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APPENDICES

Appendix A CO_2 Adsorption Isotherms of AC Compared with AC Modified with Different Loadings of 30, 50, and 75 °C

Table A1 CO_2 adsorption isotherms of AC and AC modified with PEI with different loadings at 30 °C

Sample	Tempearture (°C)	Amount of Adsorbent (g)	P_{feed} (psi)	$N_{accuumulation}$ (mmol/g)
AC	30	1.0032	3.00	0.2794
			6.00	0.8381
			9.00	1.6240
			12.00	2.3634
			14.70	**3.5271**
0.04wt% PEI/AC	30	1.0043	3.00	0.2794
			6.00	0.7450
			9.00	1.1873
			12.00	1.6175
			14.70	**1.9837**
0.16wt% PEI/AC	30	1.0021	3.00	0.2794
			6.00	0.7561
			9.00	1.2218
			12.00	1.7572
			14.70	**2.2135**

Sample	Tempearture (°C)	Amount of Adsorbent (g)	P_{before} (psi)	$N_{accuumulation}$ (mmol/g)
0.18wt% PEI/AC	30	1.0021	3.00	0.2794
			6.00	0.7683
			9.00	1.2683
			12.00	1.9081
			14.70	**2.4602**
0.22wt% PEI/AC	30	1.0077	3.00	0.2794
			6.00	0.7859
			9.00	1.3391
			12.00	2.0841
			14.70	**2.6671**
0.25wt% PEI/AC	30	0.9988	3.00	0.2794
			6.00	0.7627
			9.00	1.2050
			12.00	1.5598
			14.70	**1.9327**
0.28wt% PEI/AC	30	0.9991	3.00	0.2794
			6.00	0.7450
			9.00	1.0821
			12.00	1.4024
			14.70	**1.6794**

Table A2 CO_2 adsorption isotherms of AC and AC modified with 0.22 wt% PEI loadings at 50 °C

Sample	Tempearture (°C)	Amount of Adsorbent (g)	P_{feed} (psi)	$N_{accuumulation}$ (mmol/g)
AC	50	1.0032	3.00	0.2621
			6.00	0.6936
			9.00	1.1085
			12.00	1.5235
			14.70	**2.0360**
0.22wt% PEI/AC	50	1.0077	3.00	0.2621
			6.00	0.7154
			9.00	1.2343
			12.00	1.9332
			14.70	**2.5356**

Table A3 CO_2 adsorption isotherms of AC and AC modified with PEI with different loadings at 75 °C

Sample	Tempearture (°C)	Amount of Adsorbent (g)	P_{feed} (psi)	$N_{accuumulation}$ (mmol/g)
AC	75	1.0011	3.00	0.2432
			6.00	0.5522
			9.00	0.8716
			12.00	1.1708
			14.70	**1.5422**
0.22wt% PEI/AC	75	1.009	3.00	0.2432
			6.00	0.6438
			9.00	1.1659
			12.00	1.7992
			14.70	**2.3792**
0.25wt% PEI/AC	75	1.0117	3.00	0.2432
			6.00	0.6535
			9.00	1.2105
			12.00	1.8640
			14.70	**2.4650**
0.28wt% PEI/AC	75	1.0034	3.00	0.2432
			6.00	0.6843
			9.00	1.2616
			12.00	2.0319
			14.70	**2.8414**

Sample	Tempearture (°C)	Amount of Adsorbent (g)	P_{feed} (psi)	$N_{accuumulation}$ (mmol/g)
0.31wt% PEI/AC	75	1.0121	3.00	0.2432
			6.00	0.5878
			9.00	0.9478
			12.00	1.4343
			14.70	**1.9100**
0.35wt% PEI/AC	75	1.0098	3.00	0.2432
			6.00	0.4759
			9.00	0.6738
			12.00	0.9016
			14.70	**1.1637**

Appendix B CO_2 Adsorption Isotherms of AC and AC Modified with the Optimum PEI Loading Compared with Different Temperatures

