

SYNTHESIS, STRUCTURAL STUDY, IR SPECTROSCOPY CHARACTERIZATION AND IONIC BEHAVIOR OF $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$

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RESUME: Le composé $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$ a été préparé par réaction à l'état solide. Une analyse qualitative par microscopie électronique à balayage (M.E.B) et une étude par spectroscopie d'absorption infrarouge (I.R) ont été effectuées. L'étude structurale du composé $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$ montre que ce matériau cristallise dans le système orthorhombique (groupe spatial Cmc₂m) et présente une charpente tridimensionnelle. La structure possède des canaux, à section hexagonale, où se situent les cations Ag^+ et K^+ . Les caractéristiques tirées de l'étude structurale, favorables à une bonne mobilité ionique, nous ont encouragés à faire une étude de la conductivité ionique moyennant la méthode des impédances complexes.

Mots-clés : Analyse M.E.B, Spectroscopie I.R, Etude structurale, Spectroscopie I.C.

ABSTRACT: The $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$ compound was prepared by a solid state reaction. A qualitative analysis by scanner electronic microscope (S.E.M) and infrared (I.R) spectroscopic study were made for the state. The structural study of the $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$ compound shows that this material crystallizes in the orthorhombic system (space group Cmc₂m) and has a three dimensional framework. There are tunnels, with hexagonal section, in where Ag^+ and K^+ cations are located. The characteristics derived from the structural study, which support good ion mobility, have encouraged to study the ionic conductivity through the complex impedance method.

Key words: S.E.M analysis, I.R spectroscopy, Structural study, C.I spectroscopy.

1. INTRODUCTION

Oxides with covalent networks built up from XO_4 tetrahedra ($X = \text{P}$ [1-9], As [10-12]) and MO_6 octahedra ($M =$ highly charged cation) have been widely studied [13], due to their interest in the fields of catalysis [14], ion-exchange [15] and ion conduction [16].

The title compound was prepared in the course of a study devoted to the systems: $\text{A}_2\text{O}-\text{Nb}_2\text{O}_5-\text{As}_2\text{O}_5$ ($A =$ alkali metal) in which the following compounds were previously characterized: $\text{Ag}_{0.2}\text{K}_{0.8}\text{Nb}_4\text{AsO}_{13}$ [17], $\text{KNb}_4\text{AsO}_{13}$ [18] and $\text{NaNb}_4\text{AsO}_{13}$ [19], with the aim of obtaining materials with fast alkali-ion mobility and/or ion-exchange properties. We report here on the preparation, crystal structure and characterization of $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$.

2. SYNTHESIS

Single crystals of the title compound were obtained from a mixture of K_2CO_3 , $\text{NH}_4\text{H}_2\text{AsO}_4$, AgNO_3 and Nb_2O_5 , with a K: Ag: Nb: As molar ratio of 1:4:4:3. The mixture was heated in a porcelain crucible in air and the temperature was increased slowly to 400°C and kept at this temperature for 12h, in order to eliminate volatile products (NH_3 , H_2O and CO_2). In the second step, the finely ground product has been progressively

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heated at 900°C for a week. Finally, it was cooled to 800°C and quenched to room temperature. The obtained colorless crystals were separated from the excess flux by washing the product in boiling water.

3. MATERIAL CHARACTERIZATION

3.1. Scanning electron microscopy (S.E.M)

The semi-quantitative energy-dispersive spectroscopy (EDS) analysis of one of the colorless stick-like crystals obtained with a FEI Quanta 200 FEG scanning electron microscope, revealed the presence of only Ag, K, As, Nb and O elements (**Figure 1**).

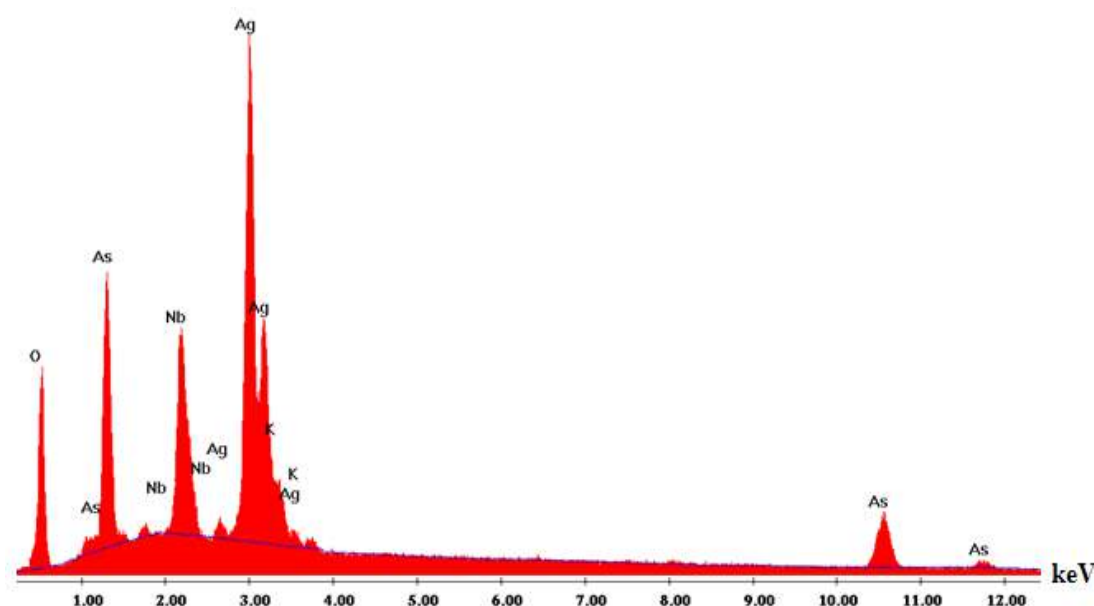


Figure 1: Spectrum of quantitative analysis by S.E.M of $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$.

