REFERENCES

Alkandary, J.A.M., Al-Ammeri, R., and Salem, A.B.S.H. (1995) Adsorption equilibria of normal paraffins on 5A molecular sieve. Separation Science and Technology, 30(16), 3195-3209.

Avery, W.F. (1969) Isobaric process for molecular sieve separation of normal paraffins from hydrocarbon mixtures. United States Patent Office, Patent No. 3,422,005.

Babich, I.V., van Langeveld, A.D., Zhu, W., Bakker, W.J.W., and Moulijn, J.A. (2001) A rotating adsorber for multistage cyclic processes: principle and experimental demonstration in separation of paraffins. Industrial Engineering Chemistry Research, 40, 357-363.

Benazzi, E., Hotier, G., Basset, J.M., Choplin, A., Theolier, A., and Nedez, C. (1994) Separation of aliphatic paraffins by adsorption. United States Patent Office, Patent No.5,326,928.

Breck, D.W. (1984) Zeolite Molecular Sieve: Structure, Chemistry, and Use. Malaban, Flo: Robert E. Krieger.

Brodbeck, J.J. (1966) Method of separating normal alkanes. United States Patent Office, Patent No. 3,291,725.

Burgess, C.G.V., Duffett R.H.E., Minkoff, G.J., and Taylor, R.G. (1964) Sorption of long chain normal paraffins in molecular sieves. Journal of Applied Chemistry, 14 August, 1964, 350-360.

Fuderer, A. (1983) Constant pressure separation of normal paraffins from hydrocarbon mixtures. United States Patent Office, Patent No. 4,374,022.

Gupta, K., Kunzru, D., and Saraf, D.N. (1980) Phase adsorption of n-paraffins on molecular sieve. Journal of Chemical and Engineering Data, 25, 14-16.

Jarsa, R.V. and Bhat, T.S.G. (1987) Sorption kinetics of higher n-paraffins on zeolite molecular sieve 5A. Industrial Engineering Chemistry Research, 26, 2544-2546.

Karge, H.G. and Weitkamp, J. (2002) Molecular Sieves Science and Technology. Germany: Springer-Verlag Berlin Heidelberg.

Mazzotti, M., Baciocchi, R., Storti, G., and Morbidelli, M. (1996) Vapor-phase SMB adsorptive separation of linear/nonlinear paraffins. Industrial Engineering Chemistry Research, 35, 2313-2321.

Milton, R.M. (1963) Hydrocarbon separation. United States Patent Office, Patent No. 3,078,645.

Paoli, H. (2002) Separation study C10-C14 paraffins adsorption over 5A zeolites. Ph.D. Thesis in chemical engineering, Institut Français du Pétrole.

Sherry, H.S. and Walton, H.F. (1966) The ion-exchange properties of zeolites. II. ion exchange in the synthetic zeolite Linde 4-A. Journal of Physical Chemistry, 71, 1457-1465.

Silva, J.A.C. and Rodrigues, A.E. (1997) Sorption and diffusion of n-pentane in pellets of 5A zeolite. Industrial Engineering Chemistry Research, 36, 493-500.

Silva, J.A.C. and Rodrigues, A.E. (1997) Fixed-bed adsorption of n-pentane/isopentane mixture in pellets of 5A zeolite. Industrial Engineering Chemistry Research, 36, 3769-3777.

Silva, J.A.C. and Rodrigues, A.E. (1999) Multisite Langmuir model applied to the interpretation of sorption of n-paraffins in 5A zeolite. Industrial Engineering Chemistry Research, 38, 2434-2438.

Wiers, B.H., Grosse, R.J., and Cilley, W.A. (1982) Divalent and trivalent ion exchange with zeolite A. Environmental Science and Technology, 16, 617-624

Yang, R.T. (1997) Gas Separation by Adsorption Processes. London: Imperial College Press.

Young, E.E., Concord, and Blytas, G.C. (1967) n-Paraffin separation process. United States Patent Office, Patent No. 3,309,415.

APPENDICES

Appendix A Sample of calculation.

Mass balance on ion exchange

Example:

50 ml of 1200 ppm calcium solution was poured down into a glass bottle containing 1 g zeolite. After equilibrium, concentration of the calcium solution was decreased to 200 ppm. Mass balance can be done following the equation:

initial concentration – equilibrium concentration = amount of the cation exchanged

$$1200 \text{ ppm} - 200 \text{ ppm} = 1000 \text{ ppm}$$

1000 ppm means there is 1 g of cation in 1000 ml solution. However, only 50 ml were used for ion exchange. So, in 1000 ppm of 50 ml, there is 0.05 g of cation.

$\therefore$ 0.05 g of cation was exchanged into zeolite 4A.

