

Two Crystal Structures of Dehydrated Ag⁺ and K⁺ Exchanged Zeolite A, Ag_{12-x}K_x-A, x = 1.3 and 2.7

Yang Kim*, Seong-Hwan Song, Jong-Yul Park, and Un-Sik Kim

Chemistry Department, Pusan National University, Pusan 609-735. Received April 8, 1988

Two crystal structures of fully dehydrated silver and potassium exchanged zeolite A, stoichiometries of Ag_{9.3}K_{2.7}A ($a = 12.282(2)$ Å) and Ag_{10.7}K_{1.3}A ($a = 12.287(2)$ Å) per unit cell, have been determined from 3-dimensional x-ray diffraction data gathered by counter methods. All structures were solved and refined in the cubic space group *Pm3m* at 21(1) °C. The crystals of Ag_{9.3}K_{2.7}A and Ag_{10.7}K_{1.3}A were prepared by flow method using exchange solutions in which mole ratios of AgNO₃ and KNO₃ were 1:10 and 1:5, respectively, with total concentration of 0.05M. The structures of the dehydrated Ag_{9.3}K_{2.7}A and Ag_{10.7}K_{1.3}A were refined to yield the final error indices $R_1 = 0.037$ and $R_2 = 0.040$ with 321 reflections, and $R_1 = 0.042$ and $R_2 = 0.043$ with 371 reflections, respectively, for which $I > 3\sigma(I)$. In both structures, eight Ag⁺ ions are found nearly at 6-ring centers and each Ag⁺ ion is nearly in the (1 1 1) plane at its O(3) ligands. The 8-ring sites are preferentially occupied by K⁺ ions in both structures. 1.3 and 1.7 reduced silver atoms per unit cell were found inside of sodalite units of Ag_{9.3}K_{2.7}A and that of Ag_{10.7}K_{1.3}A, respectively. These reduced silver species were presumably formed from the reduction of Ag⁺ ions by oxide ions of residual water molecule or of the zeolite framework. These two crystals may be presented as hexasilver cluster in 21.7% and 28.3% of sodalite unit cells for Ag_{9.3}K_{2.7}A and Ag_{10.7}K_{1.3}A, respectively.

Introduction

Dehydrated zeolite A has a large empty space at the center of its unit cube, which is nearly spherical with a diameter of 11.4 Å and is called α -cage.^{1,2} This cage is surrounded by six eight-membered rings which lie on the corner of the cube and constitutes of window to the cage. The 8-ring cations in zeolite A may block three dimensional channel system. In commerial molecular sieve 3A and 4A, the 8-ring windows are blocked by K⁺ and Na⁺ ions, respectively.¹ Zeolite as ion exchanger have been extensively investigated in recent years.² Exchangeable cations in a zeolite framework have a unique and exciting environment. These cations must find suitable coordination sites, by using the relatively rigid aluminosilicate without reorganization as a polydentate ligand³.

Ag⁺ ions in zeolite A are autoreduced upon dehydration to form uncharge silver clusters, the molecules Ag₆ each within a cube of eight Ag⁺ ions, each near the plane of a six-oxygen ring^{4,5} Hermerschmidt and Haul also identified these cluster in the sodalite cavity of dehydrated Ag⁺-exchanged zeolite A using epr spectroscopy⁶ and their results were duplicated by Grobet and Schoonheydt⁷. This was reverified by the careful work of Morton and Preston who did esr measurements on isotropically pure samples of Ag₁₂-A.⁸

Up to this time, no structural studies of mixed cation system of Ag⁺ and K⁺ ion exchanged zeolite A have been reported. A detail knowledge of the structural facts of Ag⁺ and K⁺ exchanged zeolite A could be most interesting because this can provide informations on the pore size of 8-ring and sorption properties of guest molecules. The present work is preliminary to later studies of the crystal structures of Ag_{12-x}K_x-A (0 < x < 12) treated with H₂ or other guest molecules.

