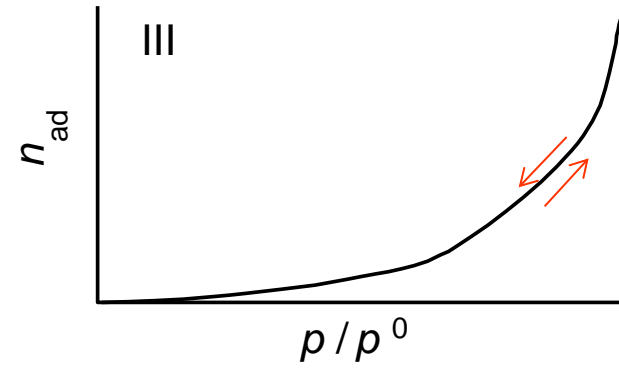
Karakteristična za mezoporozne materijale
Adsorpcione osobine određuje interakcija između adsorbenta i adsorbata u kondenzovanoj fazi . Gas se kondenzuje na pritisku manjem pod p_0

Histerezus počinje u slučaju adsorpcije N_2 na sloju debljine 4 nm

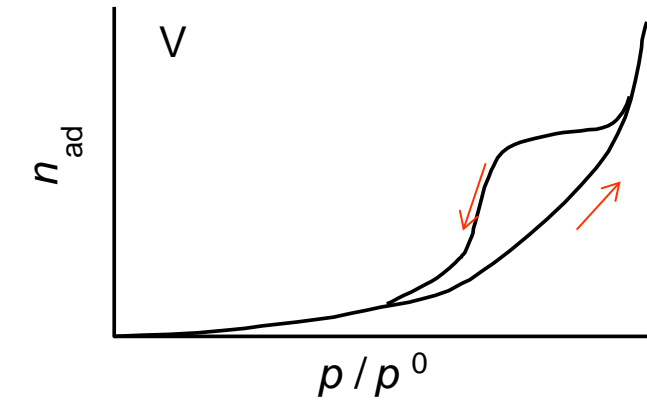


Mezoporozni materijal koji ima pore manje širine ima kompletno reverzibilnu desorpcionu granu, cilindrične zatvorene pore ili kupaste pore

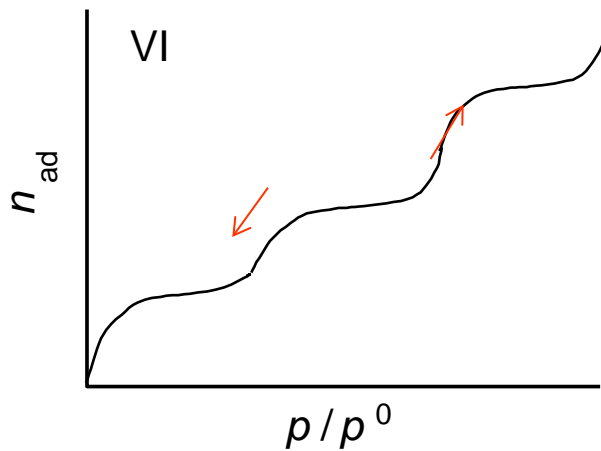
Izoterme tipa III i V



**Stroge kohezione sile između adsorbovanih molekula
Nema karakterističnog monosloja, interakcija adsorbent-adsorbat je veoma slaba, molekuli adsorbata grade klasterne na površini nano- i makroporoznih materijala**



**Vrlo slična kao tip III na malim pritiscima
Relativno slaba interakcija adsorbent-adsorbat
Kondenzacija na visokim pritiscima p
Na visokim pritiscima molekuli adsorbata grade klasterne ispunjavajući pore
*Ovaj tip se javlja pri adsorpciji vode na hidrofobnim mikroporoznim i mezoporoznim adsorbentima***

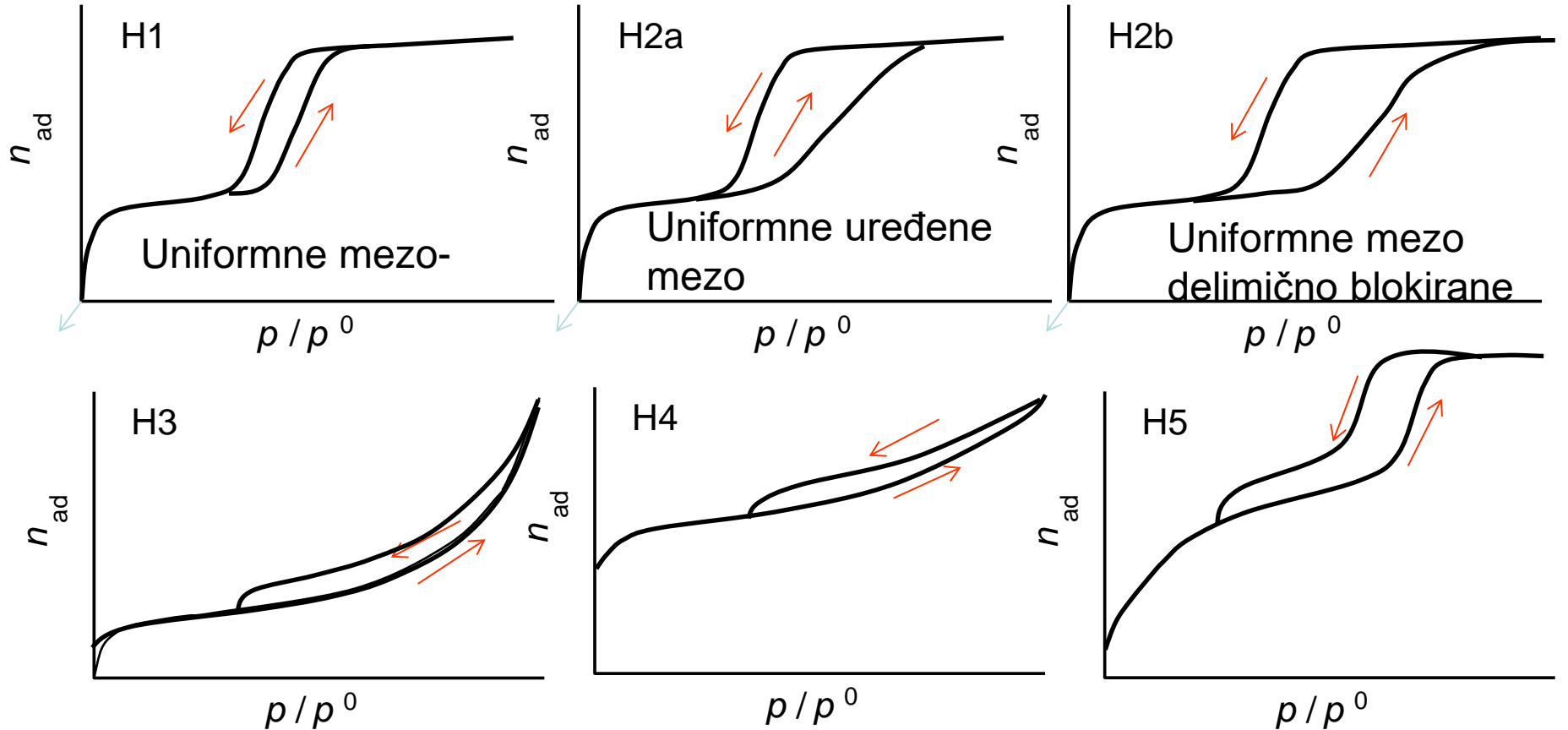


**Reprezentuje sloj po sloj adsorpcije na energetski neuniformnoj površini i plato svakog sloja određuje kapacitet datog adsorpcionog centra
Primer je adsorpcija Ar, Kr na niskim temperaturama na grafitizovanom aktivnom uglju**

Histerezične petlje

Informacije o obliku pora

Histerezične petlje su karakteristične za višeslojnu adsorpciju, generalno su povezane sa kapilarnom kondenzacijom, zavise od oblika pora, njihove povezanosti i različitih načina na koji pore mogu da budu blokirane



Agregati pločastih struktura koji slabo interaguju

Zeolitski agregati

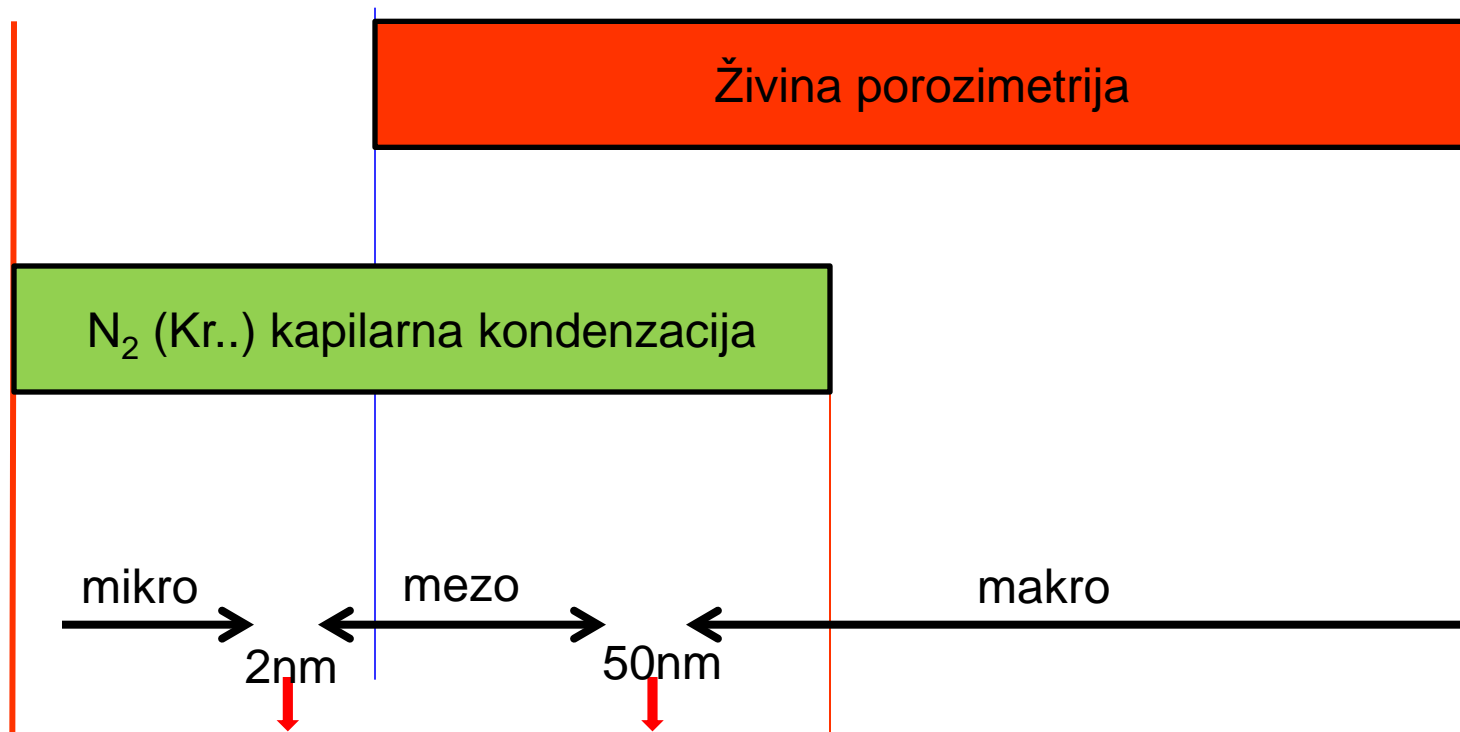
Blokirane i parcijalno blokirane

Svojstva adsorbata koji se koriste u fisisorpcionim merenjima

Adsorbate	Boiling Point (K)	A_m (nm ² /molecule)
N ₂	77.3	0.162
Ar	87.4	0.142
CO ₂	194.5	0.17
Kr	120.8	0.152

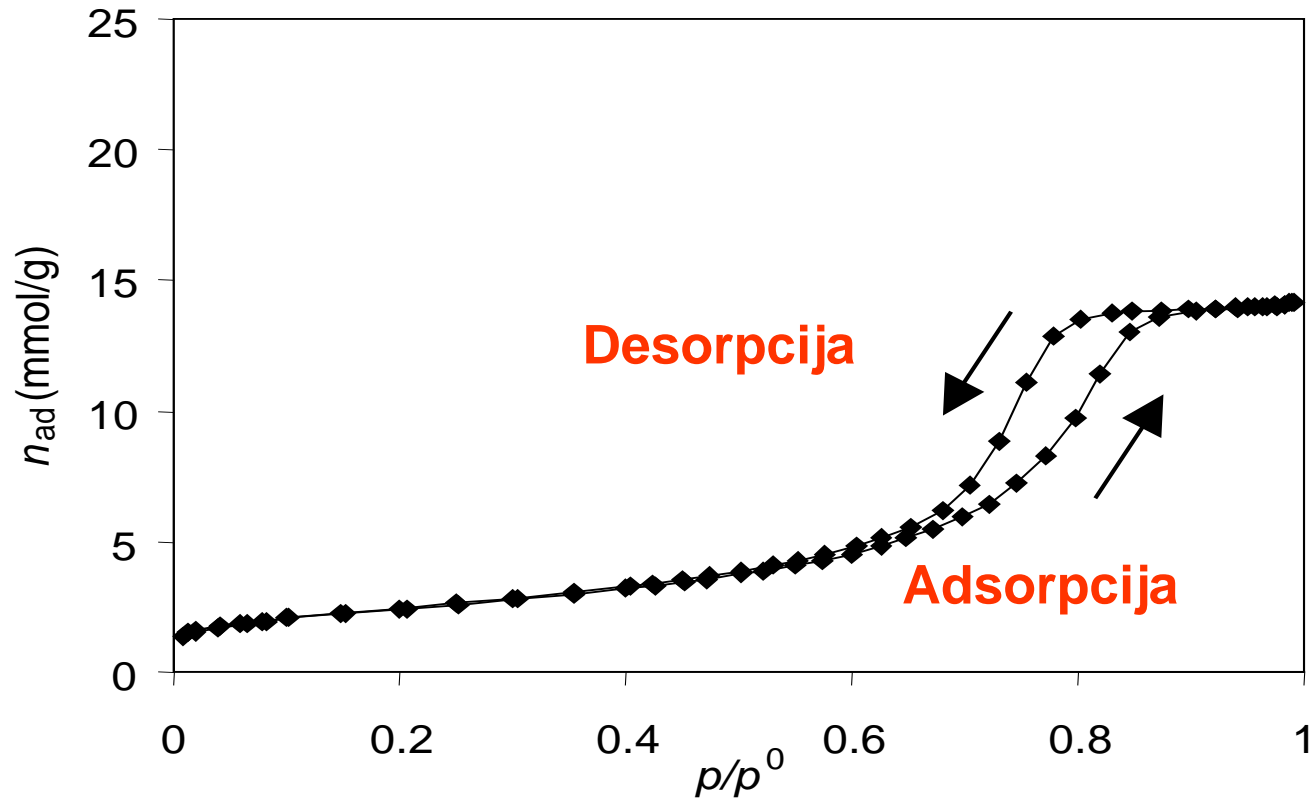
Dijametri pora i tehnike meranja

- Eksperimentalne tehnike
 - Kapilarna kondenzacija
 - Utiskivanje žive - Hg intrusion
 - Mikroskopija