3.2. Infrared spectroscopy

The infrared spectrum of $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$ (**Figure 2**) was recorded at room temperature, on a Perkin-Elmer FTIR Paragon 1000PC spectrometer, over the range 1200-400 cm^{-1} using the KBr disk method. The assignment of different vibrational bands of NbO_6 and AsO_4 groups based on those found in the literature [20], is collected in **table I**.

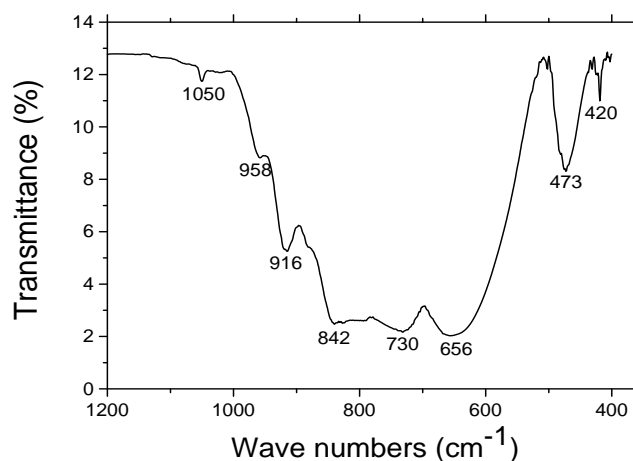


Figure 2: The infrared spectrum of the $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$.

Table I: Assignment of vibration frequencies in $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$ compound.

| Wave number (cm^{-1}) | Assignment |
|----------------------------------|-----------------------|
| 473 | $\nu_4(\text{NbO}_6)$ |
| 730 | $\nu_3(\text{NbO}_6)$ |
| 656 | |
| 420 | $\nu_4(\text{AsO}_4)$ |
| 842 | $\nu_1(\text{AsO}_4)$ |
| 916 | $\nu_3(\text{AsO}_4)$ |
| 958 | |
| 1050 | |

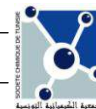
4. STRUCTURAL STUDY

4.1. Crystal data

A suitable colorless single crystal with $0.64 \times 0.45 \times 0.29 \text{ mm}^3$ dimensions was chosen for the structure determination and refinement. It was selected under a polarizing microscope and mounted on a glass fibre. The crystal data were collected on an Enraf-Nonius CAD-4 automatic four-circle diffractometer using $\text{MoK}\alpha$ radiation ($\lambda = 0.71073 \text{ \AA}$) at room temperature [21]. The unit-cell parameters were determined and refined using a least-squares method based upon 25 reflections in the range $10\text{-}15^\circ$. The crystallographic data and experimental conditions for intensity measurements are reported in **Table II**.

Table II: Summary of crystallographic data and recording conditions results for $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$.

| | |
|---|---|
| Crystal data | |
| Empirical formula | $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$ |
| Crystal system | Orthorhombic |
| Space group | Cmcm |
| Unit cell dimensions | $a = 10.438(5) \text{ \AA}$ |
| | $b = 10.443(3) \text{ \AA}$ |
| | $c = 10.042(6) \text{ \AA}$ |
| Volume (\AA^3) | 1094.60 (7) |
| Z | 4 |
| Crystal shape | prism |
| Color | colorless |
| Crystal size (mm^3) | $0.64 \times 0.45 \times 0.29$ |
| ρ (g.cm^{-3}) | 4.487 |
| Absorption coefficient μ (mm^{-1}) | 8.434 |
| Data collection | |
| Theta range for data collection | $2.76 \leq \theta \leq 26.98^\circ$ |
| Limiting indices | $-13 \leq h \leq 13$ |
| | $-1 \leq k \leq 13$ |
| | $-12 \leq l \leq 12$ |
| Scan mode | ω -2 θ |
| Absorption correction | psi-scan |
| T_{\min} ; T_{\max} | 0.015 ; 0.086 |
| Reflections collected | 2655 |
| Independent reflections | 669 |
| R_{int} | 0.0554 |



4.2. Resolution and structure refinement

The crystal structure was solved and refined against F^2 in the space group $Cmcm$ by direct methods using the SHELX-97 [22-23] computer programs included in the WingX software package [24]. The niobium, arsenic and silver atoms were first located and then the positions of other atoms were found from successive Fourier difference maps. At this step, absorption correction was applied via psi-scan [25]. The examination of the Fourier difference reveals the presence of peaks, with low intensity, close to Ag^+ and K^+ . At the end of the resolution, a charge distribution between these two ions has been applied and the corresponding formula is thus $Ag_{0.62}K_{0.38}Nb_4AsO_{13}$. The results of the final refinement are reported in **Table III**. The atomic coordinates, fractional occupancies and isotropic displacement parameters are listed in **Table IV**.