Experimental

Crystals of zeolite 4A were prepared by Charnell's method.⁹ Each of two single crystals (0.08 mm on an edge)

was lodged in a fine glass capillary.

Crystals of Ag_{9.3}K_{2.7}A and Ag_{10.7}K_{1.3}A¹⁰ were prepared using exchange solutions in which mole ratios of AgNO₃ and KNO₃ were 1:5 and 1:10, respectively, with a total concentration of 0.05 M.

Ion exchange was accomplished allowing the solution to flow past each crystal at a velocity of approximately 1.0 cm/sec for 3 days at 23(1) °C. All the crystals were evacuated at 370 °C and P = 2 × 10⁻⁶ Torr for 2 days. After cooling to room temperature, the crystal, still under vacuum was sealed in its capillary by a torch. Microscopic examination showed that both crystals became dull red.

Diffraction intensities were subsequently collected at 24 °C. The space group *Pm3m* (no systematic absences) was used throughout this work for reasons discussed previously.¹¹ An Enraf-Nonius 4-circle computer controlled CAD-4 diffractometer, equipped with scintillation counter, pulse-height analyzer, a PDP micro 11/73 computer, and a graphite monochromator was used. Molybdenum radiation (K_{α1}, $\lambda = 0.70930$ Å; K_{α2}, $\lambda = 0.71359$ Å) was used for all experiments. The unit cell constants, as determined by a least squares refinement of 2 θ intense reflections for which 20° < 2 θ < 32°, are 12.287(2) Å for Ag_{10.7}K_{1.3}A and 12.282(2) Å for Ag_{9.3}K_{2.7}A, respectively.

For each crystal, reflections from two intensity-equivalent regions of reciprocal space (hkl, h ≤ k ≤ l and lkh, 1 ≤ h ≤ k) were examined using the ω -2 θ scan technique. The data were collected using variable scan speeds. The maximum final scan speed was 5 minutes per one reflection. The intensities of three reflections in diverse regions of reciprocal space were recorded after every 100 reflections to monitor crystal and instrument stability. The raw data from each region were corrected for Lorentz and polarization effects, including that due to incident beam monochromatization; the reduced intensities were merged and the resultant estimated standard deviation were assigned to each average reflection by the computer programs, PAINT and WEIGHT.¹² Of the 877 pairs of reflections for the dehydrated Ag_{10.7}K_{1.3}A and 873 for the dehydrated Ag_{9.3}K_{2.7}A, only 374 and 321 pairs,

Table 1. Positional, Thermal, and Occupancy Parameters of dehydrated $Ag_{10.7}K_{1.3}A$

Atom	Wyc. Posi.	x	y	z	β_{11}	β_{22}	β_{33}	β_{12}	β_{13}	β_{23}	Occupancy	varied fixed
(Si, Al)	24(k)	0	1836(2)	3698(2)	24(1)	17(1)	15(1)	0	0	7(2)	24.	
O(1)	12(h)	0	2150(9)	0.5	74(8)	72(8)	12(4)	0	0	0	12.0	
O(2)	12(i)	0	2957(5)	2957(5)	38(5)	29(3)	29(3)	0	0	20(9)	12.0	
O(3)	24(m)	1104(4)	1104(4)	3369(5)	44(3)	44(3)	42(4)	39(7)	32(5)	32(5)	24.0	
Ag(1)	8(g)	1904(1)	1904(1)	1904(1)	78(1)	78(1)	78(1)	109(1)	109(1)	109(1)	7.91(3)	8.0
Ag(2)	6(e)	0	0	1700(3)	22(1)	22(1)	17(2)	0	0	0	1.77(2)	1.7
Ag(3)	12(l)	0	4330(20)	4330(20)	600(100)	280(30)	280(30)	0	0	-150(90)	1.11(6)	1.0
K(1)	12(l)	0	4450(30)	4450(30)	40(20)	140(30)	140(30)	0	0	170(50)	1.31(8)	1.3

Table 2. Positional, Thermal, and Occupancy Parameters of dehydrated $Ag_{9.3}K_{2.7}A$