Table B1 CO_2 adsorption isotherms of AC at 30, 50, and 75 °C

Sample	Tempearture (°C)	Amount of Adsorbent (g)	P_{feed} (psi)	$N_{accuumulation}$ (mmol/g)
AC	30	1.0032	3.00	0.2794
			6.00	0.8381
			9.00	1.6240
			12.00	2.3634
			14.70	**3.5271**
AC	50	1.0032	3.00	0.2621
			6.00	0.6936
			9.00	1.1085
			12.00	1.5235
			14.70	**2.0360**
AC	75	1.0011	3.00	0.2432
			6.00	0.5522
			9.00	0.8716
			12.00	1.1708
			14.70	**1.5422**

Table B2 CO_2 adsorption isotherms of AC modified with PEI at 30, 50, and 75 °C

Sample	Tempearture (°C)	Amount of Adsorbent (g)	P_{feed} (psi)	$N_{accuumulation}$ (mmol/g)
0.22wt% PEI/AC	30	1.0077	3.00	0.2794
			6.00	0.7859
			9.00	1.3391
			12.00	2.0841
			14.70	**2.6671**
0.22wt% PEI/AC	50	1.0077	3.00	0.2621
			6.00	0.7154
			9.00	1.2343
			12.00	1.9332
			14.70	**2.5356**
0.22wt% PEI/AC	75	1.0030	3.00	0.2432
			6.00	0.6438
			9.00	1.1659
			12.00	1.7992
			14.70	**2.3792**

Appendix C CO_2 Adsorption Isotherms in Three Times of the Adsorption-Desorption Cycles over AC Modified with the Optimum PEI Loadings at 30, 75 °C

Table C1 CO_2 adsorption isotherms in three times of the adsorption-desorption cycles over AC modified with 0.28 wt% PEI at 75 °C

Sample	Tempearture (°C)	Amount of Adsorbent (g)	P_{feed} (psi)	$N_{accuumulation}$ (mmol/g)
0.28wt% PEI/AC	75	1.0077	3.00	0.2432
			6.00	0.6843
			9.00	1.2616
			12.00	2.0319
			14.70	**2.8414**
0.28wt% PEI/AC	75	1.0367	3.00	0.2432
			6.00	0.5724
			9.00	0.9778
			12.00	1.3832
			14.70	**1.8590**
0.28wt% PEI/AC	75	1.0455	3.00	0.2432
			6.00	0.5424
			9.00	0.9073
			12.00	1.2519
			14.70	**1.7001**

Table C2 CO_2 adsorption isotherms in three times of the adsorption-desorption cycles over AC modified with 0.22 wt% PEI at 30 °C

Sample	Tempearture (°C)	Amount of Adsorbent (g)	P_{feed} (psi)	$N_{accuumulation}$ (mmol/g)
0.22wt% PEI/AC	30	0.9767	3.00	0.2794
			6.00	0.8381
			9.00	1.5775
			12.00	2.2116
			14.70	**2.6257**
0.22wt% PEI/AC	30	1.0067	3.00	0.2794
			6.00	0.7859
			9.00	1.4490
			12.00	1.9667
			14.70	**2.3156**
0.22wt% PEI/AC	30	1.0089	3.00	0.2794
			6.00	0.7683
			9.00	1.4145
			12.00	1.9267
			14.70	**2.2689**

Appendix D Calculation for CO_2 Adsorption Capacity in Unit of mmol/g of Adsorbent

From; $$PV = ZnRT$$

Properties of CO_2 (Daubert *et al.*, 1982)

Critical Temperature (T_r) = 31.04 °C (304.2 K)

Critical Pressure (P_r) = 72.8 atm (7382 kPa)

Acentric Factor (ω) = 0.2276

Step 1: To find pressure reduced (Pr)

Data:

Pressure feed (P_1)= 3 psi (0.204 atm), Pressure remained (P_{11})= 0 psi (0 atm)

Pressure feed (P_2)= 6 psi (0.408 atm), Pressure remained (P_{22})= 0.56 psi (0.038 atm)

Pressure feed (P_3)= 9 psi (0.612 atm), Pressure remained (P_{33})= 3.06 psi (0.208 atm)

Pressure feed (P_4)= 12 psi (0.816 atm), Pressure remained (P_{44})= 4 psi (0.272 atm)

Pressure feed (P_5)= 14.7 psi (1 atm), Pressure remained (P_{55})= 8.56 psi (0.582 atm)