Table III: Results of final refinement of $Ag_{0.62}K_{0.38}Nb_4AsO_{13}$ structure.

| | |
|---|-----------|
| R [$I > 2\sigma(I)$] | 0.0277 |
| $\omega R_2 (F^2)$ | 0.0755 |
| Goodness of fit (S) | 1.221 |
| Reflections | 665 |
| Parameters | 70 |
| Extinction coefficient | 0.0131(7) |
| $\Delta\rho_{\max} (e.\text{\AA}^{-3})$ | 1.176 |
| $\Delta\rho_{\min} (e.\text{\AA}^{-3})$ | -1.561 |

Table IV: Atomic coordinates, fractional occupancies and equivalent isotropic thermal factors in $Ag_{0.62}K_{0.38}Nb_4AsO_{13}$.

| Atoms | x | y | z | $U_{eq} (\text{\AA}^2)^{(*)}$ | Occup. ^(*) | Wyc. ^(*) |
|-------|-------------|--------------|-------------|-------------------------------|-----------------------|---------------------|
| Nb1 | 0.17186 (5) | 0.22970 (5) | 1/4 | 0.0055 (2) | 1 | 8g |
| Nb2 | 0.17648 (5) | 1/2 | 0 | 0.0055 (2) | 1 | 8e |
| As1 | 0 | 0.66002 (9) | 1/4 | 0.0069 (3) | 1 | 4c |
| Ag1 | 0 | -0.0486 (6) | 0.1705 (10) | 0.038 (3) | 0.15(6) | 8f |
| Ag2 | 0 | -0.0495 (6) | 1/4 | 0.085 (5) | 0.33(9) | 4c |
| K1 | 0 | -0.0635 (10) | 0.0593 (16) | 0.035 (2) | 0.19(2) | 8f |
| O1 | 0.1503 (3) | 0.3426 (3) | 0.1104 (4) | 0.0125 (7) | 1 | 16h |
| O2 | 0 | 0.1626 (6) | 1/4 | 0.0086 (13) | 1 | 4c |
| O3 | 0 | 0.5667 (4) | 0.1111 (4) | 0.0067 (8) | 1 | 8f |
| O4 | 0.2167 (3) | 0.0790 (3) | 0.1158 (3) | 0.0108 (7) | 1 | 16h |
| O5 | -0.1269 (4) | 0.7580 (4) | 1/4 | 0.0106 (9) | 1 | 8g |

$$^{(*)} U_{eq} = (1/3) \sum_i \sum_j U^{ij} a_i^* a_j^* a_i \cdot a_j.$$

^(*)Occup. : Occupancies

^(*)Wyc. : Wyckoff

4.3. Structure description

The structural unit of $Ag_{0.62}K_{0.38}Nb_4AsO_{13}$ is built from $As(1)O_4$ tetrahedron and two $Nb(1)O_6$ octahedra linked by sharing vertices and with $Nb(2)_2O_{10}$ groups formed from a pair of edge-sharing $Nb(2)O_6$ octahedra (**Figure 3**). The structure can be described as infinite chains of $(Nb(1)O_6-Nb(1)O_6-As(1)O_4)$ arranged along [100] (**Figure 4**). The junction between these strings is ensured with edge-sharing $Nb(2)O_6$ octahedra (**Figure 5**). It results in a three-dimensional framework delimiting large cavities, of hexagonal section, where Ag^+ and K^+ ions are located (**Figure 6**).

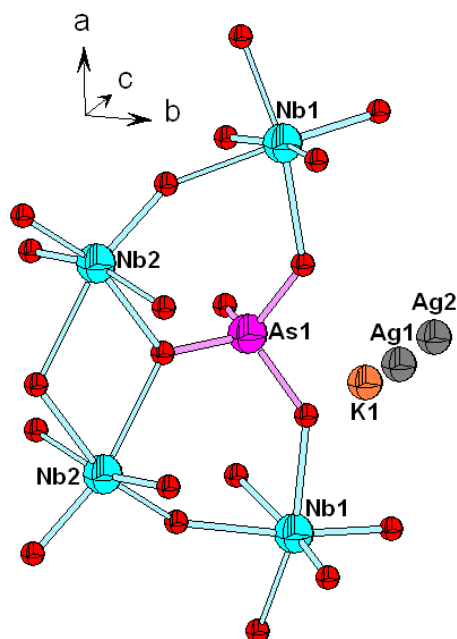


Figure 3: Representation of the structural unit of $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$.*

The main interatomic distances are given in **Table V**.

Table V: Main interatomic distances (Å) in $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$.