Adsorpcione izoterme

1. Volumerijski metod
2. Gravimetrijski metod



p pritisak gasa

p^0 napon pare na datoj temperaturi

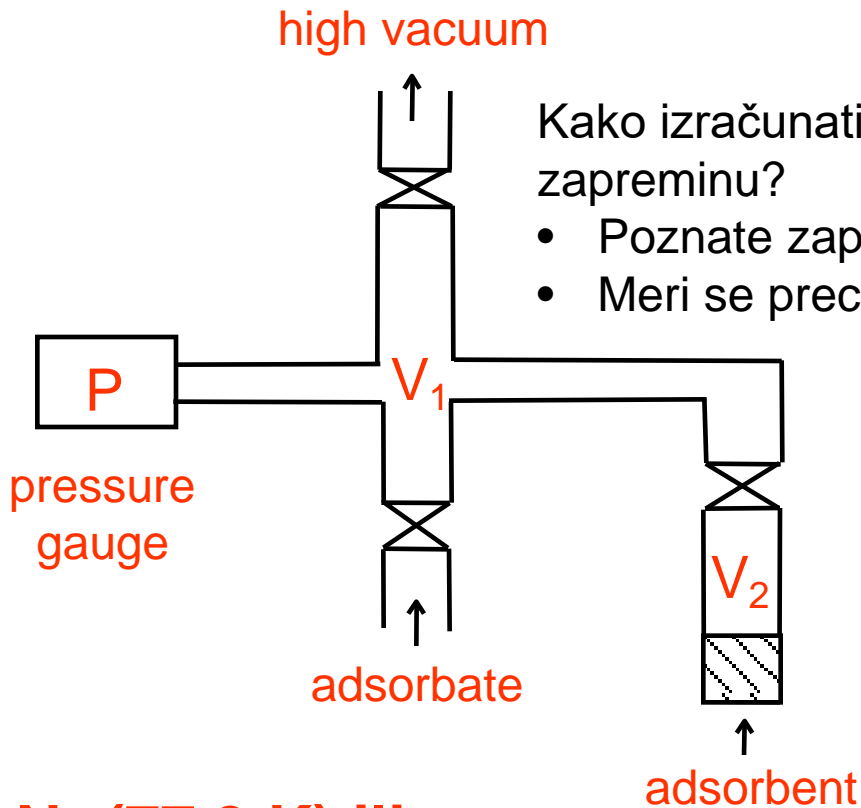
Zapreminska adsorpciona merenja

1. Precizno merenje pritiska
2. Visoki vakuum
3. Precizna kalibracija sistema
4. Održavanje temperature na temperaturi ključanja gasa sa kojim se meri adsorpcija

$$PV=nRT$$

Kako izračunati broj molova adsorbovanog gasa i njegovu zapreminu?

- Poznate zapremine V_1 i V_2
- Meri se precizno pritisak



N_2 (77.3 K) ili

Ar, He, CH_4 , CO_2 , Kr

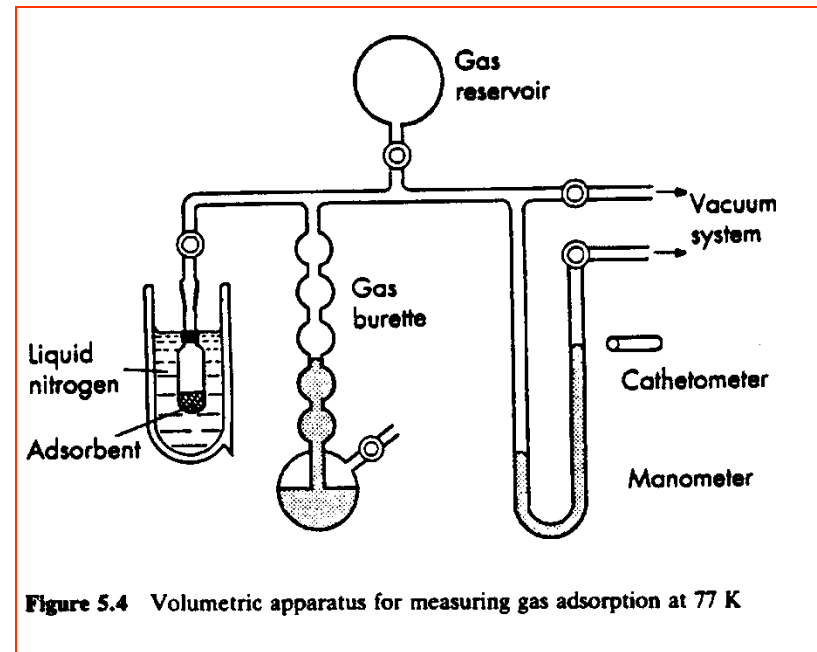


Figure 5.4 Volumetric apparatus for measuring gas adsorption at 77 K

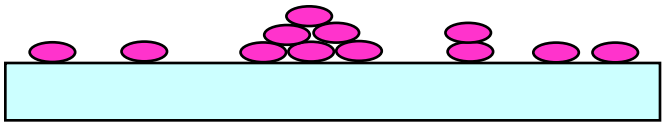
BET ADSORPCIONA IZOTERMA

Pretpostavke:

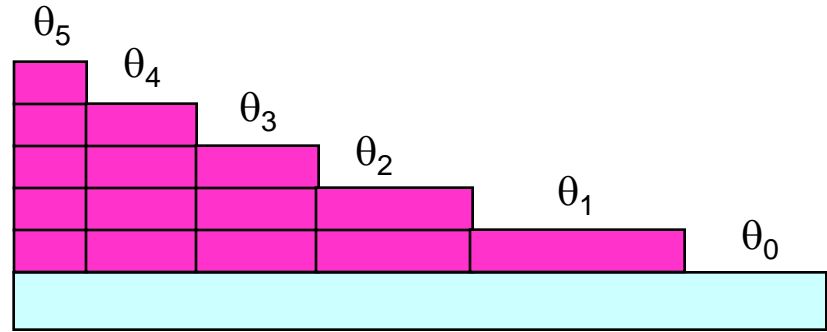
- Na svaki sloj se primenjuje se Langmirov model adsorpcije.
- Entalpija adsorpcije, ΔH_{ads} za prvi sloj ima vrednost za interakciju adsorbent-adsorbat, a za svaki naredni sloj se uzima entalpija isparavanja ΔH_{vap} .
- isparavanje (ili desorpcija) se odvija sa eksponirane površine .
- Brzina isparavanja je jednaka sa brzinom kondenzacije datog sloja.

BET Model

realnost



model



$$\sum \theta_i = 1$$

$$n_{ad} = n_m (\theta_0 + 2\theta_1 + 3\theta_2 + \dots)$$

Langmuir-ov model za svaki sloj

1st layer

$$k_a^0 \theta_0 p = k_d^1 \theta_1$$

$$\theta_1 = \frac{k_a^0}{k_d^1} p \theta_0 = K_1 p \theta_0$$

nth layer

$$k_a^{n-1} \theta_{n-1} p = k_d^n \theta_n$$

$$\theta_n = \frac{k_a^0}{k_d^1} p \theta_{n-1} = K_n p \theta_{n-1}$$

$$K_1 = K_{1,0} e^{-\frac{\Delta H_{ads}}{RT}}$$

$$K_n = K_{n,0} e^{-\frac{\Delta H_n}{RT}} \approx K_{n,0} e^{-\frac{\Delta H_{cond}}{RT}}$$

➔ $C = e^{\frac{\Delta H_{ads} - \Delta H_{cond}}{RT}}$

$$\frac{n_{ad}}{n_m} = \frac{C \frac{p}{p^0}}{\left(1 - \frac{p}{p^0}\right) \left(1 + (C-1) \frac{p}{p^0}\right)}$$

BET (Brunauer, Emmett, Teller) Metod

- Modifikacija Langmirove izoterme
- Monoslojna i multislojna adsorpcija
- Slojevi adsorbovanih molekula se razlikuju po:
 - Prvi sloj se adsorbuje sa entalpijom adsorpcije $\Delta H_{ad,1}$
 - Drugi i sledeći slojevi se adsorbuju sa $H_{ad,2} = \Delta H_{cond}$

BET izoterma:

$$\frac{p}{n_{ad}(p^0 - p)} = \frac{1}{n_m C} + \frac{C-1}{n_m C} \cdot \frac{p}{p^0}$$

$$C = \exp\left(\frac{\Delta H_{ad} - \Delta H_{cond}}{RT}\right)$$

- BET jednačina ne fituje sve tipove adsorpcionih izotermi
 - Različiti mehanizmi igraju različitu ulogu pri niskim i visokim p

BET jednačina

p pritisak gasa

p° napon pare

V_m zapremina

monomolekulskog sloja

V je merena zapremina

adsorbovanog gasa

$$\frac{V}{V_m} = \frac{cX}{(1-x)[1+(c-1)x]}$$

$$\frac{x}{V(1-x)} = \frac{1}{cV_m} + \frac{(c-1)x}{cV_m},$$

$$x = p / p_o$$

1: Crta se $x / [V(1-x)]$ su f-ji od x

2: odrediti iz linernog dela grafika

odsečak $1 / (cV_m)$

nagib $(c-1) / (cV_m)$

3: izračunati c, V_m

$$V_m = 1 / (\text{nagib} + \text{odsečak})$$

V_m se koristi za određivanje specifične površine.

Specifična površina & Monomolekularna adsorpcija

Specifična površina
(m²/g)

Avogadrova
konstanta
(molekula/mol)

$$S = n_m A_m N$$

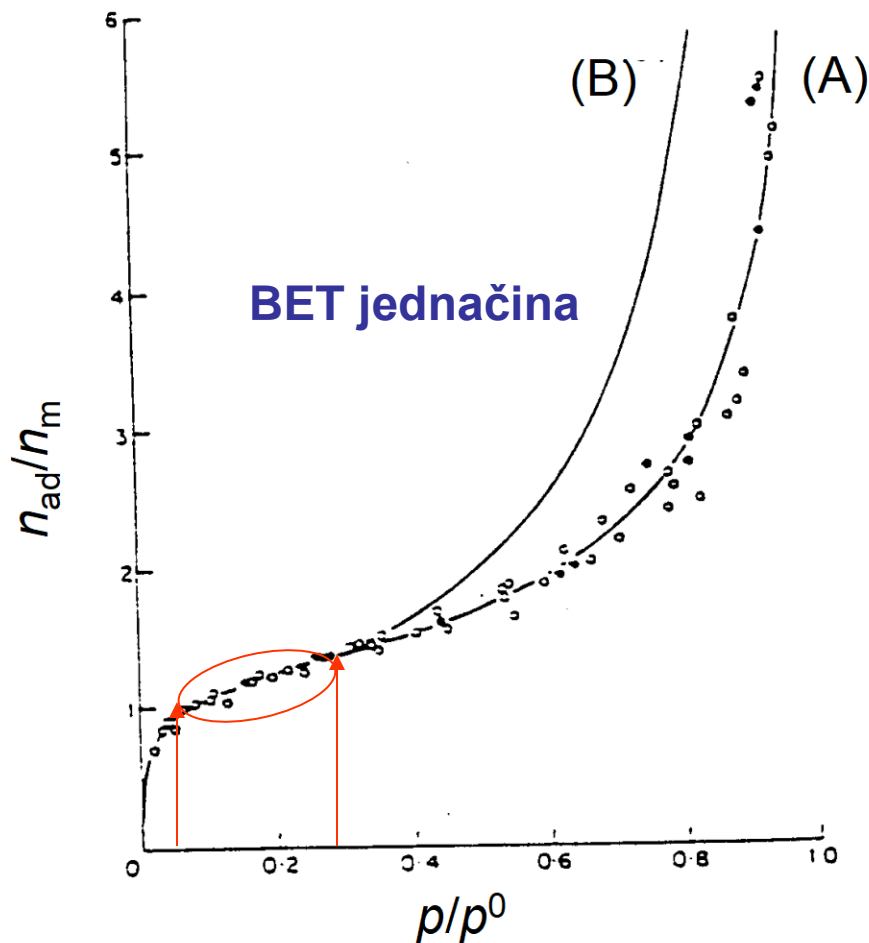
Monomolekulski
kapacitet (mol/g)

Površina koju zauzima
jedan molekul
(m²/molekulu)

BET model: S_{BET}

t model: S_t

Porozna silika i alumina



Nizak p/p_0 :

- ispunjavaju se mikropore
- favorizovano je popunjavanje najaktivnijih centara (heterogenost)

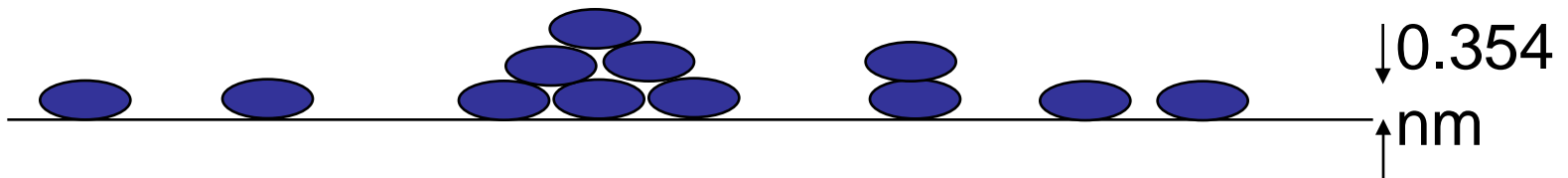
Visok p/p_0 :