Number of n-C10 desorbed per unit cell

The crystallographic unit cell of 52% Ca-Na-A zeolite: $Na_6Ca_3[(AlO_2)_{12}(SiO_2)_{12}]$

Molecular weight of one unit cell = 1687.2 g/mole

There are $6.02*10^{23}$ unit cell per mole

$\therefore$ In 1 g of 52% Ca-Na-A there are [1g/(1687.2 g/mole)] * ($6.02*10^{23}$ unit cell/mole)

= $3.57 * 10^{20}$ unit cell

Amount of n-C10 desorbed can be obtained from thermogravimetric experiment in gram per 1g zeolite which can be converted to molecule per 1g zeolite by divide it by molecular weight of n-C10 (144 g/mole) and times $6.02*10^{23}$ molecule/mole.

Finally, number of n-C10 molecule desorbed per unit cell can be calculated by divide the amount of n-C10 molecule desorbed per 1 g of zeolite by amount of unit cell per 1 g of zeolite.

Calculation of average time

The average time of breakthrough curve can be calculated by integration of the area on the left side of breakthrough curve from the following equation:

$$\mu = \bar{t} = \int_{0}^{\infty} \left[1 - \frac{Cs(t) - Ci}{Cf - Ci} \right] dt \qquad (A1)$$

where $C_s(t)$ is the signal value at specific time (t)

C_i is average base signal value of the breakthrough curve obtained.

C_f is average final signal value of the breakthrough curve obtained.

Calculation was done in Microsoft Excel.

Appendix B Calibration curve of Atomic Absorption Spectrometer (AAS).

AAS calibration curve of sodium

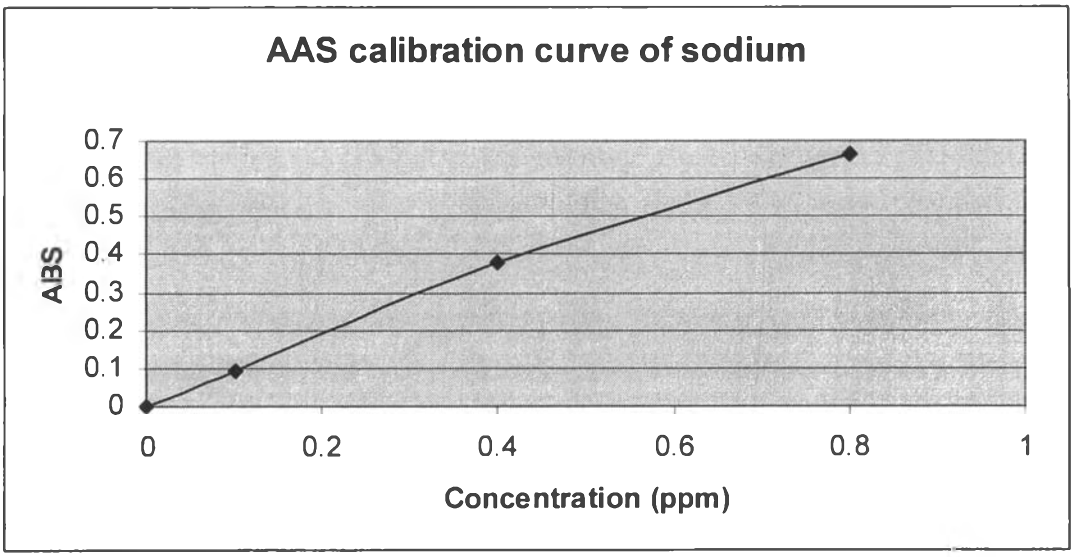

Figure B1 AAS calibration curve of sodium.

AAS calibration curve of calcium

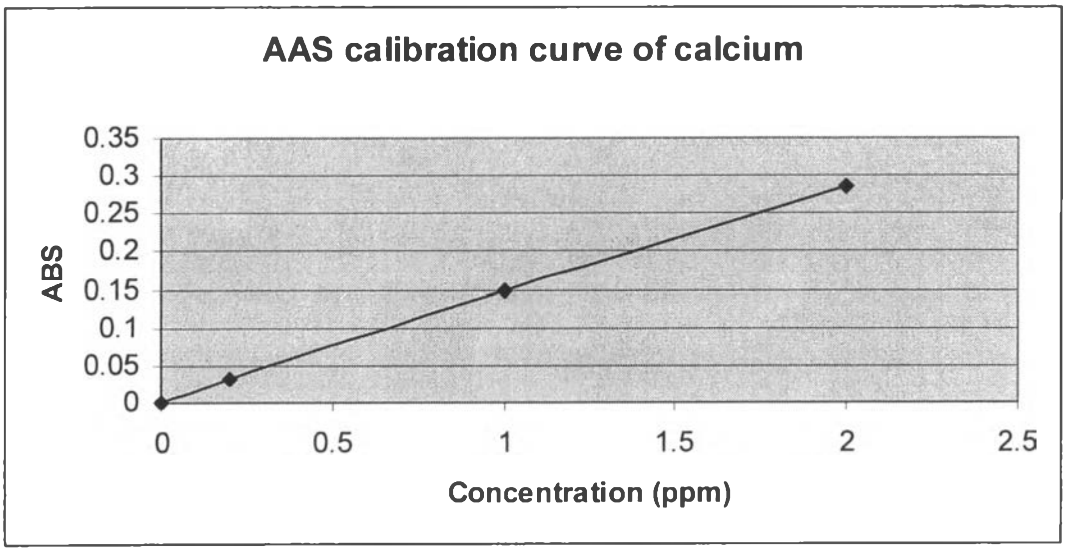

Figure B2 AAS calibration curve of calcium.