| As1O₄ tetrahedron | | | |
|-------------------------------------|------------|-------------------------|------------|
| As1 – O5 ^(b) | 1.673 (5) | As1 – O3 | 1.701 (4) |
| As1 – O5 | 1.673 (5) | As1 – O3 ^(a) | 1.701 (4) |
| Nb1O₆ octahedron | | | |
| Nb1 – O1 ^(b) | 1.845 (3) | Nb1 – O5 ^(c) | 2.121 (5) |
| Nb1 – O1 | 1.845 (3) | Nb1 – O4 | 2.124 (3) |
| Nb1 – O2 | 1.926 (3) | Nb1 – O4 ^(b) | 2.124 (3) |
| Nb2O₆ octahedron | | | |
| Nb2 – O4 ^(d) | 1.810 (3) | Nb2 – O1 | 2.002 (3) |
| Nb2 – O4 ^(e) | 1.810 (3) | Nb2 – O3 ^(g) | 2.264 (3) |
| Nb2 – O1 ^(f) | 2.002 (3) | Nb2 – O3 | 2.264 (3) |
| Ag1O₃ polyhedron | | | |
| Ag1 – O2 | 2.347 (18) | Ag1 – O5 ^(h) | 2.544 (19) |
| Ag1 – O5 ⁽ⁱ⁾ | | 2.544 (19) | |
| Ag2O₃ polyhedron | | | |
| Ag2 – O2 | 2.216 (9) | Ag2 – O5 ⁽ⁱ⁾ | 2.408 (7) |
| Ag2 – O5 ^(h) | | 2.408 (7) | |
| K1O₇ polyhedron | | | |
| K1 – O4 | 2.770 (8) | K1 – O5 ^(h) | 2.985 (12) |
| K1 – O4 ^(a) | 2.770 (8) | K1 – O5 ⁽ⁱ⁾ | 2.985 (12) |
| K1 – O4 ⁽ⁱ⁾ | 2.864 (11) | K1 – O2 | 3.048 (16) |
| K1 – O4 ^(k) | | 2.864 (1) | |

* The CIF file corresponding to the studied structure has been deposited in the database of FIZ Karlsruhe Number: CSD 422384.

Symmetry transformations used to generate equivalent atoms: (a): $-x, y, z$; (b): $x, y, -z+1/2$; (c): $x+1/2, y-1/2, z$; (d): $-x+1/2, y+1/2, z$; (e): $-x+1/2, -y+1/2, -z$; (f): $x, -y+1, -z$; (g): $-x, -y+1, -z$; (h): $-x, y-1, z$; (i): $x, y-1, z$; (j): $-x, -y, -z$; (k): $x, -y, -z$.

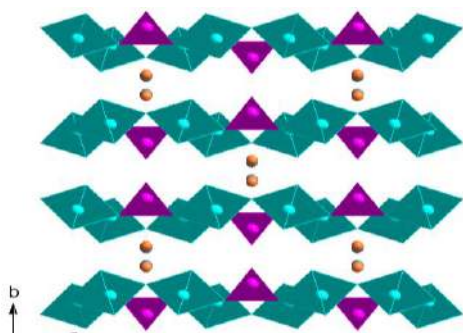


Figure 4: Representation of strings.

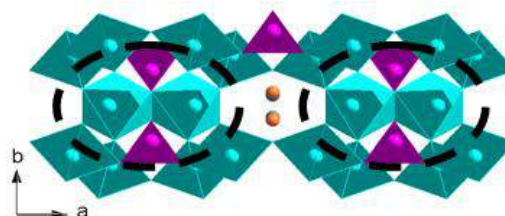


Figure 5: Junction between channels.

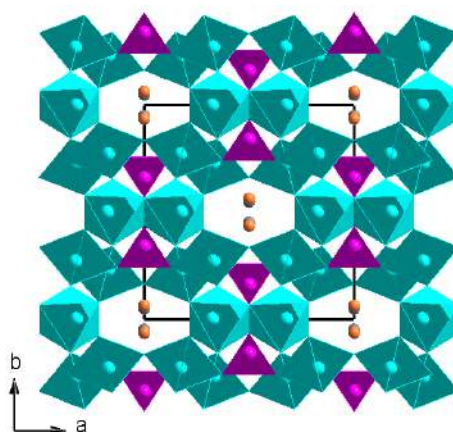


Figure 6: Projection of the structure along c axis.

4.4. Comparison of $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$ structure

The compounds $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$, $\text{Ag}_{0.2}\text{K}_{0.8}\text{Nb}_4\text{AsO}_{13}$ [17], $\text{KNb}_4\text{AsO}_{13}$ [18] and $\text{NaNb}_4\text{AsO}_{13}$ [19] are isostructural. They have the same anionic framework. However, a difference occurs at the asymmetric unit. Indeed, in the following compounds: $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$, $\text{Ag}_{0.2}\text{K}_{0.8}\text{Nb}_4\text{AsO}_{13}$ and $\text{NaNb}_4\text{AsO}_{13}$, the asymmetric unit is linear and consists of two NbO_6 octahedra and one AsO_4 tetrahedra (Figure 7a), while in $\text{KNb}_4\text{AsO}_{13}$, it comes in the form of a cyclic unit built of two NbO_6 octahedra and one AsO_4 tetrahedra (Figure 7b).

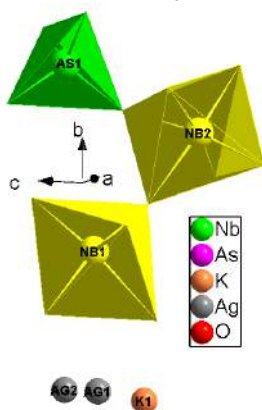


Figure 7a: Asymmetric unit of $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$.

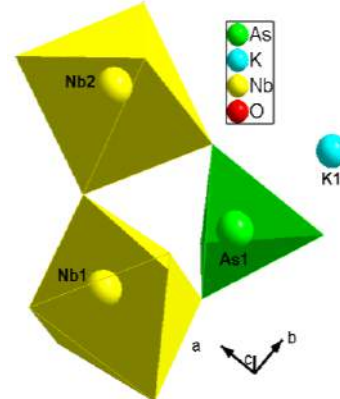


Figure 7b: Asymmetric unit of $\text{KNb}_4\text{AsO}_{13}$.