- kapilarna kondenzacija

Opseg $0.05 < p/p_0 < 0.3$ se koristi za određivanje S_{BET}

t -metod

- **BET**
 - Važi samo u intervalu malih pritisaka only
 - Interpretacija nije laka
- **Debljina (t) adsorbovanog sloja se izračunava**



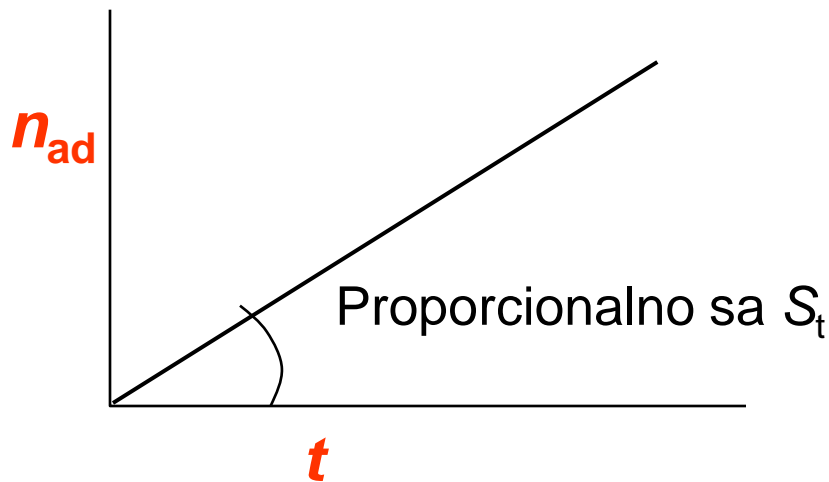
- **Grafik t u funkciji p za neporozne materijale ima vrednost površine**
- **t -grafik pomaže u interpretaciji rezultata**

t-metod

$$S_t = n_m \cdot A_m \cdot N$$

$$\Rightarrow S_t = \frac{n_{\text{ad}}}{t} \cdot 0.354 \cdot 10^{-9} \cdot A_m \cdot N$$

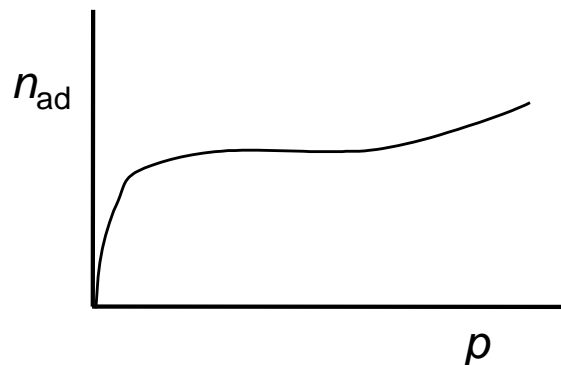
$$\Rightarrow S_t = 5.73 \cdot 10^{-6} \cdot \frac{n_{\text{ad}}}{t}$$



$$t = \frac{n_{\text{ad}}}{n_m} \cdot 0.354 \text{ nm}$$

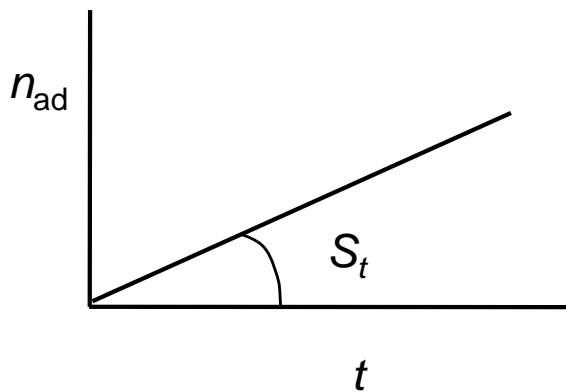
Oblik t-grafika

Adsorption isotherm

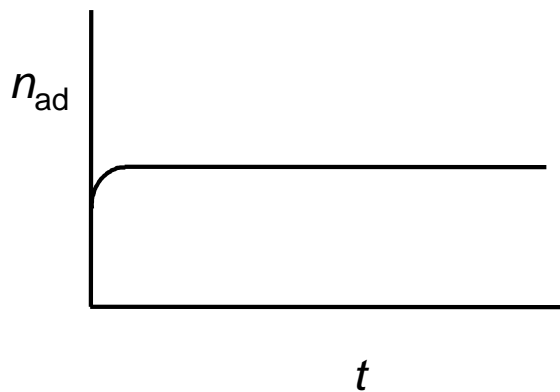


$$t = f(p) \quad \Downarrow$$

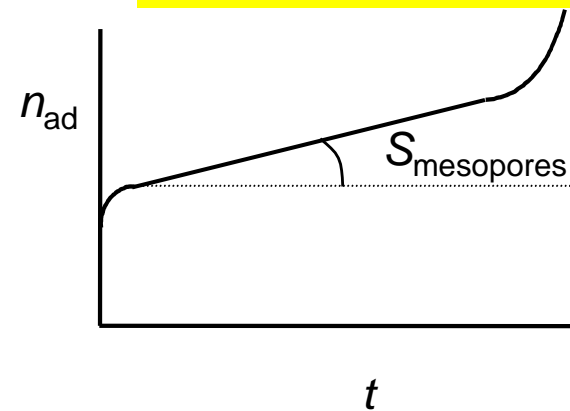
Non-porous



Microporous

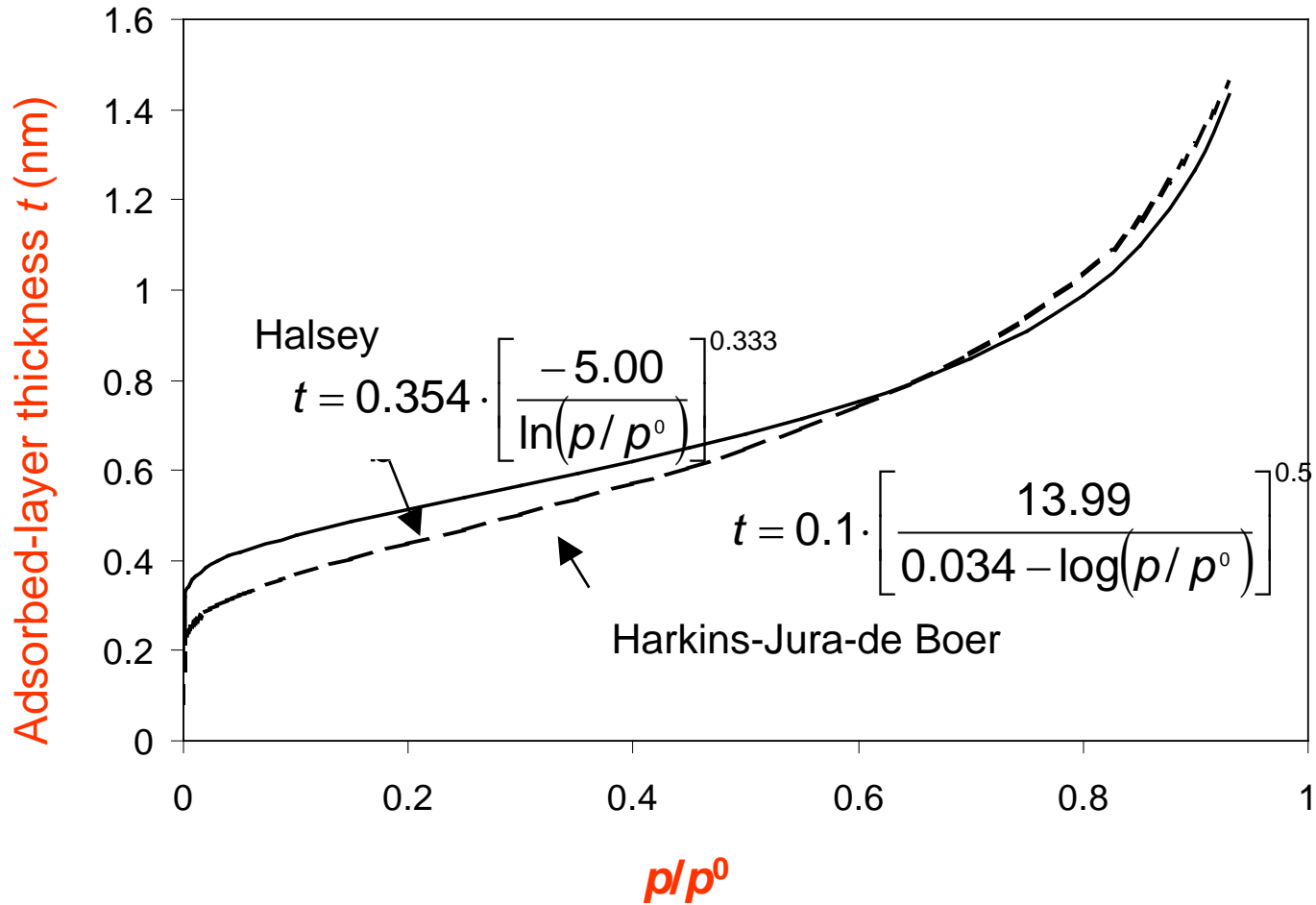


Micro- and mesoporous



$$t = \frac{n_{ad}}{n_m} \cdot 0.354 \text{ nm}$$

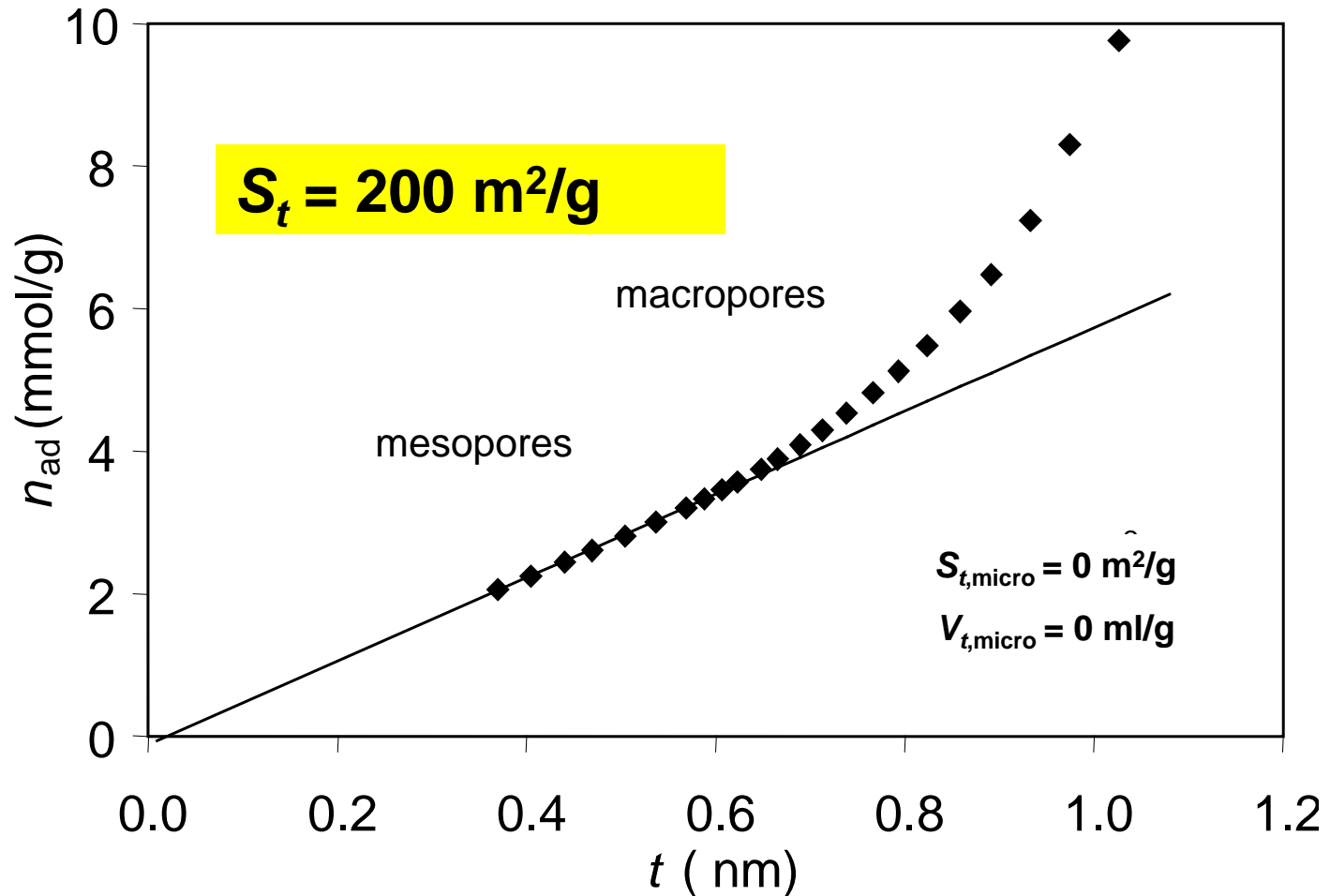
t -krive



Interpretacija t-krive

γ -alumina

$$t = \frac{n_{\text{ad}}}{n_{\text{m}}} \cdot 0.354 \text{ nm}$$



Zapremina mikropora

Adsorpciona izoterma tipa I ima horizontalni plato i daje kapacitet za adsorpciju u mikroporama n_p odakle se može izračunati zapremina mikropora V_p uz pretpostavku da se pore popunjavaju kondenzujući gas do normalnog tečnog stanja. (Gurivič, ref u IUPAC Tec. Rep).

Drugi veoma često korišćen metod je Dubinin Raduškevič jednačina.

Dubinin-Radushkevich jednačina: $V = V_o \exp(-b \varepsilon^2)$

V_o je zapremina pora a V , zapremina zauzeta pri datoj vrednosti p_o/p .