AAS calibration curve of strontium

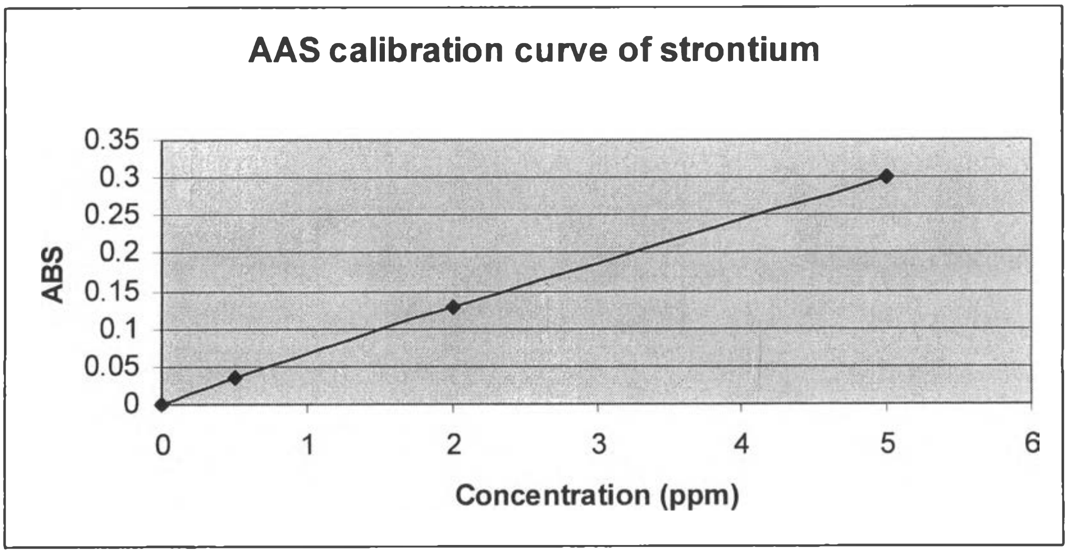

Figure B3 AAS calibration curve of strontium.

AAS calibration curve of magnesium

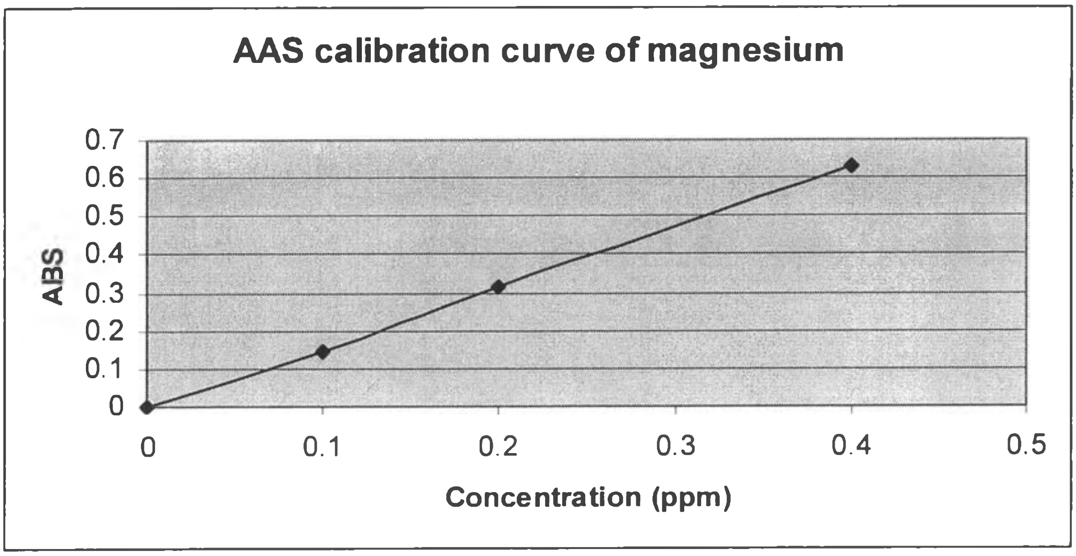

Figure B4 AAS calibration curve of magnesium.

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