If the first coordination sphere is limited to radius equal to 3 Å according to Shannon [26], the environments of Na⁺, K⁺ and Ag⁺ ions are different. The figures 8, 9, 10 and 11 illustrate the coordination of these ions.

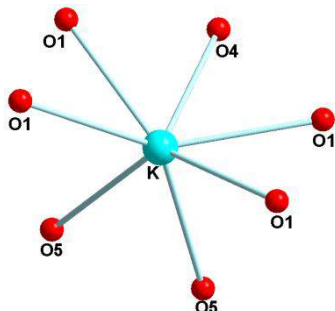


Figure 8: The K⁺ environment in KNb₄AsO₁₃.

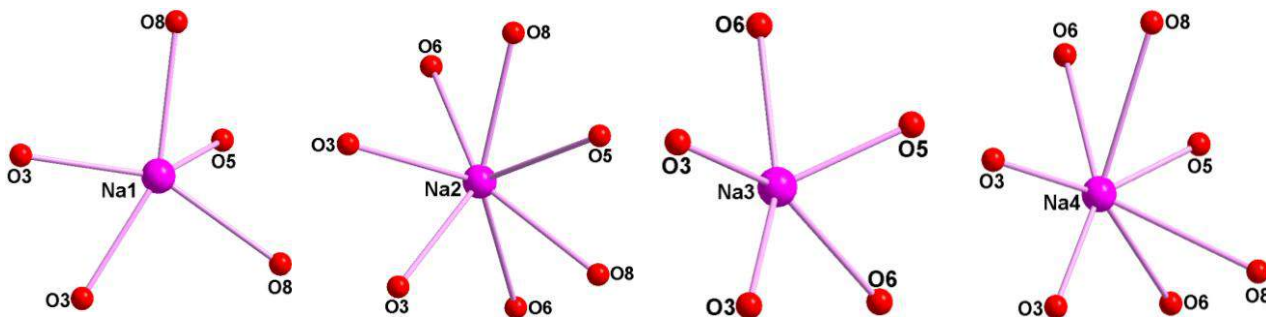


Figure 9: The Na⁺ environment in NaNb₄AsO₁₃.

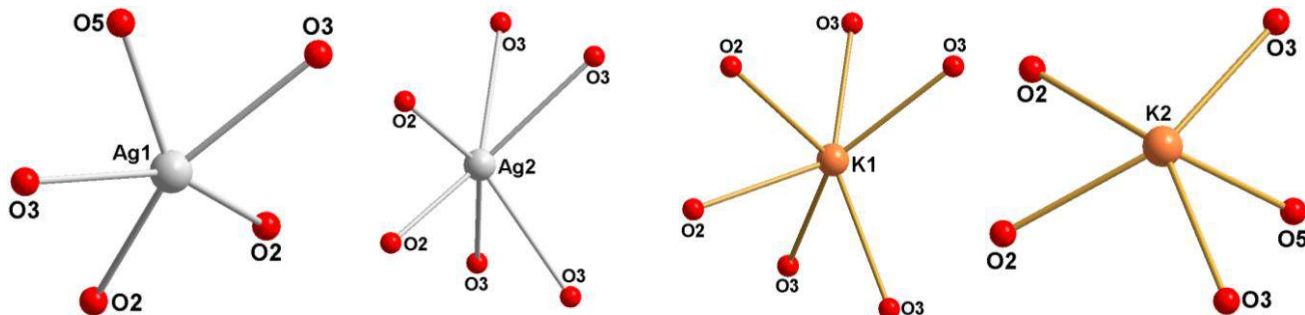


Figure 10: The K⁺ and Ag⁺ environments in Ag_{0.2}K_{0.8}Nb₄AsO₁₃.

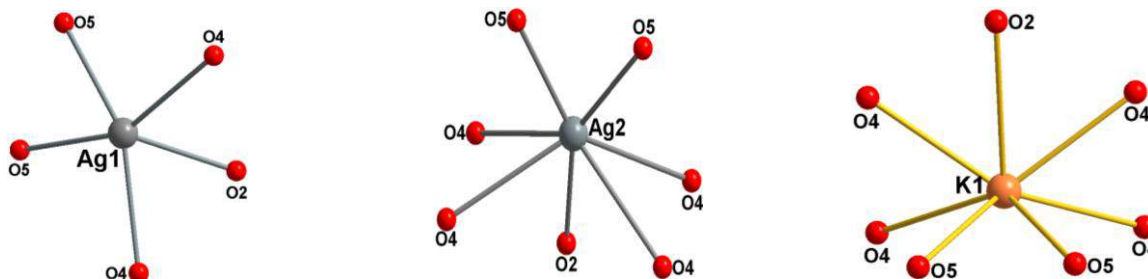


Figure 11: The K⁺ and Ag⁺ environments in Ag_{0.62}K_{0.38}Nb₄AsO₁₃.

5. IONIC CONDUCTIVITY

5.1. Cell preparation

The electrical properties of the title compound have been investigated using complex impedance spectroscopy (CIS), which is an important tool to examine the electrical properties of a polycrystalline material by means of the correlation between the sample electrical behavior and its microstructure.