Gde ε_x predstavlja rad uložen da se savlada sila kojom adsorbent drži molekule adsorbata i da se molekul adsorbata nađe na rastojanju l od površine.

$$\varepsilon_x = RT \ln \frac{p_o}{p}$$

$$\ln V = \ln V_o - \left(\frac{RT}{E} \right)^2 \ln \left(\frac{p_o}{p} \right)$$

Zapremina mikropora

Raspodela veličine pora

Kelvinova jednačina za azot

$$\ln \frac{p}{p^0} = - \frac{2\gamma V_L}{RT} \frac{1}{r_m}$$

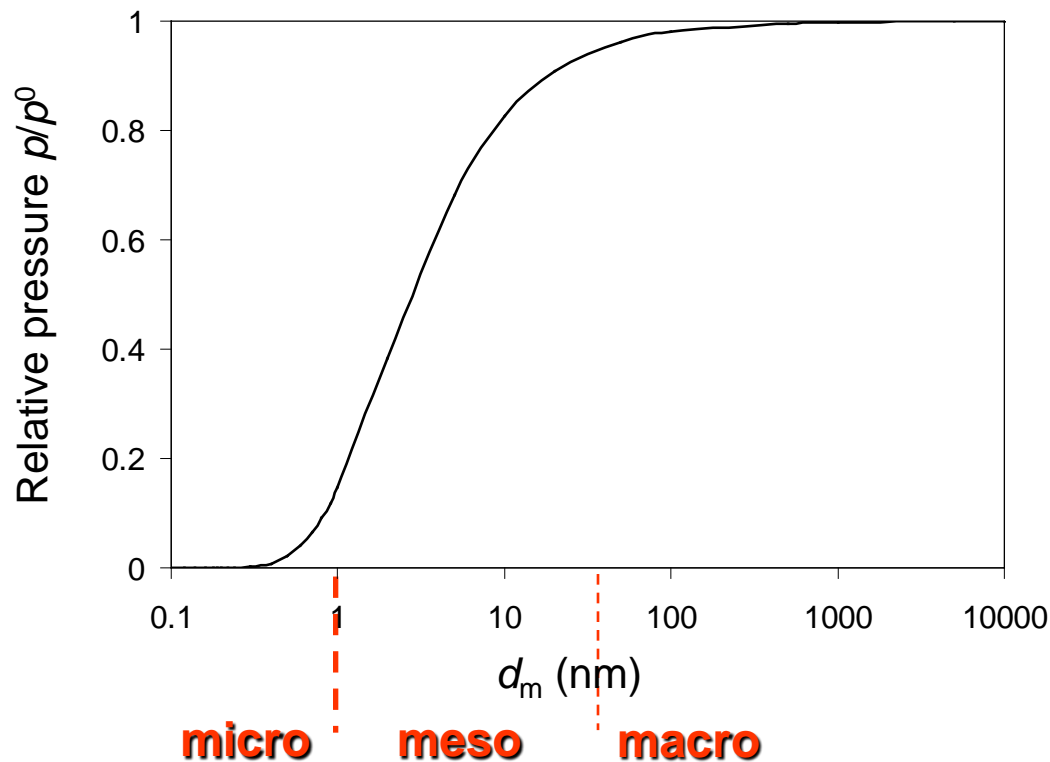
Model

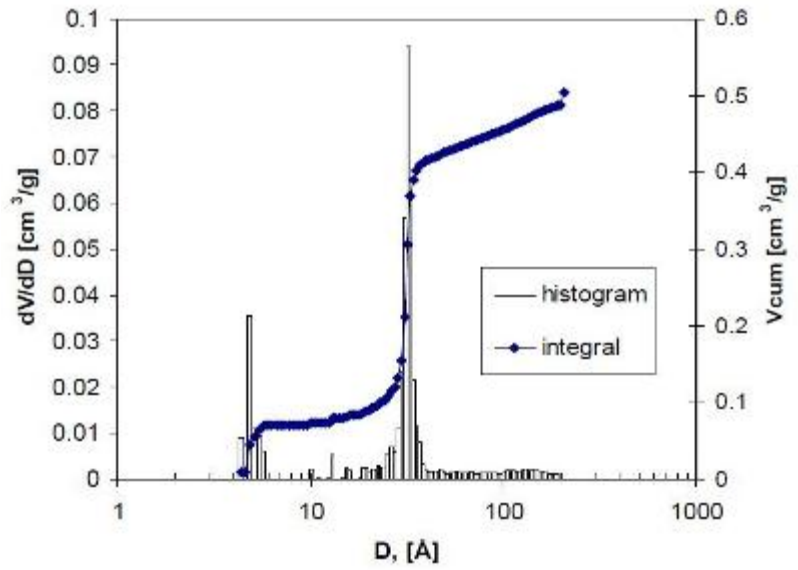
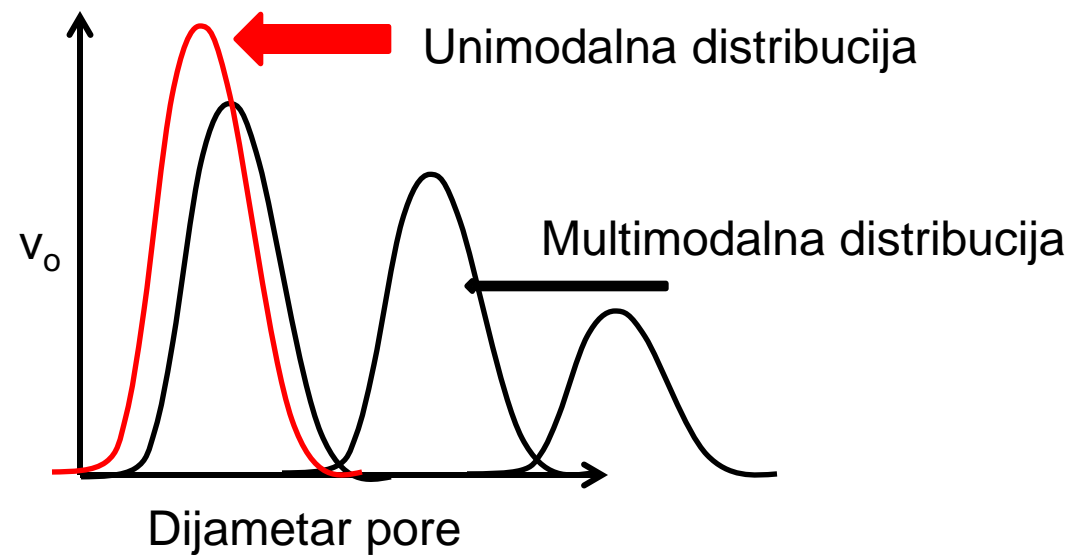
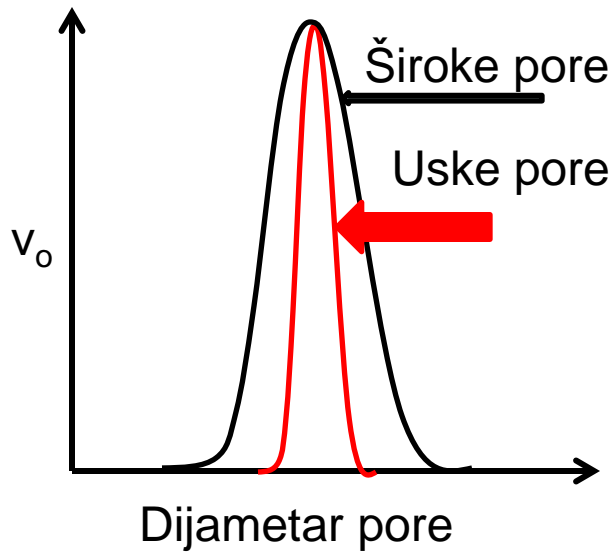
Kanali sa cilindričnim porama

$V_L = 34.68 \cdot 10^{-6} \text{ m}^3/\text{mol}$ molarna zapremina

$\gamma = 8.88 \text{ mN/m}$ površinski napon

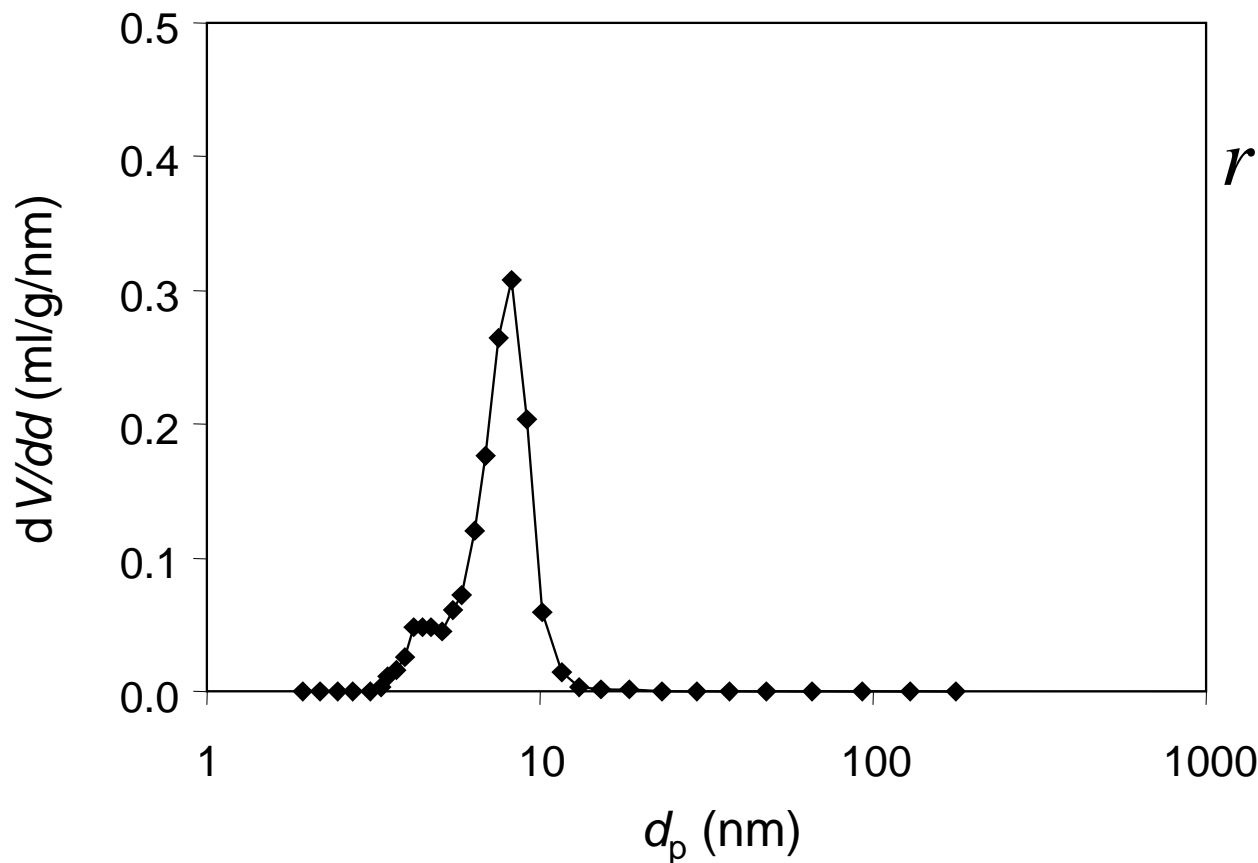
r radijus površine





Raspodela veličine pora γ -alumina

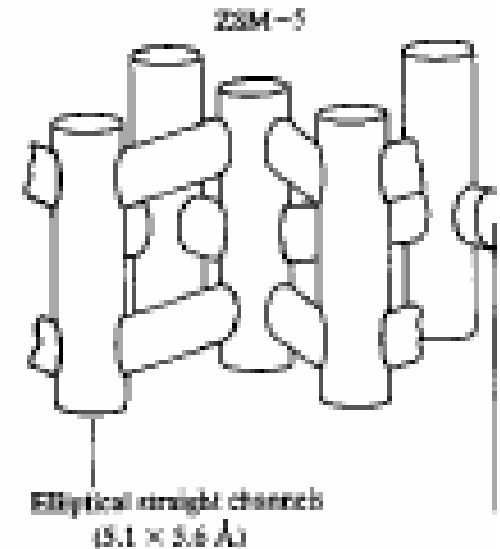
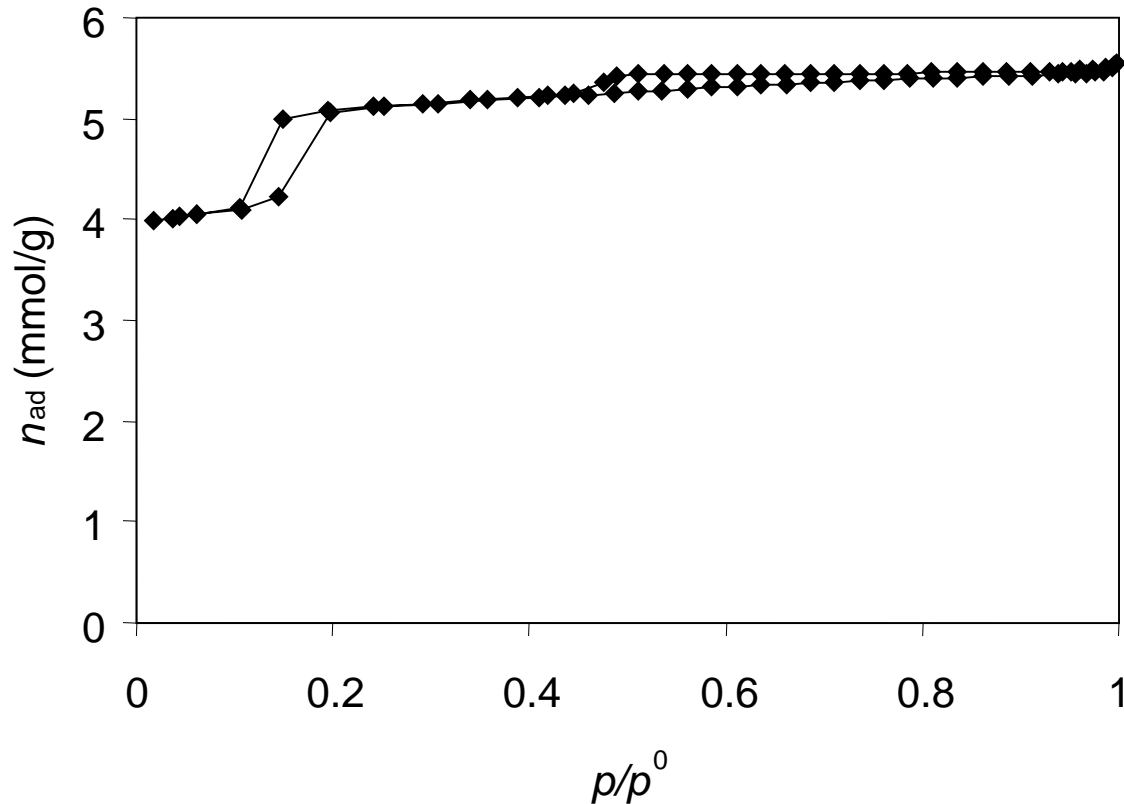
$$t = \frac{n_{\text{ad}}}{n_{\text{m}}} \cdot 0.354 \text{ nm}$$



$$r = t + \frac{2\gamma V}{RT \ln \frac{p^o}{p_o}}$$

$$\ln V = \ln V_o - \left(\frac{RT}{E} \right)^2 \ln \left(\frac{p_o}{p} \right)$$