Atom	Wyc. Posi.	x	y	z	β_{11}	β_{22}	β_{33}	β_{12}	β_{13}	β_{23}	Occupancy	varied fixed
(Si, Al)	24(k)	0	1837(2)	3701(2)	23(1)	19(1)	17(1)	0	0	5(2)	24.0	
O(1)	12(h)	0	2151(8)	0.5	61(7)	62(8)	20(5)	0	0	0	12.0	
O(2)	12(h)	0	2963(5)	2963(5)	35(5)	32(3)	32(3)	0	0	27(9)	12.0	
O(3)	24(m)	1116(3)	1116(3)	3370(5)	40(2)	40(2)	44(4)	27(7)	26(5)	26(5)	24.0	
Ag(1)	8(g)	1894(1)	1894(1)	1894(1)	71(1)	71(1)	71(1)	94(1)	94(1)	94(1)	7.81(5)	8.0
Ag(2)	6(e)	0	0	1702(34)	26(2)	26(2)	22(3)	0	0	0	1.36(2)	1.3
K(1)	12(l)	0	4510(10)	4510(10)	130(20)	180(20)	180(20)	0	0	-10(40)	2.98(10)	2.7

^a Positional and isotropic thermal parameters are given $\times 10^4$. Numbers in parentheses are the esd's in units of the least significant digit given for the corresponding parameter. ^b The anisotropic temperature factor = $\exp[-(\beta_{11}h^2 + \beta_{22}k^2 + \beta_{33}l^2 + \beta_{12}hk + \beta_{13}hl + \beta_{23}kl)]$. ^c Occupancy factors given as the number of atoms or ions per unit cell. Occupancy for (Si) = 12; occupancy for (Al) = 12.

Table 3. Selected Interatomic Distances (Å) and Angles (deg)

	$Ag_{10.7}K_{1.3}A$	$Ag_{9.3}K_{2.7}A$
(Si, Al)-O(1)	1.646(3)	1.641(3)
(Si, Al)-O(2)	1.651(4)	1.654(4)
(Si, Al)-O(3)	1.677(3)	1.681(3)
Ag(1)-O(3)	2.275(5)	2.262(5)
Ag(2)-O(3)	2.809(6)	2.821(6)
Ag(3)-O(1)	2.80(1)	
Ag(3)-O(2)	2.38(3)	
K(1)-O(1)	2.92(1)	2.97(2)
K(2)-O(2)	2.60(3)	2.69(1)
Ag(2)-Ag(2)	2.945(5)	2.957(5)
Ag(1)-Ag(2)	3.317(1)	3.299(1)
O(1)-(Si, Al)-O(2)	110.0(4)	109.6(4)
O(1)-(Si, Al)-O(3)	111.1(3)	111.0(3)
O(2)-(Si, Al)-O(3)	108.3(2)	107.9(2)
O(3)-(Si, Al)-O(3)	108.0(3)	109.2(3)
(Si, Al)-O(1)-(Si, Al)	152.9(7)	152.7(7)
(Si, Al)-O(2)-(Si, Al)	156.9(4)	156.4(4)
(Si, Al)-O(3)-(Si, Al)	144.1(3)	143.2(3)
O(3)-Ag(1)-O(3)	119.8(1)	119.9(2)
O(3)-Ag(2)-O(3)	57.8(1)	58.2(1)
Ag(1)-Ag(2)-Ag(1)	89.67(2)	89.71(2)

Numbers in parentheses are estimated standard deviations in the units of the last significant digit given for the corresponding value.

for which $I > 3\sigma(I)$, respectively, were used in subsequent structure determinations.

The initial structural parameters used in least-squares refinement were those previously found for Ag^+ , Si, Al, and O atom in the structure of the dehydrated $Ag_{12}A$.⁵ From the initial difference Fourier synthesis, Ag(2) and K(1) were located and refined (see Table 1 and 2). In zeolite A structure, 12 monovalent cations should be found per unit cell. 8 Ag^+ ions at Ag(1) are refined on the threefold axis of unit cell which is the maximum occupancy number at that position.