Impedance measurements were carried out in a Hewlett-Packard 4192-A automatic bridge monitored by a HP microcomputer. The frequency/temperature ranges are 0.01-13000kHz/330-610°C, respectively. Pellets of 13mm diameter and 1.82mm thickness were prepared by pressing the powder sample at 12 tones. Then the pellets were sintered at 500°C for 12 hours in order to improve continuity between the grains. Silver electrodes were painted in the two faces of the pellets with a silver paste to ensure good electrical contact.

5.2. Experimental results

Typical complex plots of imaginary part of impedance $-Z''$ versus the real part Z' at various temperatures ($Z^* = Z' - jZ''$) are shown in **figure 12** in which semicircles are observed. The presence of semicircles arcs indicates that the electrical process of this material is due to the contribution of grain, the second arc due to the grain boundaries are either masked by the first arc or completely absent in the diagram. The ionic conductivity as function of the temperature has been obtained from the values of intercept of the extrapolated high-frequency semicircles with the real axis (**Figure 13**).

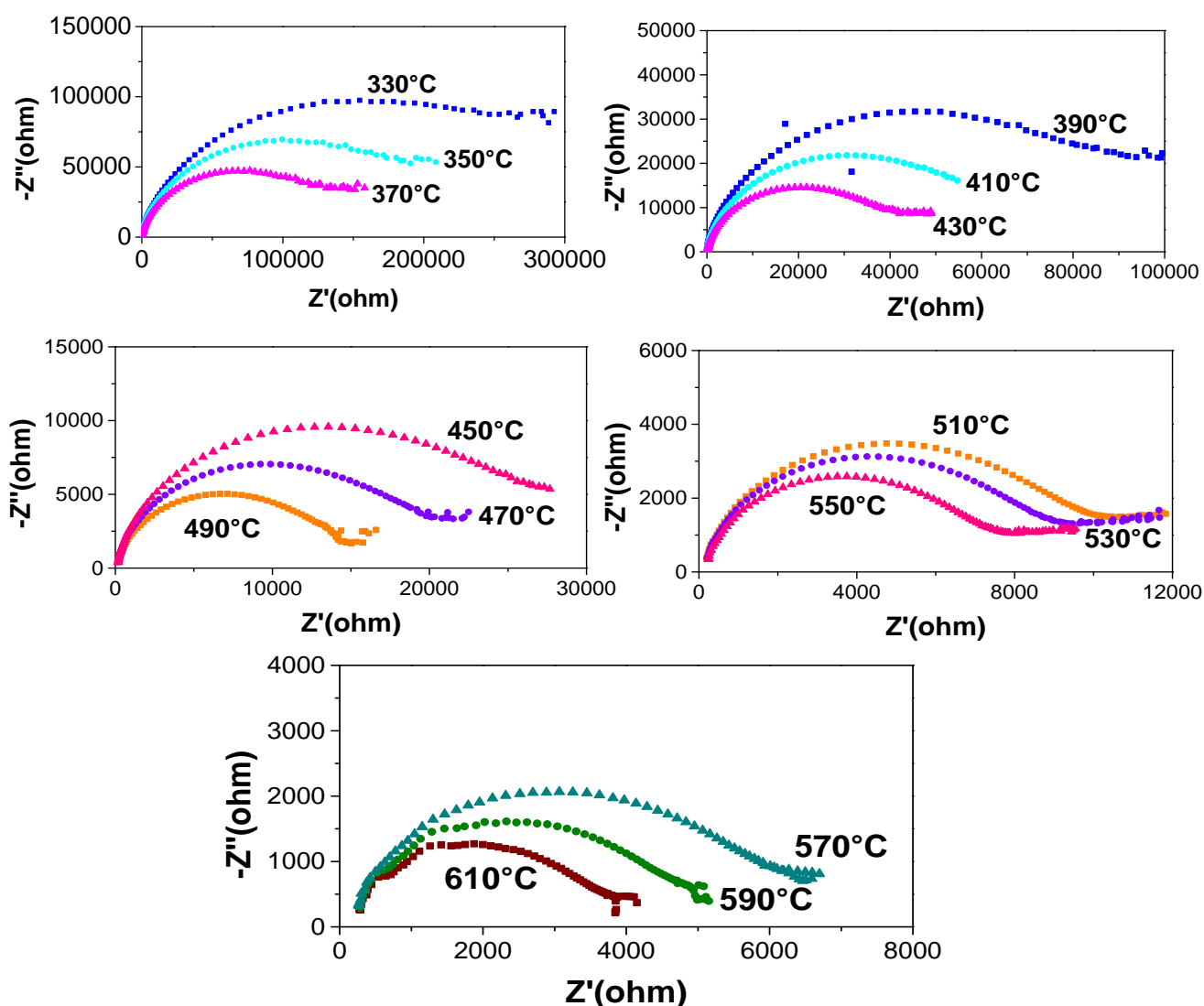


Figure 12: Complex impedance diagrams for $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$ over temperature range 450 and 610°C.