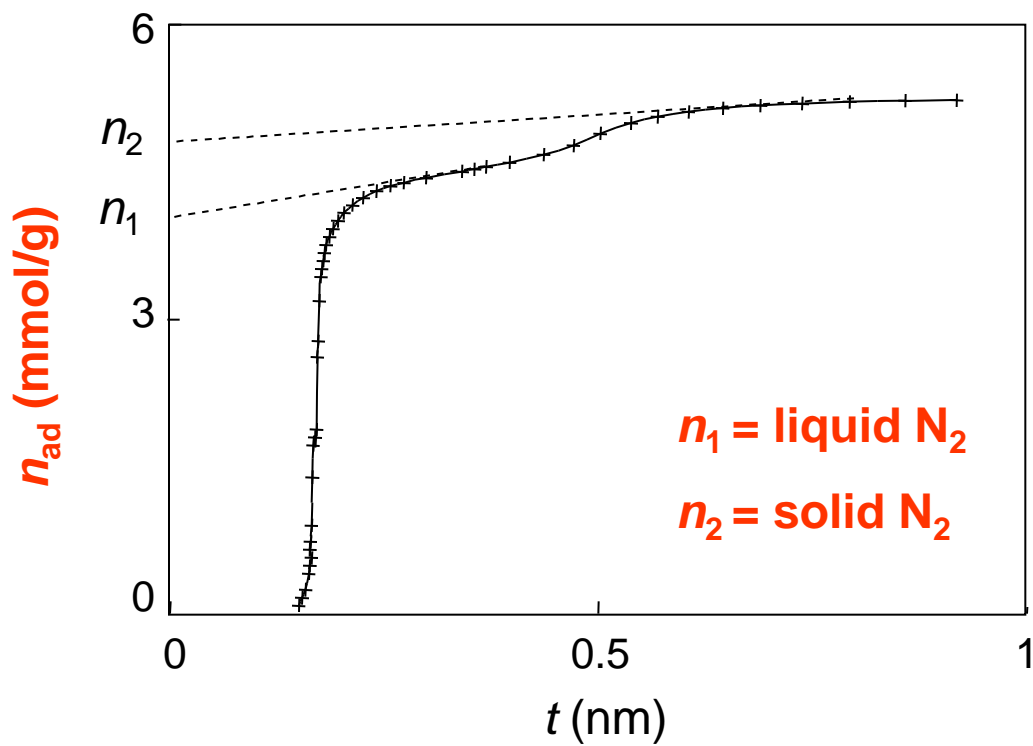
N₂ Adsorpciona izoterma na ZSM-5 zeolitu



Jaka adsorpcija pri niskom p zbog kondenzacije u mikroporama

Pri višim p dolazi do saturacije zbog konačne zapremine mikro pora

t -kriva fizisorpcije N_2 na ZSM-5 zeolitu



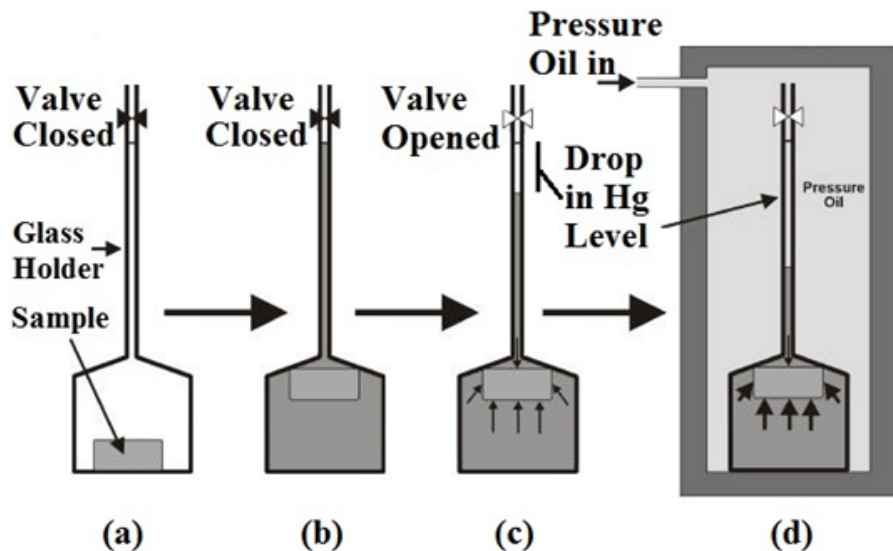
Živina porozimetrija

- Hg ne kvasi površine; potreban pritisak da bi se živa utisnula u pore

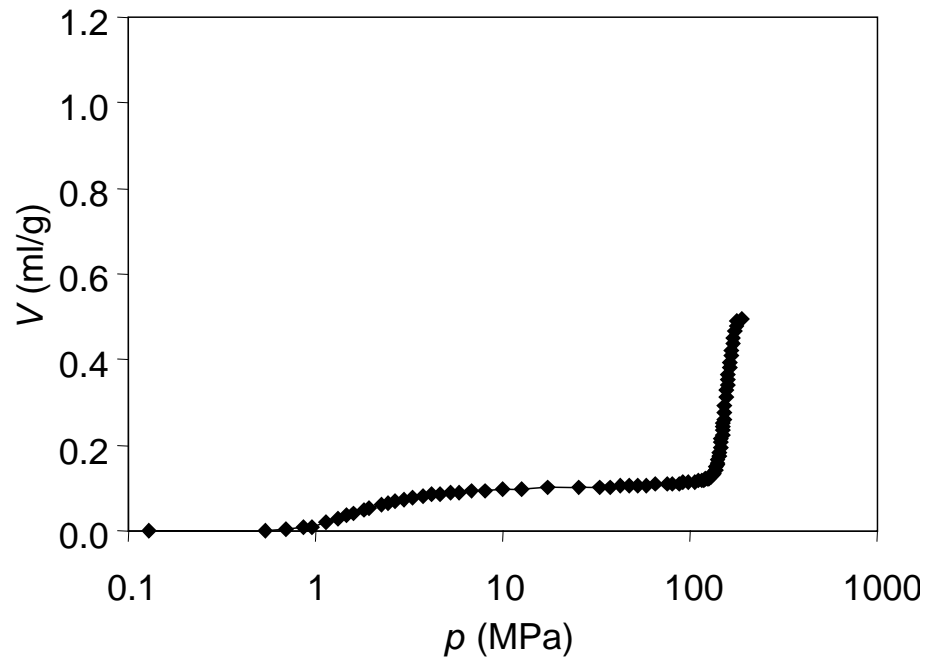
$$d_p = \frac{14860}{p}$$

(d u nm, p u bar-ima)

- Odgovarajući metod da se odredi zapremina i veličina pora



Hg porozimetrija na γ -alumini



Razlike između S_{Hg} i S_{BET} za mikroporozne materijale

- Hg ne može da prodre u male mikro pore, N_2 može
- Nepouzdana vrednosti kontaktnog ugla i vrednosti površinskog napona

Teksturalna svojstva komercijalnih katalizatora

Material	Mean d_p (nm)	S_{BET} (m ² /g)
Catalyst supports		
Silica gel	10	200
	6	400
	4	800
γ -Al ₂ O ₃	10	150
	5	500
Zeolite	0.6-2	400-800
Activated carbon	2	700-1200
TiO ₂	400-800	2-50
Aerosil SiO ₂	-	50-200
Catalysts		
MeOH synthesis (Cu/ZnO/Al ₂ O ₃)	20	80
NH ₃ synthesis (Fe/Al ₂ O ₃ /K ₂ O)	100	10
Reforming (Pt/Re/Al ₂ O ₃)	5	250
Epoxidation (Ag/ α -Al ₂ O ₃)	200	0.5

S_{Hg} i S_{BET}

Adsorbent	S_{Hg} m ² /g	S_{BET} m ² /g	θ deg
Iron Oxide	14.3	13.3	130
Tungsten Oxide	0.11	0.10	130
Anatase	15.1	10.3	130
Hydroxy Apatite	55.2	55.0	130
Carbon Black (Spheron-6)	107.8	110.0	130
0.5 % Ru/ γ -Al ₂ O ₃	237.0	229.0	140
0.5 % Pd/ γ -Al ₂ O ₃	115.0	112.0	140
TiO ₂ Powder	31.0	25.0	140
Sintered Silica Pellets	20.5	5.0	140
Zeolite H-ZSM-5	39.0	375.0	140
Norit Active Carbon R1 Extra	112.0	915.0	140

Teksturalna svojstva

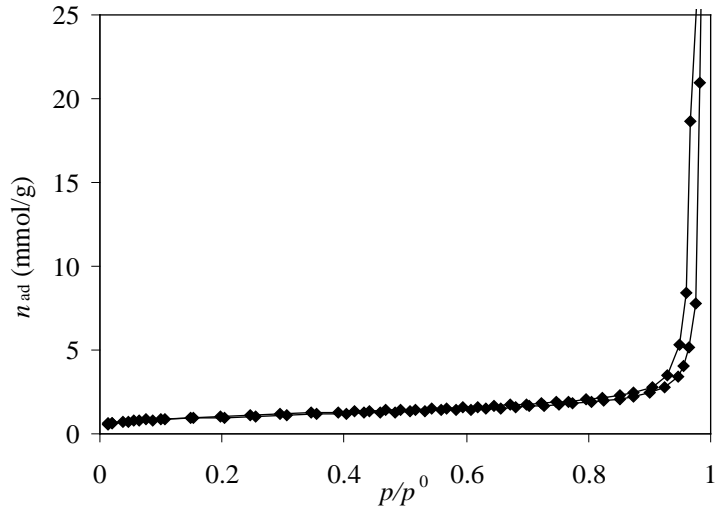
	N ₂ -physisorption				Hg-porosimetry		
	S_{BET}	S_t	V_p	d_p	S_{Hg}	V_p	d_p
	m ² /g	m ² /g	ml/g	nm	m ² /g	ml/g	nm
Wide Pore Silica	78	52	0.91	47	80	0.92	54
γ -Alumina	196	202	0.49	10	163	0.49	10
α -Alumina	9	8	0.12	112	12	0.48	150
Active Carbon	1057 ^a	28	0.51	2	0.6	0.46	106
Raney Ni	76	-	0.14	5.80	-	-	-
ZSM-5	345	344	0.19	0.58	11	1.1	820 ^b

^a p/p_0 range of 0.01-0.1 was used in the calculation.

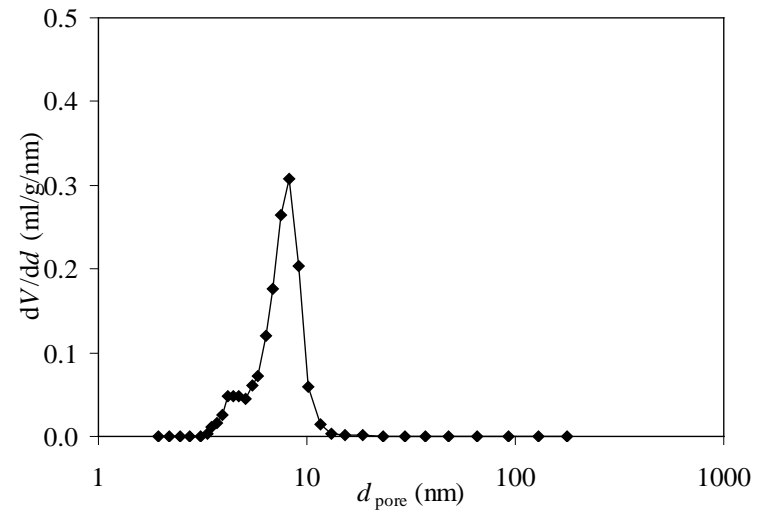
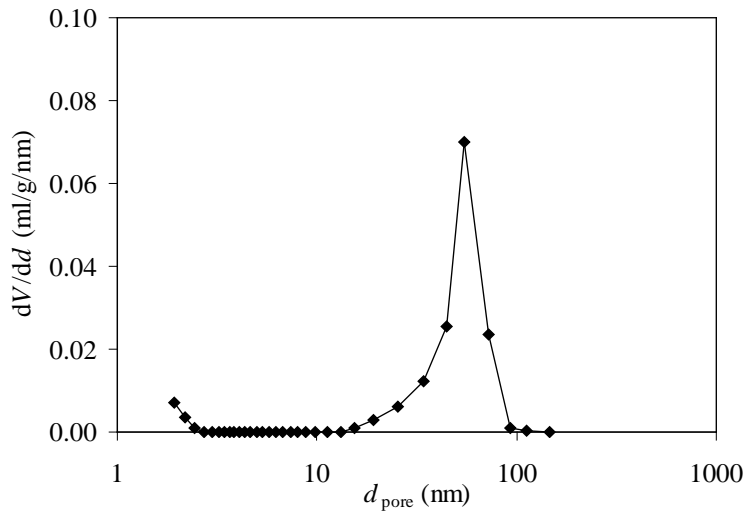
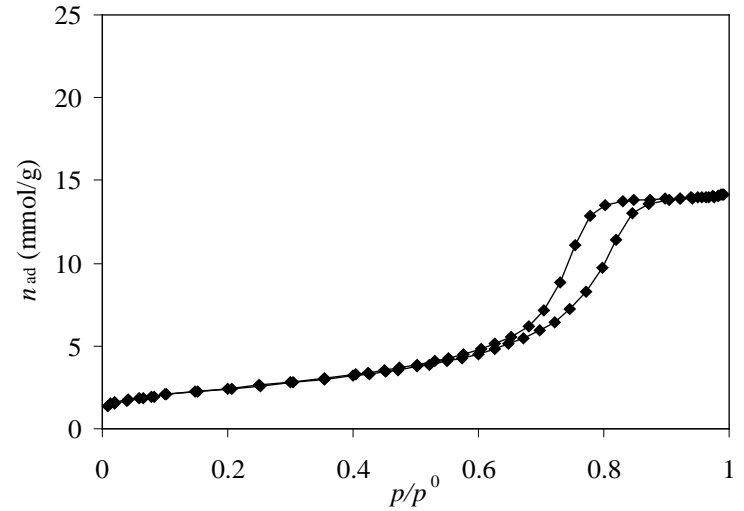
^b intraparticle voids.