In the structure of $Ag_{9.3}K_{2.7}A$, 1.3 Ag species at Ag(2) and 2.7 K^+ ions at K(1) were refined with the constraint that the sum of occupancies be 4.0. By similar techniques, 1.7 Ag species at Ag(2) and 1.0 Ag^+ ion at Ag(3) and 1.3 K^+ ions at K(1) were located in the structure of $Ag_{10.7}K_{1.3}A$.

The structure of the dehydrated $Ag_{9.3}K_{2.7}A$ and that of the dehydrated $Ag_{10.7}K_{1.3}A$ was refined to give the final error indices $R_1 = 0.037$ and $R_2 = 0.040$, and $R_1 = 0.042$ and $R_2 = 0.043$, respectively.

Atomic scattering factors for Ag^+ , Ag^0 , O^- , K^+ , and (Si, Al)^{1.75+} were used.^{13,14} The function describing (Si, Al)^{1.75+} is the mean of the Si^0 , Si^{4+} , Al^0 and Al^{3+} function. All scattering factors were modified to account for the real component ($\Delta f'$) of the anomalous dispersion correction.^{15,16} Final position, thermal and occupancy parameters are presented in Table 1 and 2; bond angles and lengths are given in Table 3.

Discussion

In the dehydrated $Ag_{12x}K_xA$ (where $x = 2.7$ and 1.3), eight Ag^+ ions at Ag(1) lie on threefold axes of the unit cell, each nearly at the center of one of the eight 6-rings per unit cell (see Figure 1 and 2 and Table 4). Each of these ions ap-

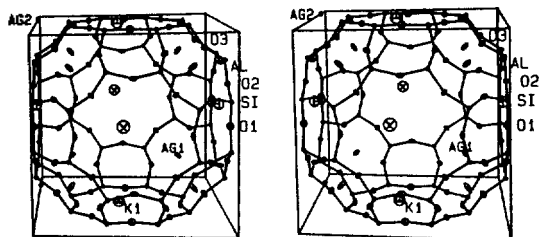


Figure 1. A stereoview of the large cavity of dehydrated $\text{Ag}_{10.7}\text{K}_{1.3}\text{A}$ is shown with ellipsoids of 20% probability.

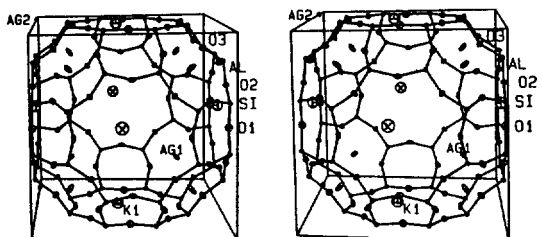


Figure 2. A stereoview of the large cavity of the dehydrated $\text{Ag}_{9.3}\text{K}_{2.7}\text{A}$ is shown. All 6-ring sites are filled with 8 Ag^+ ions at Ag(1) and all 8-ring site and filled with K^+ ions. 70% of unit cells may have this arrangements and remaining 30% would have only 2 K^+ ions at K(1) per unit cell.

Table 4. Deviations of atoms (Å) from the (111) plane at O(3)

	$\text{Ag}_{10.7}\text{K}_{1.3}\text{A}$	$\text{Ag}_{9.3}\text{K}_{2.7}\text{A}$
O(2)	0.239(3)	0.231(3)
Ag(1)	0.095(1)	0.058(1)
Ag(2)	-2.751(2)	-2.765(3)

A negative deviation indicates that the atom lies on the same side of the plane as the origin.

proaches three zeolite framework oxygens at O(3) at a distance of 2.275(5) Å for $\text{Ag}_{10.7}\text{K}_{1.3}\text{A}$ and that of 2.262(5) Å for $\text{Ag}_{9.3}\text{K}_{2.7}\text{A}$, respectively. For comparison, the sum of the Ag^+ and O^{2-} radii is 2.58 Å.¹⁷ It appears that the relatively short 2.27 Å bonds between the Ag^+ ions at Ag(1) and oxide ions of the zeolite framework, are quite covalent. On the surface of each sodalite unit, and consistent with its high symmetry, O_h , these eight Ag^+ ions lie at the corners of a cube, 4.68 Å on an edge.