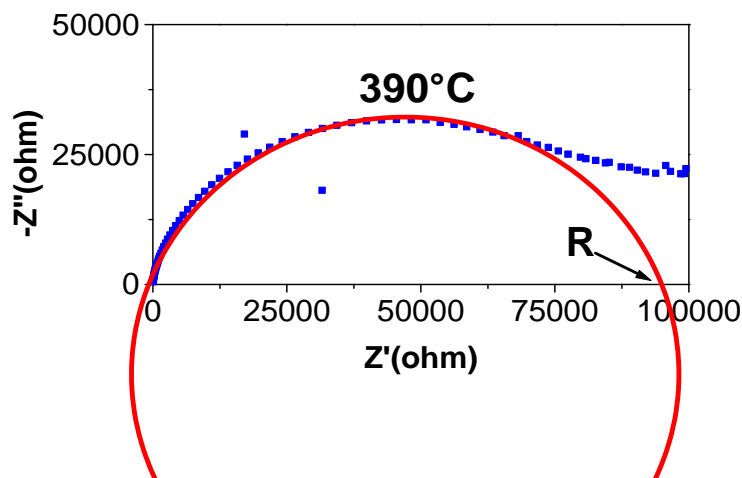


Figure 13: Determination method of R at 390°C.

Conductivity results lead to the values listed in **Table VI**.

Table VI: Conductivity measurements values.

| | | | | | |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| T (°C) | 330 | 350 | 370 | 390 | 410 |
| σ ($\Omega^{-1} \cdot \text{cm}^{-1}$) | 3.98×10^{-7} | 5.89×10^{-7} | 8.28×10^{-7} | 1.24×10^{-6} | 1.91×10^{-6} |
| T (°C) | 430 | 450 | 470 | 490 | 510 |
| σ ($\Omega^{-1} \cdot \text{cm}^{-1}$) | 3.03×10^{-6} | 4.51×10^{-6} | 6.66×10^{-6} | 9.02×10^{-6} | 1.39×10^{-5} |
| T (°C) | 530 | 550 | 570 | 590 | 610 |
| σ ($\Omega^{-1} \cdot \text{cm}^{-1}$) | 1.54×10^{-5} | 1.90×10^{-5} | 2.36×10^{-5} | 3.01×10^{-5} | 3.87×10^{-5} |

The conductivity variation indicates an increase of conductivity with rise in temperature with a typical Arrhenius-type behavior linear dependence of thermal conductivity logarithm $\text{Ln}(\sigma T)$ on inverse of temperature $10^4/T$ (K^{-1}) (**Figure 14**). This type of temperature dependence of the conductivity indicates that the electrical conduction in the materials is a thermally activated process. It can be explained in accordance with the expression: $\sigma T = A_0 \exp(-E_a/kT)$, where A_0 is the pre-exponential factor, E_a the activation energy, T the absolute temperature and k the Boltzmann constant.

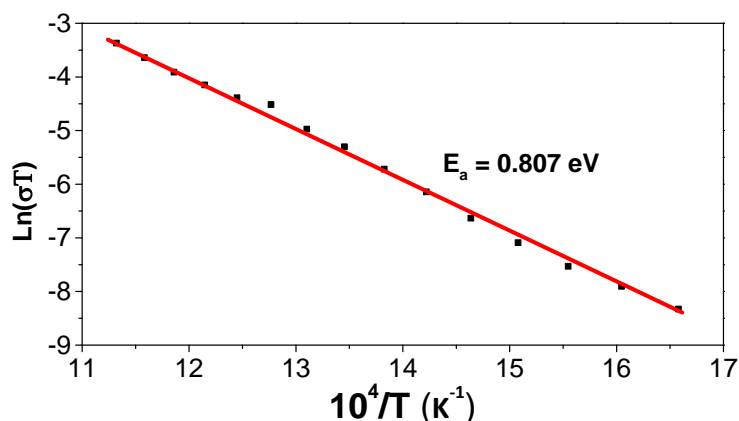


Figure 14: Arrhenius plot of conductivity for $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$.

5.3. Structural interpretation of the ionic conductivity

The conductivity value σ is $3.87 \times 10^{-5} \Omega^{-1} \text{cm}^{-1}$ at 883K and the ionic jump activation energy is $E_a = 0.807 \text{eV}$. The ionic conductivity of this material is allotted to dimensions of the channels sections. The bottleneck widths of the channels vary from 5.347 to 6.062 Å (**Figure 15**) and thus they result bigger than the geometrical size sum of 4.94 and 5.68 Å corresponding respectively to $2 \times (r_{\text{Ag}^+} + r_{\text{O}^{2-}}) = 2 \times (1.09 + 1.38)$ and to $2 \times (r_{\text{K}^+} + r_{\text{O}^{2-}}) = 2 \times (1.46 + 1.38)$ [26].

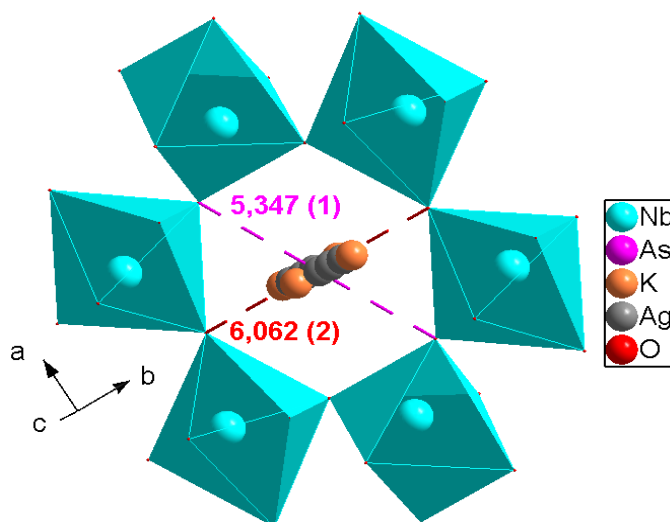


Figure 15: View of the shape and size of the tunnel sections in $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$.