N₂ adsorpcione izoterme & raspodela veličine pora

wide-pore silica

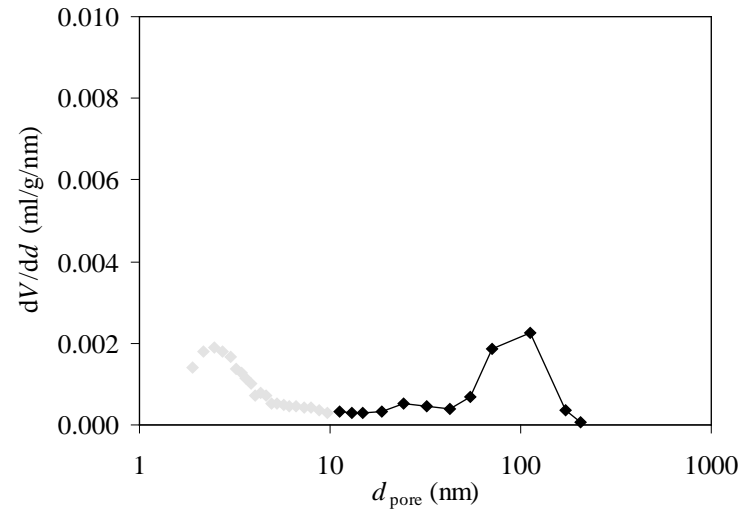
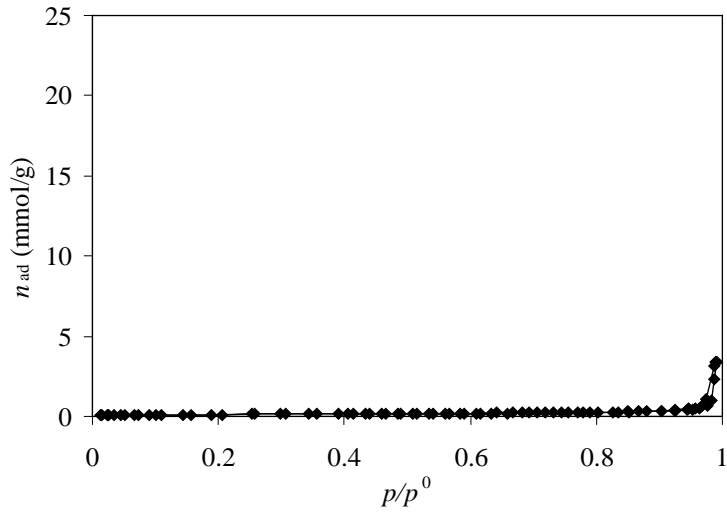


γ -alumina

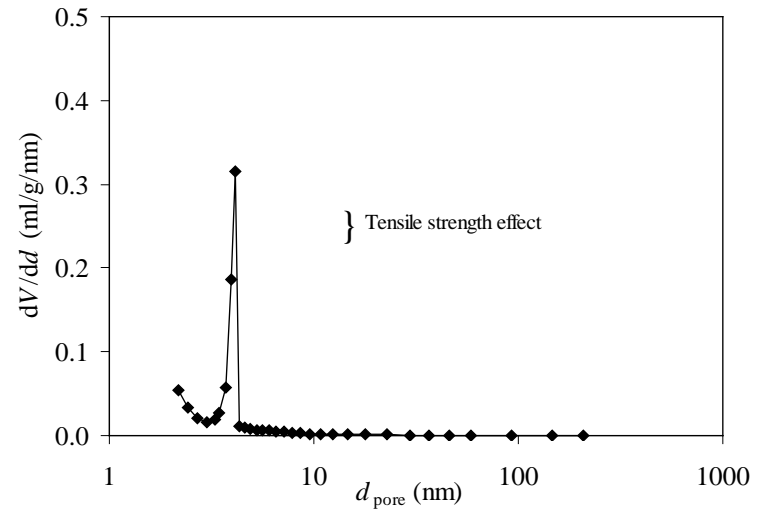
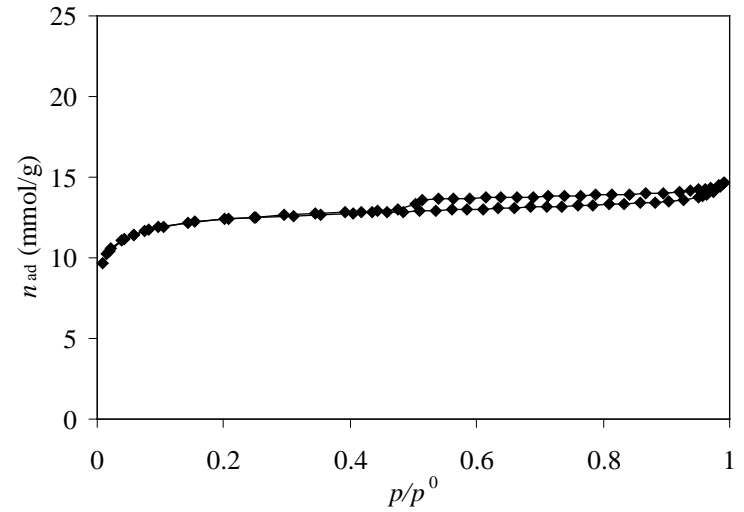


N₂ adsorpcione izoterme & raspodela veličine pora

α-alumina

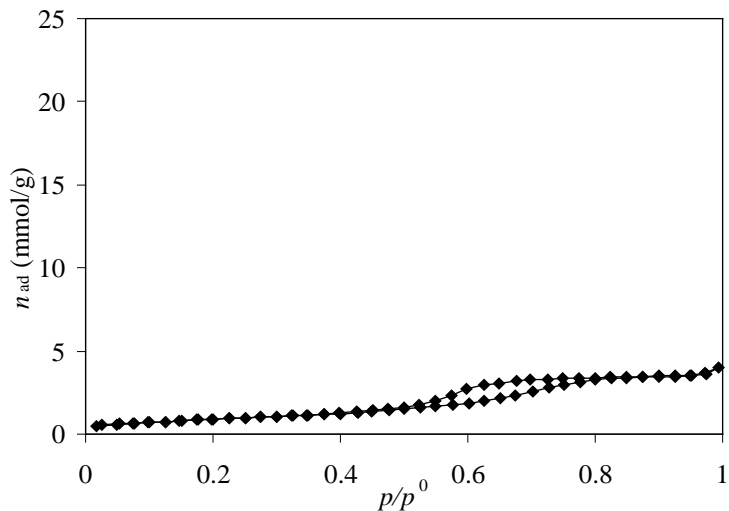


activated carbon

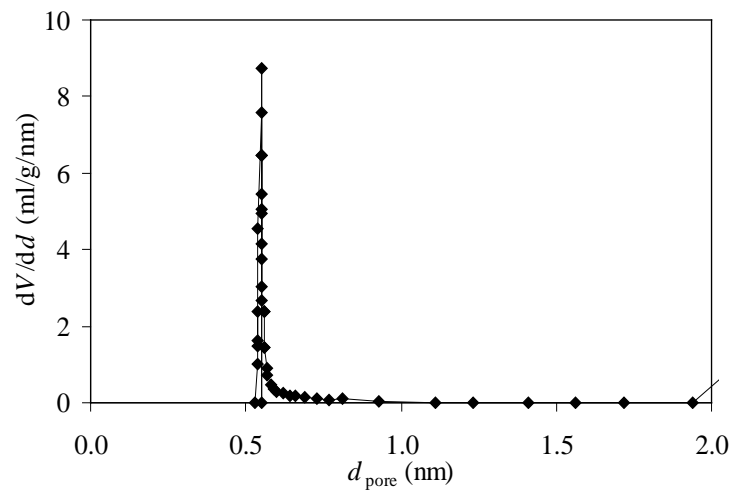
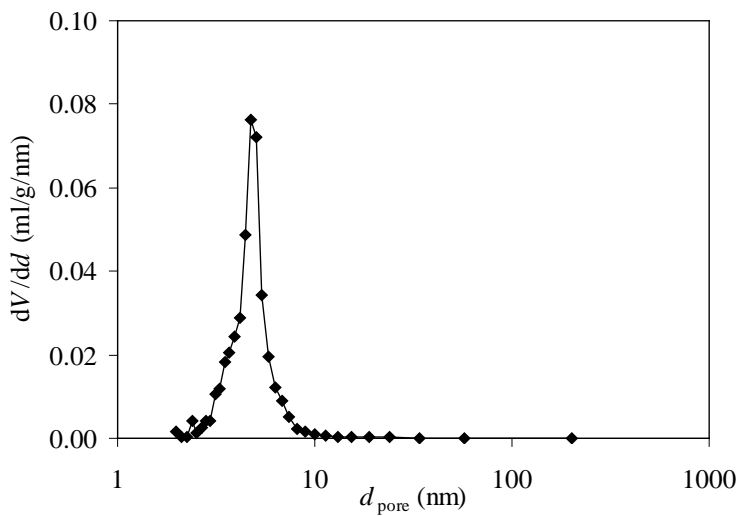
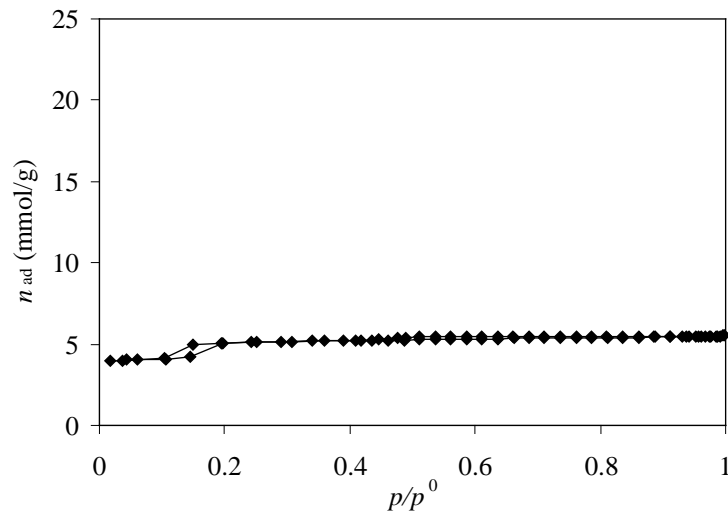


N₂ adsorpcione izoterme & raspodela veličine pora

Raney Ni

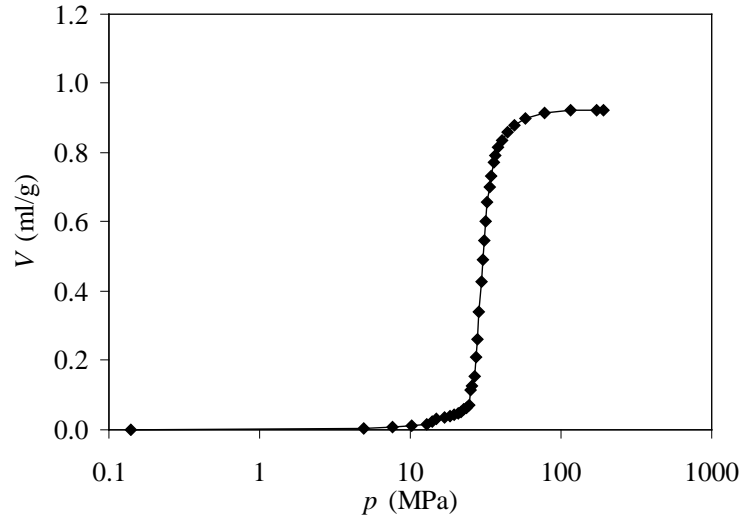


ZSM-5

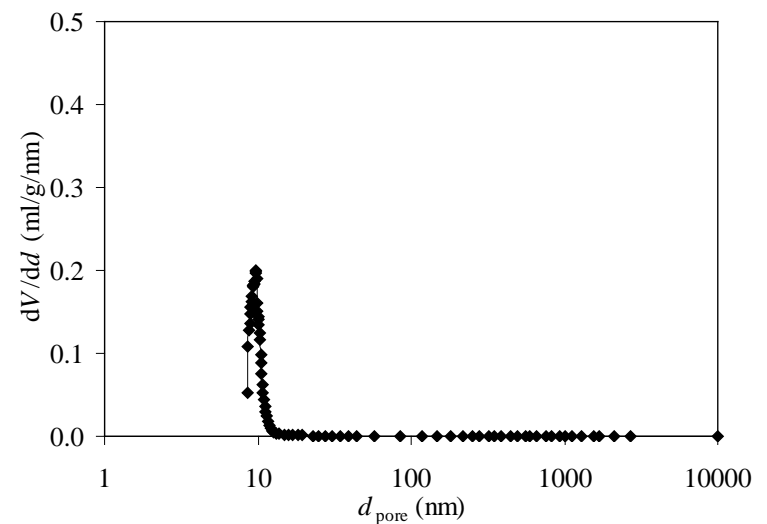
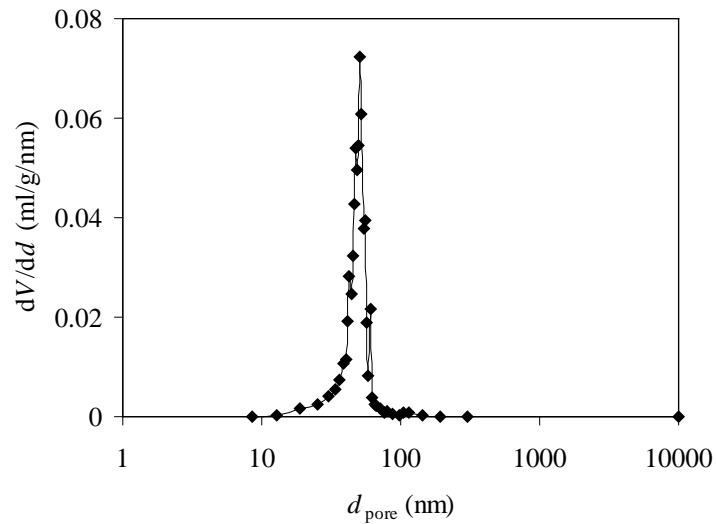
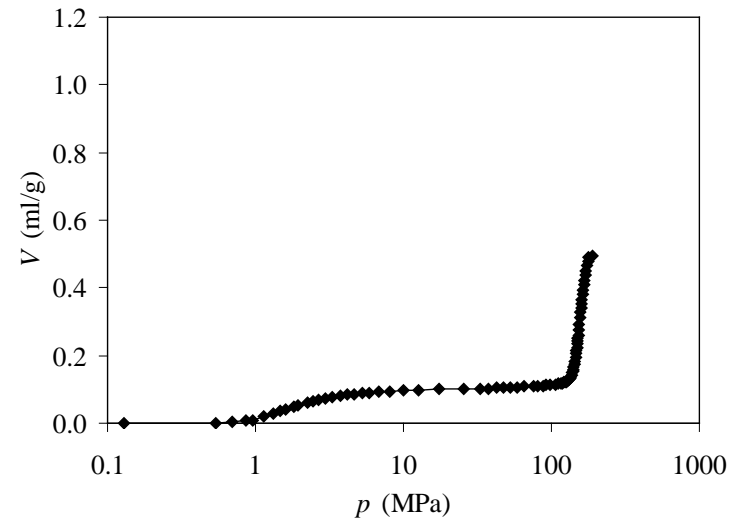