Solution;

$$P_r = \frac{P}{P_C}$$

$$P_{r1} = \frac{P}{P_C} = \frac{P_1 - P_{11}}{P_c} = \frac{0.204 - 0\ atm}{72.8\ atm} = 0.0028$$

$$P_{r2} = 0.0051,\ P_{r3} = 0.0056,\ P_{r4} = 0.0075,\ P_{r5} = 0.0057$$

Step 2: To find temperature reduced (T_r)

Data: Temperature adsorption = 30 °C (303 K)

Solution;

$$T_r = \frac{T}{T_c}$$

$$T_r = \frac{T}{T_c} = \frac{303\ K}{304.2\ K} \sim 1$$

Step 3: To find compressibility factor (Z)

Data: $P_{r1} = 0.0028$, $P_{r2} = 0.0051$, $P_{r3} = 0.0056$, $P_{r4} = 0.0075$, $P_{r5} = 0.0057$

$T_r = 1$

From Figure D1, Compressibility factor (Z_1) = 1.00

Compressibility factor (Z_2) = 0.99

Compressibility factor (Z_3) = 0.99

Compressibility factor (Z_4) = 0.98

Compressibility factor (Z_5) = 0.99

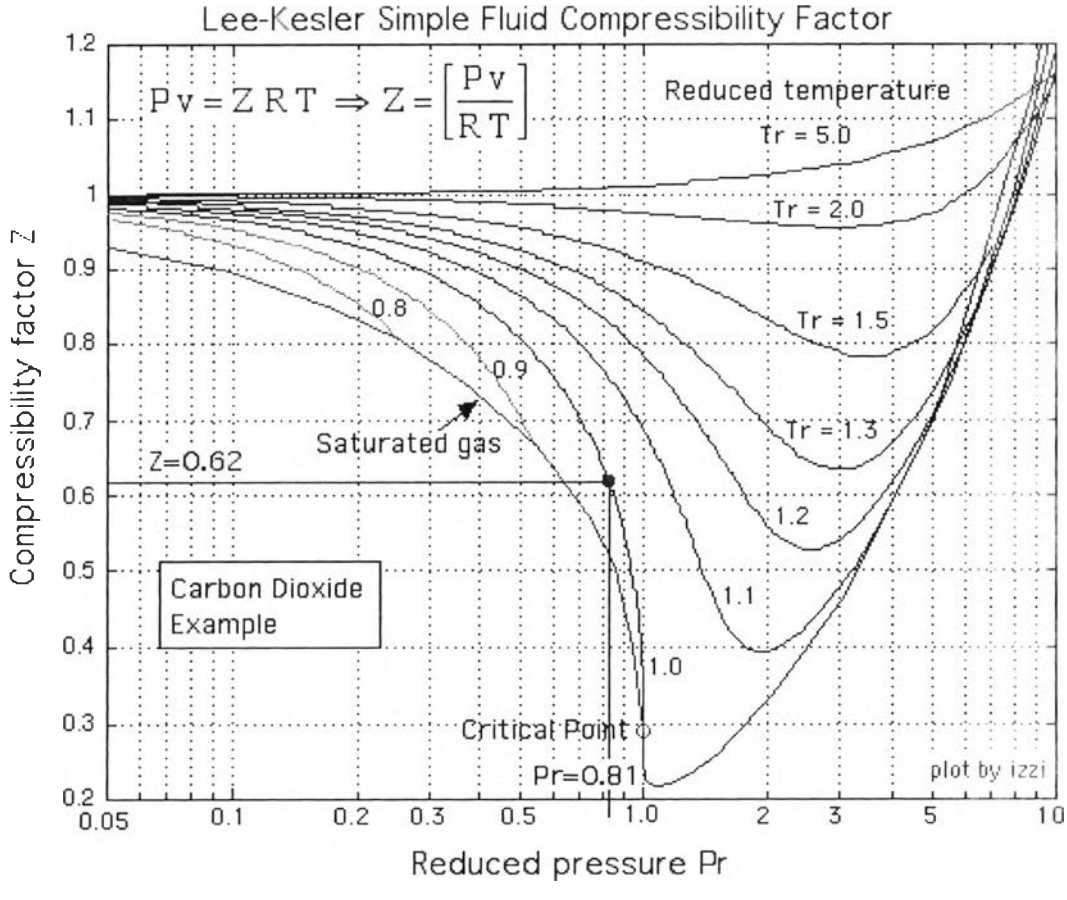

Figure D1 Relationship between the reduced pressure and reduced temperature related on compressibility factor (Urieli, 2011).