On Ag^+ ion at Ag(3) for dehydrated $\text{Ag}_{10.7}\text{K}_{1.3}\text{A}$ is associated with 8-ring oxygens. This position is located in the plane of the 8-rings, but not at their center so that favorable approaches to framework oxygens may be made. This Ag^+ ion is 2.38(3) Å from the nearest framework oxygen at O(2) and 2.80(3) Å from two oxygens at O(1). This coordination environment is relatively unsatisfactory, partly because its ligand atoms are all to one side, not arranged around it. Its large anisotropic thermal parameters also indicate it (see Table 2). 1.3 K^+ ion at K(1) for $\text{Ag}_{10.7}\text{K}_{1.3}\text{A}$ and 2.7 K^+ ions at K(1) for $\text{Ag}_{9.3}\text{K}_{2.7}\text{A}$ lie close to the center of 8-ring plane compared with Ag^+ ion at Ag(3) for $\text{Ag}_{10.7}\text{K}_{1.3}\text{A}$. The K^+ ions of $\text{Ag}_{10.7}\text{K}_{1.3}\text{A}$ and $\text{Ag}_{9.3}\text{K}_{2.7}\text{A}$ are 2.60(3) Å and 2.69(1) Å, apart from two adjacent O(2) and 2.92(1) Å and 2.97(2) Å, from the nearest O(2), respectively (see Table III). If the K(1) were located at the center of the 8-rings, the K⁺-O atomic distances of $\text{Ag}_{10.7}\text{K}_{1.3}\text{A}$ and $\text{Ag}_{9.3}\text{K}_{2.7}\text{A}$ would be 3.47 Å and 3.50 Å, to all four O(1)'s, respectively, and 3.56 Å

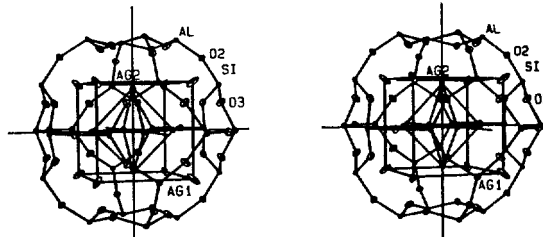


Figure 3. $(\text{Ag}^+)_8(\text{Ag}_6)$. The octahedral hexasilver molecule at Ag(2) is stabilized by coordination to eight Ag^+ ions at Ag(1). Ellipsoids of 20% probability are used. (The occupancy at Ag(2) is given as 1.7 in Table 1, together with the corresponding thermal parameters.)

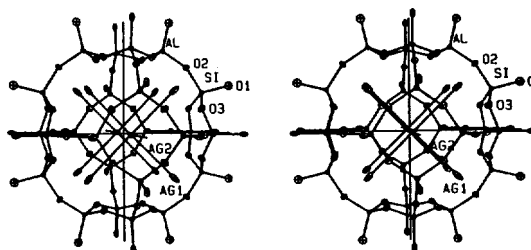


Figure 4. A stereoview of sodalite unit containing two Ag_3^{3+} clusters (heavy line) is shown as another possible alternative. Ellipsoids of 20% probability are used.

and 3.54 Å, to all O(2)'s, respectively, as both distances are greater than the sum of the atomic radii of K^+ and O^{2-} , 2.65 Å. Accordingly, it is reasonable that the K(1)'s are not found at the centers of the 8-rings.