Hg porozimetrija & raspodela veličine pora

wide-pore silica

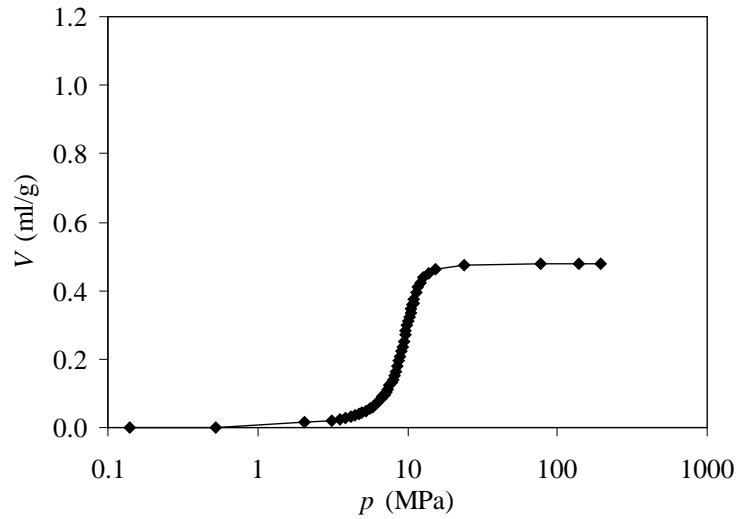


γ -alumina

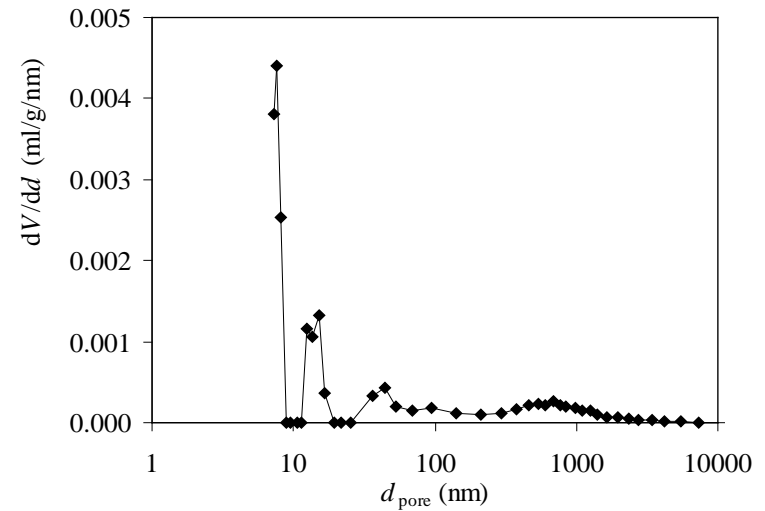
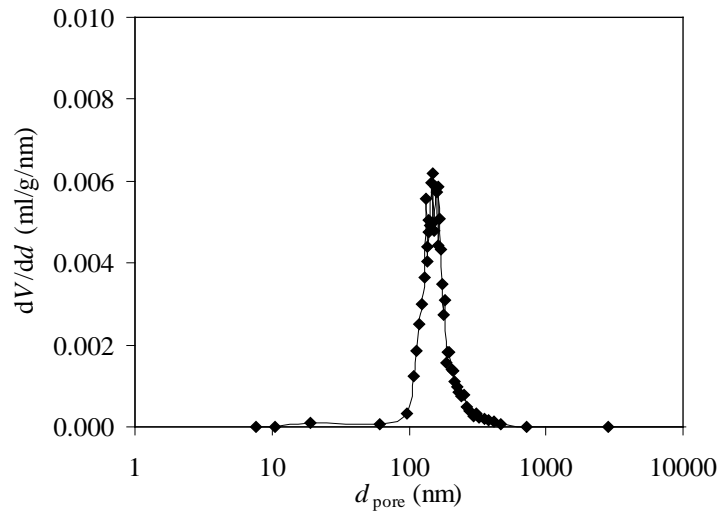
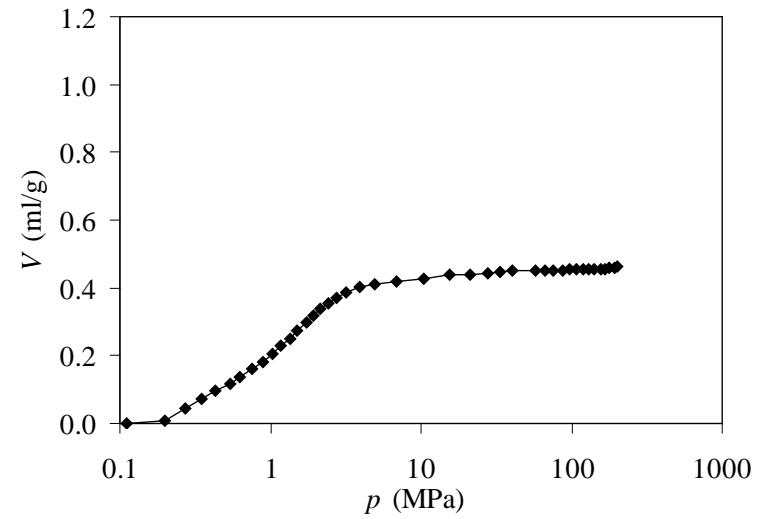


Hg porozimetrija & raspodela veličine pora

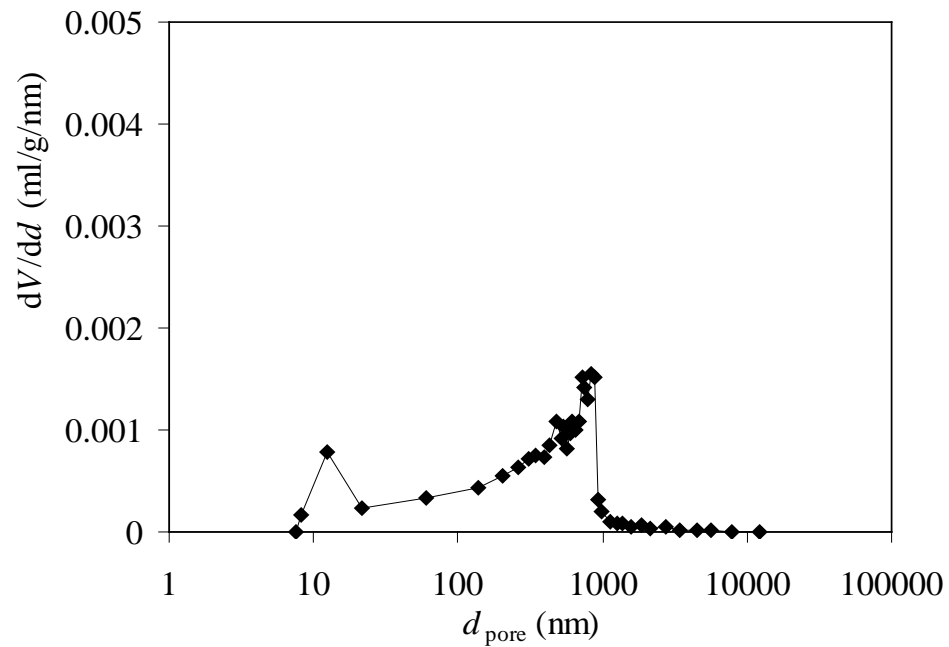
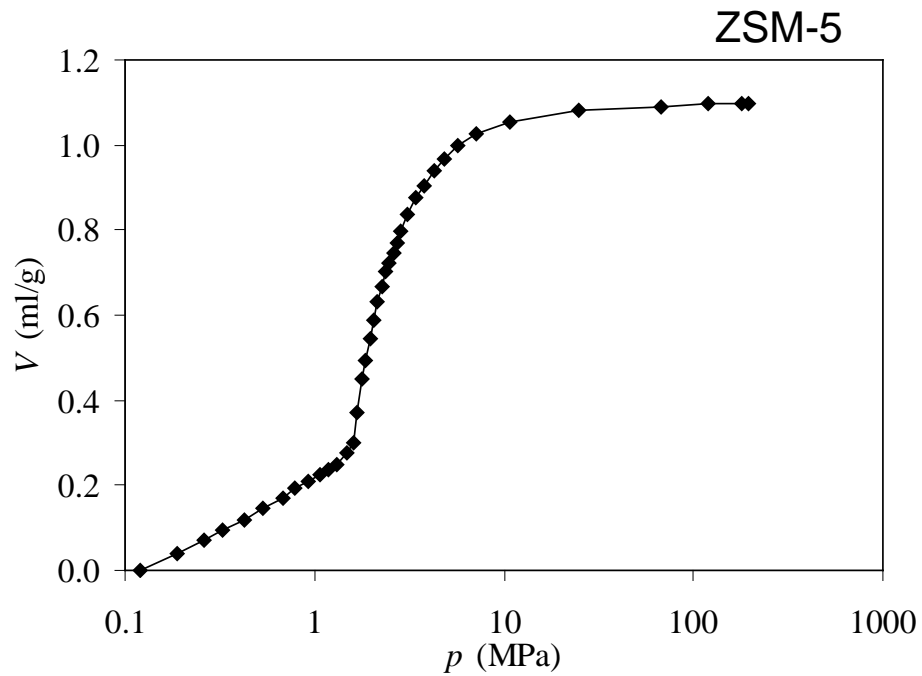
α -alumina



activated carbon

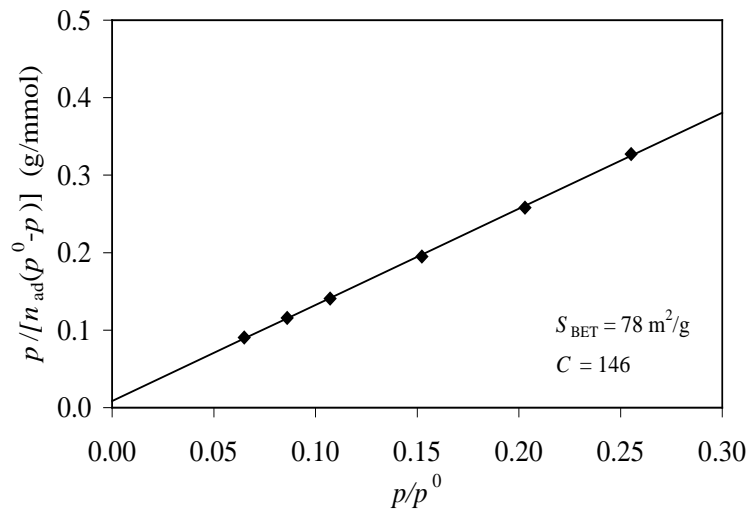


Hg porozimetrija & raspodela veličine pora

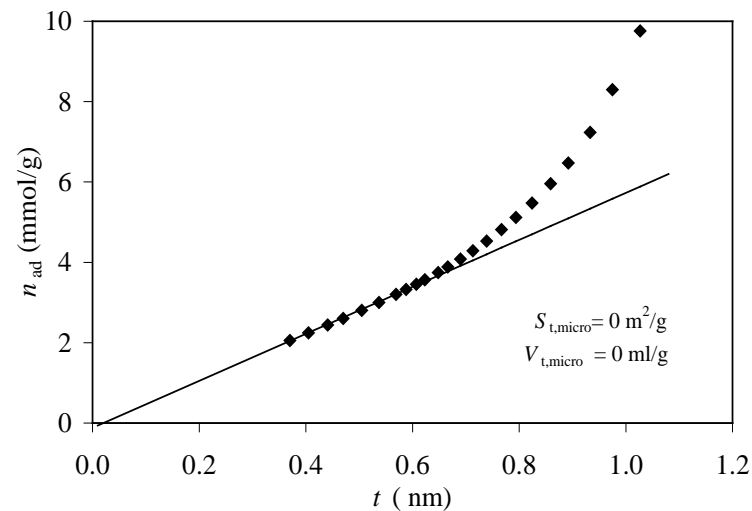
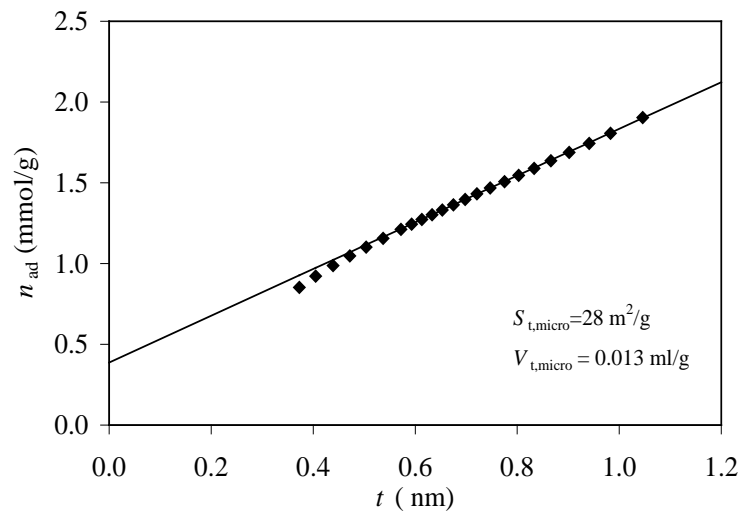
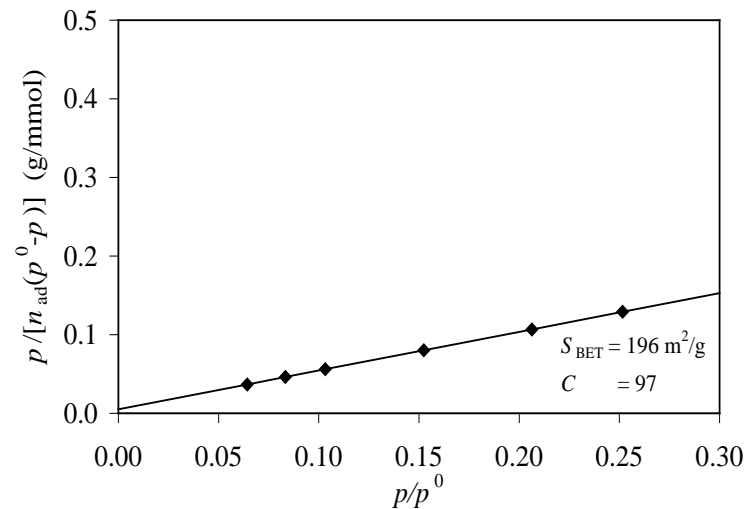