Step 4: To find CO_2 adsorption capacity (mmol/g)

Data:

Pressure feed (P_1)= 3 psi (0.204 atm), Pressure remained (P_{11})= 0 psi (0 atm)

Pressure feed (P_2)= 6 psi (0.408 atm), Pressure remained (P_{22})= 0.56 psi (0.038 atm)

Pressure feed (P_3)= 9 psi (0.612 atm), Pressure remained (P_{33})= 3.06 psi (0.208 atm)

Pressure feed (P_4)= 12 psi (0.816 atm), Pressure remained (P_{44})= 4 psi (0.272 atm)

Pressure feed (P_5)= 14.7 psi (1 atm), Pressure remained (P_{55})= 8.56 psi (0.582 atm)

Temperature adsorption = 30 °C (303 K)

Volume of reactor = 34.032 cm^3

R = 82.05 cm^3*atm/mol/K

Compressibility factor (Z_1) = 1.00

Compressibility factor (Z_2) = 0.99

Compressibility factor (Z_3) = 0.99

Compressibility factor (Z_4) = 0.98

Compressibility factor (Z_5) = 0.99

Solution;

$$n_1 = \frac{PV}{Z_1 RT} = \frac{(0.204 - 0\ atm)(34.032\ cm^3)}{(1.00)(82.05\ \frac{cm^3 \times atm}{mole \times K})(303K)} = 0.000279\ mol$$

$$n_1 = \frac{0.000279\ mol}{1.0077g\ of\ adsorbent} \times \frac{1{,}000\ mmol}{1\ mol} = 0.2771\ mmol/g$$

$n_1 = 0.2771\ mmol/g,$ $n_2 = 0.5077\ mmol/g,$ $n_3 = 0.5543\ mmol/g,$

$n_4 = 0.754\ mmol/g,$ $n_5 = 0.574\ mmol/g$

So, $N_{accumulation} = n_1+n_2+n_3+n_4+n_5$ = 2.6671 mmol/g

Appendix E Calculation the PEI-Impregnated on the AC

From; $$q_e = (C_0 - C_e)\frac{V_{PEI\ solution}}{m_{adsorbent}}$$

Properties of PEI 50 wt% in H_2O (Sigma Aldrich)

Density = 1.08 g/mL

Viscosity = 200 cP

Average molecular weight = 600,000 – 1,000,000 g/mol

Step 1: To prepare stock solution in 100 mL of volumetric flask

500 g/L → 10 g/L

PEI 50 wt% in H_2O = 50 g/100 mL or 500 g/L

→ 10 g/L

From; $C_1V_1 = C_2V_2$

$(500\ g/L)(V_1) = (10\ g/L)(100\ mL)$

$V_1 = 2\ mL$

Because the PEI 50 wt% in H_2O is very high viscosity, it is easier to prepare in unit of mass than unit of volume.

From; $\rho = m/V$

So; $m = (1.08\ g/mL)x(2\ mL)$

$m = 2.16\ g$

Prepared PEI solution 100 mL by methanol as a solvent

Step 2: To prepare initial concentration of 0.1 g/L

→ 0.1 g/L

10 g/L → 0.1 g/L

From; $C_1V_1 = C_2V_2$

$(10\ g/L)(V_1) = (0.1\ g/L)(100\ mL)$

$V_1 = 1\ mL$

Step 3: To measure concentration via UV-visible spectrometer

The absorbance at 203 nm

Concentration of PEI solution before impregnation → 0.94 g/L

Concentration of PEI solution after impregnation → 0.07112 g/L

Step 4: To calculate PEI- impregnated sample

$$q_e = (0.94 - 0.07112) g/L \frac{20\ mL}{1\ g} x \frac{1\ L}{1000\ mL}$$

$$q_e = 0.0004552\ gPEI/gAC$$

$$q_e = 0.045\ wt\%\ PEI/AC$$

So; PEI-impregnated on AC = 0.045 wt% PEI/AC

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Presentations and Proceedings:

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