The Ag(2) position is quite similar to that of the neutral silver atom in the structure of dehydrated partially decomposed Ag_{12}A .^{4,5} The distances between Ag(2) and the nearest oxygens at O(3) are quite long, 2.806(6) Å for $\text{Ag}_{10.7}\text{K}_{1.3}\text{A}$ and 2.821(6) Å for $\text{Ag}_{9.3}\text{K}_{2.7}\text{A}$, respectively, as it is compared to the corresponding ion to ion distances observed, and is about the same as was seen before between a neutral silver atom and framework oxide ions, O(3) as it is observed before.^{4,5} The shortest available Ag(2)-Ag(2) distance, 2.95(1) Å, may be considered slightly longer than the Ag(2)-Ag(2) bond in natural silver metal, 2.889 Å¹⁸ (see Figure 3).

The distance between Ag(1) and Ag(2) is ca 3.30 Å (see Table 3). This distance is equal to that of $\text{Ag}^+-\text{Ag}^\circ$ in the structure of dehydrated Ag_{12}A and similar to that of $\text{Ag}^+-\text{Ag}^\circ$ in the structure of the dehydrated $\text{Ag}_{6.5}\text{Ti}_{5.5}\text{A}$.¹⁹ This distance between Ag(1) and Ag(2) is too long to be an $\text{Ag}^\circ-\text{Ag}^\circ$ bond and too short to be an unmoderated Ag^+-Ag^+ contact. This is consistent with the conclusion (*vide supra*) that Ag(1) contains silver ions and Ag(3) silver atoms.

The Ag^+ ions which have been reduced are located at the least favorable positions such as an Ag^+ ions on opposite 4-ring site and Ag^+ ions on 8-ring sites. Neutral silver atom were also seen in the structures such as dehydrated $\text{Ti}_2\text{Ag}_{12-x}\text{A}$ ($6 < x < 2$),^{19,20} $\text{Ag}_{7.6}\text{Na}_{4.4}\text{A}$ ²¹ and Ag_{12}A treated first with H_2 and then with O_2 , both at 330 °C.²²

Since 1.3 silver atoms for $\text{Ag}_{9.3}\text{K}_{2.7}\text{A}$ and 1.7 silver atoms for $\text{Ag}_{10.7}\text{K}_{1.3}\text{A}$ are located inside of sodalite unit, this indicates that a neutral hexasilver cluster seems to be formed in about 22 and 28 percent of sodalite units, respectively. As an other alternative, Ag species at Ag(2) might interact with

four of the eight Ag species at Ag(1) and form $(Ag_5)^{4+}$ clusters. This $(Ag_5)^{4+}$ cluster has C_{4v} , near D_{4h} symmetry. The 1.3 or 1.7 Ag species at Ag(2) indicates that 30% of the sodalite units for $Ag_{9.3}K_{2.7}A$ and 70% of sodalite units for $Ag_{10.7}K_{1.3}A$ have two $(Ag_5)^{4+}$ clusters and the remaining 70% or 30% of the sodalite unit, respectively, may have only one $(Ag_5)^{4+}$ clusters (see Figure 4).

A comparison of crystal structure of dehydrated $Ag_{9.3}K_{2.7}A$ and that of $Ag_{10.7}K_{1.3}A$, indicates that K^+ ions preferentially occupy 8-ring site and Ag^+ ions occupy 6-ring sites. This result is reasonable considering ionic radii of K^+ ion (1.33 Å) and that of Ag^+ ion (1.26 Å). Larger K^+ ion will better fit to larger 8-ring site over small 6-ring site. These results are also consistent with the structures of $Ag_9Cs_3A^{23}$ and $Ag_9Rb_3A^{24}$. In both structures, larger three Cs^+ ions and three Rb^+ ions are located on the center of each 8-rings of unit cell.

Acknowledgement. This work was supported by the Basic Science Research Institute Program, Ministry of Education, Korea, 1987.