BET- & *t*-krive

wide-pore silica

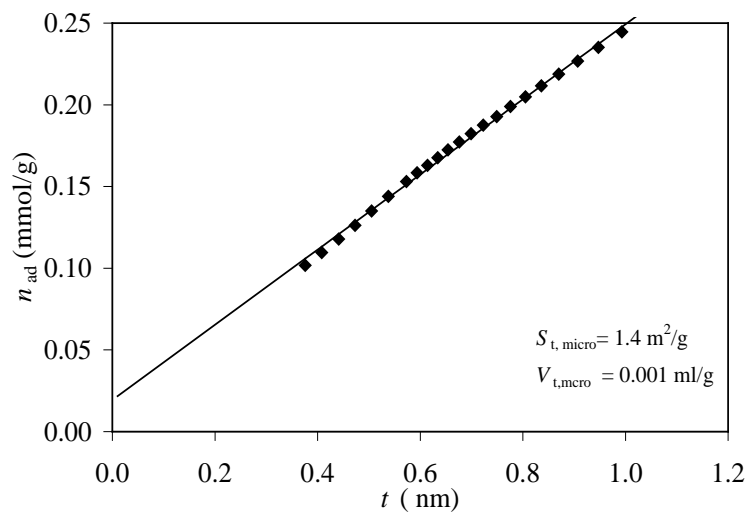
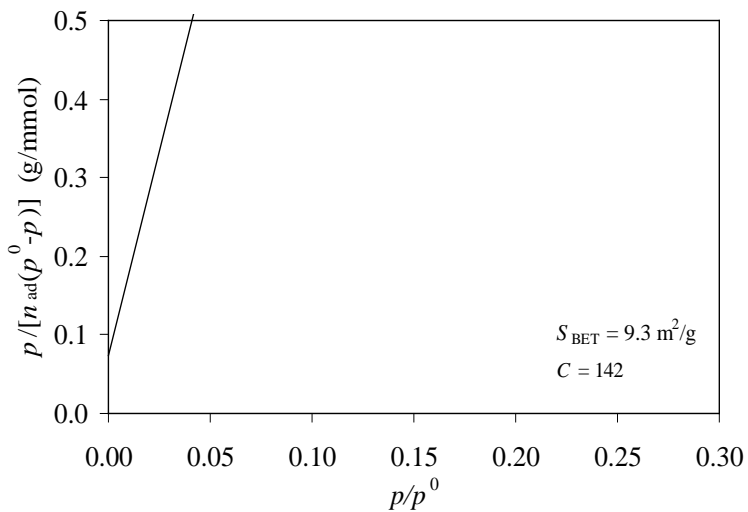


γ -alumina

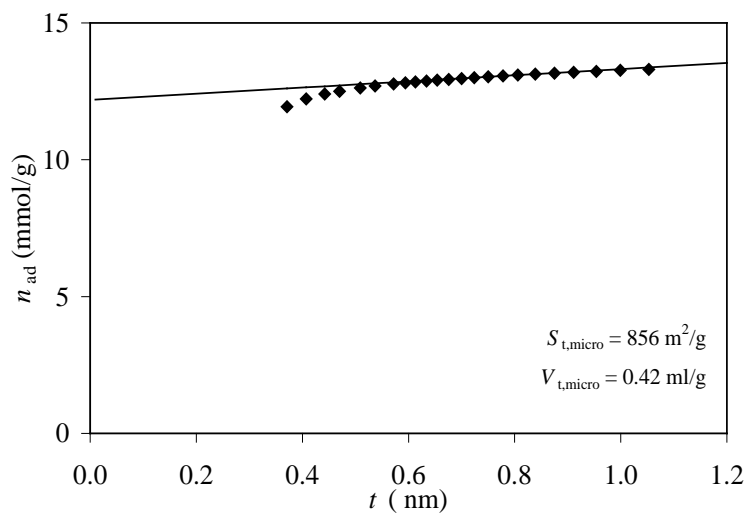
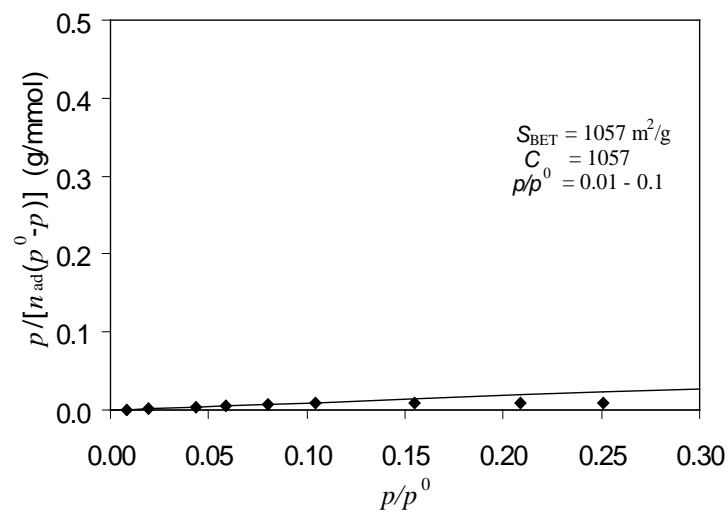


BET- & *t*-krive

α -alumina

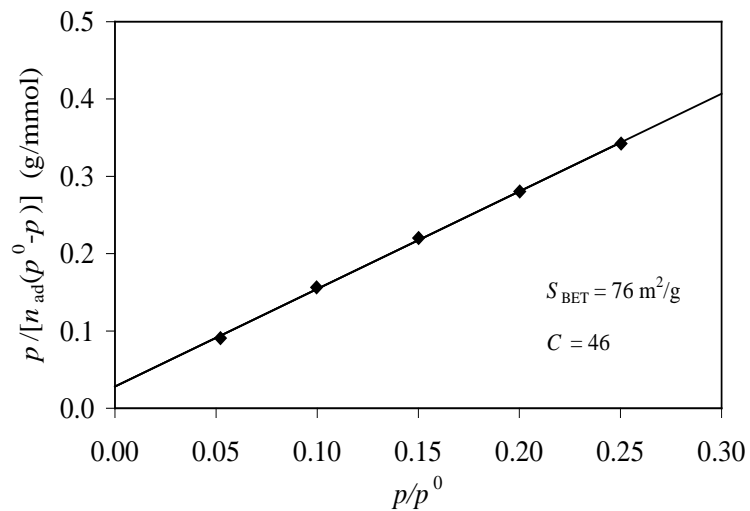


activated carbon

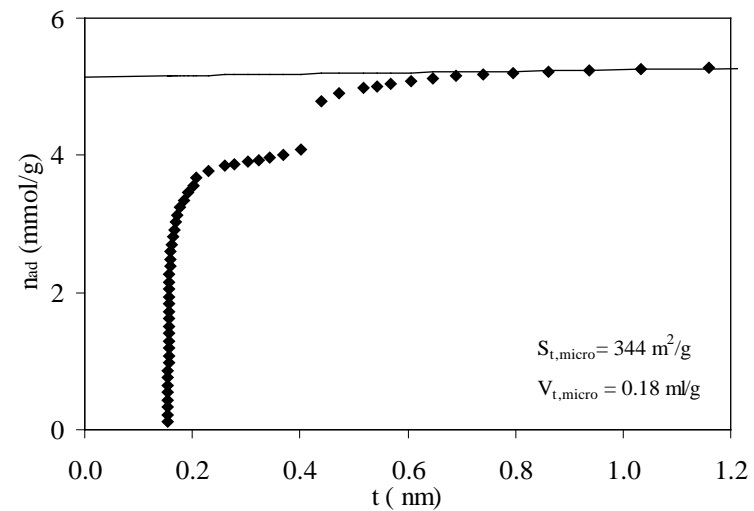
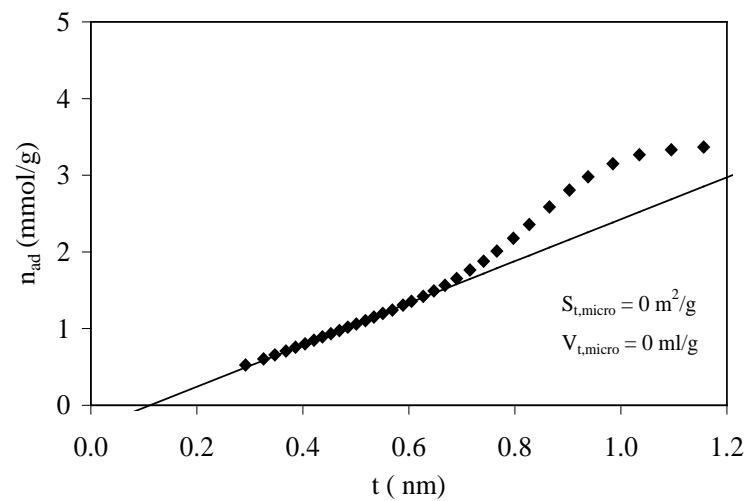
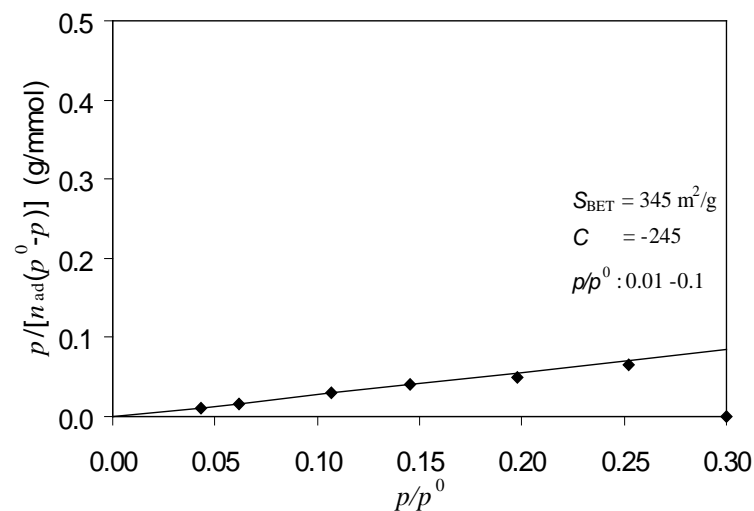


BET- & *t*-krive

Raney Ni



ZSM-5



Gas Purification

H₂O/olefin-containing cracked gas,

natural gas, air, synthesis gas, etc.

CO₂/C₂H₄, natural gas, etc.

Hydrocarbons, halogenated organics,

solvents/vent streams

Sulfur compounds/natural gas, hydrogen,

liquefied petroleum gas (LPG), etc.

SO₂/vent streams

Odors/air

Indoor air pollutants—VOCs

Tank-vent emissions/air or nitrogen

Hg/chlor-alkali cell gas effluent

Silica, alumina, zeolite (3A)

Zeolite, carbon molecular
sieve

Activated carbon, silicalite,
others

Zeolite, activated alumina

Zeolite, activated carbon

Silicalite, others

Activated carbon, silicalite,
resins

Activated carbon, silicalite

Zeolite

Liquid Purifications

H₂/organics, oxygenated organics,

halogenated organics, etc., dehydration

Silica, alumina, zeolite, corn grits

Organics, halogenated organics,

oxygenated organics, etc./H₂O—water purification

Activated carbon, silicalite, resins

Inorganics (As, Cd, Cr, Cu,

Se, Pb, F, Cl, radionuclides, etc.)/H₂O—water purification

Activated carbon

Odor and taste bodies/H₂O

Activated carbon

Sulfur compounds/organics

Zeolite, alumina, others

Decolorizing petroleum fractions, syrups, vegetable oils, etc.

Activated carbon

Various fermentation products/fermentor effluent

Activated carbon, affinity agents

Drug detoxification in the body

Activated carbon

Liquid Bulk Separations

Normal paraffins/isoparaffins, aromatics

Zeolite

p-xylene/*o*-xylene, *m*-xylene

Zeolite

Detergent-range olefins/paraffins

Zeolite

p-Diethyl benzene/isomer mixture

Zeolite

Fructose/glucose

Zeolite

Chromatographic analytical separations

Wide range of
inorganic, polymer,
and affinity agents

OBAVEŠTENJE

Mole se studenti da se do petka jave na:

maja@ffh.bg.ac.rs

da bi dobili dodatni materijal i zadatak