The fact that Ag^+ and K^+ ions occupy a part of their crystallographic sites is not sufficient for a good conductivity and this can be explained by the presence of low anisotropic thermal factors of $\text{Ag}^+(1)$ and K^+ ions in different directions (**Table VII**). Although, the anisotropic thermal factor along the direction [001] of $\text{Ag}^+(2)$ ion is high, the ionic conductivity of the material is modest and this is due to the displacement of $\text{Ag}^+(2)$ which is probably blocked by K^+ ion. The cation K^+ is larger for the ionic conductivity.

Table VII: Anisotropic thermal factors (\AA^2).

| Atoms | U_{11} | U_{22} | U_{33} | U_{12} | U_{13} | U_{23} |
|------------|----------|----------|----------|----------|----------|----------|
| K | 0.01196 | 0.02963 | 0.05498 | 0.00000 | 0.00000 | 0.00736 |
| Ag1 | 0.02367 | 0.00738 | 0.09248 | 0.00000 | 0.00000 | 0.00259 |
| Ag2 | 0.05707 | 0.00650 | 0.19754 | 0.00000 | 0.00000 | 0.00000 |

The conductivity value σ is $3.87 \times 10^{-5} \Omega^{-1} \text{cm}^{-1}$ at 883K and the activation energy for ions migration deduced from the slope is $E_a = 0.807 \text{eV}$, then $\text{Ag}_{0.62}\text{K}_{0.38}\text{Nb}_4\text{AsO}_{13}$ can be placed in the family of mild ionic conductors, comparable to those found for other compounds [27-32] in **table VIII**.

Table VIII: Conductivity σ ($\Omega^{-1} \text{cm}^{-1}$) and conduction activation energy E_a (eV) of other compounds.

| Compound | Temperature range (K) | E_a (eV) | σ ($\Omega^{-1} \text{cm}^{-1}$) | Reference |
|--|-----------------------|------------|--|-----------|
| Low ionic conductors ($E_a > 1 \text{eV}$) | | | | |
| $\text{Na}_3\text{Sb}_3\text{As}_2\text{O}_{14}$ | 688 - 752 | 1.900 | $\sigma_{688\text{K}} = 0.45 \times 10^{-6}$ | [27] |
| $\text{K}_4\text{Ni}_7(\text{AsO}_4)_6$ | 671 - 908 | 1.390 | $\sigma_{750\text{K}} = 0.99 \times 10^{-6}$ | [28] |
| $\text{Rb}_2\text{MoO}_2\text{As}_2\text{O}_7$ | 712 - 771 | 1.351 | $\sigma_{750\text{K}} = 2.16 \times 10^{-6}$ | [29] |
| $\text{K}_2\text{MoO}_2\text{As}_2\text{O}_7$ | 652 - 851 | 1.232 | $\sigma_{750\text{K}} = 1.80 \times 10^{-6}$ | [29] |
| $\text{KMoO}_2\text{AsO}_4$ | 663 - 843 | 1.230 | $\sigma_{750\text{K}} = 3.90 \times 10^{-6}$ | [29] |

| Mild ionic conductors | | | | | |
|--|-----------|-------|---------------------------------------|------|--|
| β -LiMoO ₂ AsO ₄ | 623 - 738 | 0.904 | $\sigma_{738K} = 0.78 \times 10^{-5}$ | [30] | |
| NaMoO ₂ AsO ₄ | 623 - 773 | 0.897 | $\sigma_{750K} = 1.50 \times 10^{-5}$ | [29] | |
| RbMoO ₂ AsO ₄ | 685 - 781 | 0.795 | $\sigma_{750K} = 0.81 \times 10^{-5}$ | [29] | |
| Ag _{0.62} K _{0.38} Nb ₄ AsO ₁₃ (*) | 603 - 883 | 0.807 | $\sigma_{883K} = 3.87 \times 10^{-5}$ | (*) | |
| Good ionic conductors | | | | | |
| Li ₃ Sc ₂ (AsO ₄) ₃ | 400 - 600 | 0.910 | $\sigma_{600K} = 1.40 \times 10^{-3}$ | [31] | |
| Li ₃ In ₂ (AsO ₄) ₃ | 400 - 600 | 0.901 | $\sigma_{600K} = 1.20 \times 10^{-3}$ | [31] | |
| Li ₃ Fe ₂ (AsO ₄) ₃ | 400 - 600 | 0.710 | $\sigma_{600K} = 7.60 \times 10^{-3}$ | [31] | |
| Very good ionic conductors | | | | | |
| K ₃ Sc ₂ (AsO ₄) ₃ | 300 - 600 | 0.570 | $\sigma_{600K} = 0.52 \times 10^{-3}$ | [32] | |
| Na ₃ Sc ₂ (AsO ₄) ₃ | 400 - 600 | 0.460 | $\sigma_{600K} = 1.70 \times 10^{-3}$ | [31] | |

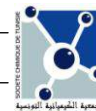
(*)This work

6. CONCLUSION

This study has highlighted the existence of a new material Ag_{0.62}K_{0.38}Nb₄AsO₁₃ characterized by an open framework delimiting channels where Ag⁺ and K⁺ ions are located. Measurements of ionic conductivity versus temperature show that this material can be placed in the family of mild ionic conductors.

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