References

1. D. W. Breck, Zeolite Molecular Sieve, *John Wiley*, 1974, pp. 83-92.
2. "New Developments in Zeolite Science and Technology" Edited by Y. Murakami, A. Iijima, and J. W. Ward, Kodansha, Tokyo, 1986, pp. 273-361.
3. A discussion of the structure and of the nomenclature used for zeolite A is available; (a) K. Seff, *Acc. Chem. Res.*, **9**, 121 (1976).
4. Y. Kim and K. Seff, *J. Am. Chem. Soc.*, **99**, 7055 (1977).
5. Y. Kim and K. Seff, *J. Am. Chem. Soc.*, **100**, 6989 (1978).
6. D. Hermerschmidt and R. Haul, *Ber. Bunsenges. Phys. Chem.*, **84**, 902 (1980).
7. P. J. Grobet and R. A. Schoonheydt, *Surf. Sci.*, **156**, 893 (1985).
8. J. R. Morton and K. P. Preston, *J. Magn. Resonance*, **68**, 121 (1986).
9. J. F. Charnell, *J. Cryst. Growth*, **8**, 291 (1971).
10. The nomenclature refer to the content of the Pm3m unit cell. For example, $Ag_{9.3}K_{2.7}A$ represents $Ag_{9.3}K_{2.7}Si_{12}Al_{12}O_{48}$, exclusive of water if a hydrated crystal is considered.
11. K. Seff and M. D. Mellum, *J. Phys. Chem.*, **88**, 3560 (1984).
12. Principal computer programs used in this study was "Structure Determination Package Programs" supplied from the Enraf-Nonius, Netherland, 1987.
13. P. A. Doyle and P. S. Turner, *Acta. Crystallogr. Sec. A*, **24**, 390 (1968).
14. "International Tables for X-ray Crystallography" Vol. IV. Kynoch press, Birmingham, England, p. 73, 1974.
15. D. T. Chromer, *Acta, Crystallogr.*, **18**, 17 (1965).
16. Reference 11, pp. 159-160.
17. "Handbook of Chemistry and Physics," 63rd ed., Chemical Rubber Co., Cleveland, Ohio, 1982/1983, PF 176.
18. "Tables of Interatomic Distances and Configuration in Molecules and Ions" Special Publication No. 11, The Chemical Society, Burlington House, London, P-S3, 1958.
19. Y. Kim and K. Seff, *J. Phys. Chem.*, **82**, 1307 (1978).
20. D. S. Kim, S. H. Song, and Y. Kim, *Bull. Korean Chem. Soc.*, **9**, 303 (1988).
21. Y. Kim and K. Seff, *J. Phys. Chem.*, **91**, 671 (1987).
22. Y. Kim and K. Seff, *J. Phys. Chem.*, **82**, 921 (1978).
23. Y. Kim and K. Seff, *Bull. Korean Chem. Soc.*, **8**, 69 (1987).
24. Y. Kim and S. H. Song, Accepted to the *Jour. Korean Chem. Soc.*

Separation of Optical Isomers of Amino Acids with Addition of Benzyl-L-proline Copper (II) Chelate by Reversed Phase Liquid Chromatography

Sun Haing Lee*, Dae Sub Oh, and Byoung-Eog Kim

Department of Chemistry, Kyungpook National University Taegu, 702-701. Received May 9, 1988

Separation of optical isomers of dansyl amino acids by a reversed phase liquid chromatography has been accomplished by adding a copper (II) chelate of N-benzyl-L-proline to the mobile phase. The pH, the eluent composition and the concentration of copper (II) chelate all affect the optical separations. The elution orders between D and L DNS-amino acids were constant except dansyl phenylalanine showing that D forms of DNS-amino acids elute earlier than L forms. These behaviors are different from the results obtained by the use of copper (II) proline. The retention mechanism for the optical separation of the dansyl amino acids can be explained by the equilibrium of ligand exchange and by hydrophobic interaction.

Introduction

The resolution of optical isomers of amino acids by a high performance liquid chromatography (HPLC) has been interested, especially for the synthesis of peptides and the

determination of the chemical structure. There are two different methods for the optical resolution of amino acids. The one is to use a chiral stationary phase (CSP) so that the chiral separation can be carried out by difference in the interaction in the solutes with the stationary phase between the optical