

39 (NH₄)₂SO₄ family

39A Pure compounds

No. 39A-1 (NH₄)₂SO₄, Ammonium sulfate

(*M* = 132.13; [D: 140.19])

1a	Ferroelectric activity in (NH ₄) ₂ SO ₄ was discovered by Matthias and Remeika in 1956.		56Mat
b	phase	II ^{a)}	I ^{a)} ^{a)} 56Mat
	state	F ^{a)}	P ^{a)}
	crystal system	orthorhombic ^{b)}	orthorhombic ^{b)} ^{b)} 66Sch
	space group	Pna2 ₁ –C _{2v} ⁹ ^{b)}	Pnam–D _{2h} ¹⁶ ^{b)}
	Θ [°C]	–49.5 ^{a)}	
	<i>P_s</i> [001].		58Hos
	ρ = 1.55 · 10 ³ kg m ^{–3} at RT.		58Hos
	Transparent, colorless.		58Hos
2a	Crystal growth: cooling method from aqueous solution.		62Kaf
	Solubility in water.		62Kaf
b	Crystal form: Fig. 39A-1-001.		
3a	Unit cell parameters:		
	<i>a</i> = 7.782 Å, <i>b</i> = 10.636 Å, <i>c</i> = 5.993 Å at RT.		66Sch
	<i>a</i> = 7.837(7) Å, <i>b</i> = 10.01(1) Å, <i>c</i> = 5.967(6) Å at 180 K.		66Sch
	Unit cell parameters: Table 39A-1-001.		
b	<i>Z</i> = 4 in phase I and II.		66Sch
	Crystal structure determined by neutron diffraction:		
	Table 39A-1-002, Table 39A-1-003, Table 39A-1-004, Table 39A-1-005,		
	Table 39A-1-006, Table 39A-1-007, Table 39A-1-008, Table 39A-1-009,		
	Table 39A-1-010; Fig. 39A-1-002, Fig. 39A-1-003.		
	Crystal structure determined by X-ray diffraction:		
	Table 39A-1-011, Table 39A-1-012, Table 39A-1-013.		
	Thermal motions of SO ₄ : see Table 39A-3-005, Table 39A-3-006 in No. 39A-3.		
4	Thermal expansion: Fig. 39A-1-004, Fig. 39A-1-005.		
5a	Dielectric constant: Fig. 39A-1-006, Fig. 39A-1-007; see also		73Ike
	Dielectric anomaly around 403...413 K: Fig. 39A-1-008;		
	see also		93Son,
	<i>T</i> > Θ _f , κ _c – κ _∞ = <i>C</i> /(<i>T</i> – Θ _p), κ _∞ = 9.4(2), <i>C</i> = 29(2) K, Θ _p = 214.8(4) K, Θ _f = 233 K.		96Kim1
	dΘ _f /d <i>p</i> = –4.1 · 10 ^{–8} K Pa ^{–1} (up to 6 · 10 ^{–8} Pa) for (NH ₄) ₂ SO ₄ .		76Mes
	dΘ _f /d <i>p</i> = –5.2 · 10 ^{–8} K Pa ^{–1} (up to 6 · 10 ^{–8} Pa) for [(NH ₄) ₂ SO ₄] _{0.9} [NH ₄ BeF ₃] _{0.1} .		72Tsu
	Fig. 39A-1-009; see also		72Tsu
	Dielectric dispersion: Fig. 39A-1-010, Fig. 39A-1-011, Fig. 39A-1-012.		
	For κ' and κ'' in infrared region, see subsection 9a.		
b	Effect of <i>E</i> _{bias} on κ _c : Fig. 39A-1-013, Fig. 39A-1-014.		
c	Spontaneous polarization: Fig. 39A-1-015; see also		58Hos

6a	Heat capacity: Fig. 39A-1-016, Fig. 39A-1-017. $\Delta Q_m = 3900 \text{ J mol}^{-1}$, $\Delta S_m = 17.6 \text{ J K}^{-1} \text{ mol}^{-1}$.	58Hos
7a	Electromechanical coupling: Fig. 39A-1-018.	
b	Electrostriction: Fig. 39A-1-019.	
8a	Elastic compliance: Fig. 39A-1-020. Elastic stiffness: Table 39A-1-014; Fig. 39A-1-038 in subsection 10b.	
9a	Refractive indices: Table 39A-1-015. Birefringences: Fig. 39A-1-021. κ' and κ'' in infrared region: Fig. 39A-1-022, Fig. 39A-1-023, Fig. 39A-1-024, Fig. 39A-1-025, Fig. 39A-1-026. See also Absorption bands of Tl-doped crystal: see	85Kwu 87Abe
b	Electrooptic effect: Fig. 39A-1-027, Fig. 39A-1-028.	
c	Piezoelectric constant: Table 39A-1-016, Table 39A-1-017.	
d	Gyration tensor: Fig. 39A-1-029, Fig. 39A-1-030.	
e	Nonlinear optical susceptibility: Table 39A-1-018; Fig. 39A-1-031.	
10a	Raman scattering: Fig. 39A-1-032, Fig. 39A-1-033, Fig. 39A-1-034, Fig. 39A-1-035, Fig. 39A-1-036, Fig. 39A-1-037. Raman scattering from the internal modes associated with (SO ₄) ²⁻ and (NH ₄) ⁺ ions: see	73Jai
b	Brillouin scattering: Fig. 39A-1-038.	
11	Electrical conductivity: Fig. 39A-1-039, Fig. 39A-1-040. Electrical conduction: see $\sigma_b = \sigma_0 \exp(-\Delta U/kT)$, $\Delta U = 0.76 \text{ eV}$, $\sigma_0 = 2.9 \cdot 10^{13} \Omega^{-1} \text{ m}^{-1}$. Effects of heat treatment on σ , and effects of surface layer on σ : see Mobility μ : see	81Sya 63Sch 74Kha 74Kha
13a	NMR of proton and deuteron: Fig. 39A-1-041, Fig. 39A-1-042, Fig. 39A-1-043, Fig. 39A-1-044, Fig. 39A-1-045, Fig. 39A-1-046, Fig. 39A-1-047. NMR of ¹⁴ N: Fig. 39A-1-048. ¹⁴ N quadrupole coupling constants and asymmetry parameters at 296.1 K: (e^2qQ/h) _I = 154.53 kHz, (e^2qQ/h) _{II} = 115.71 kHz, $\eta_I = 0.684$, $\eta_{II} = 0.749$ (subscripts I and II point to two chemically nonequivalent sets of N sites in the unit cell). See also NMR of ¹⁵ N: see NMR of ¹⁷ O: Fig. 39A-1-049, Fig. 39A-1-050.	80Bat 72Bli 72Gib, 87Gru
b	ESR of (NH ₃) ⁺ : Fig. 39A-1-051; see also ESR of (NH ₂) ⁺ : see ESR of (SeO ₃) ⁻ : Table 39A-1-019; see also ESR of (CrO ₄) ³⁻ : Table 39A-1-020. ESR of (CrO ₃) ⁻ : see ESR of (VO) ²⁺ : Table 39A-1-021, Table 39A-1-022, Table 39A-1-023; see also ESR of Mn ²⁺ : Fig. 39A-1-052, Fig. 39A-1-053. ESR of Cd ⁺ : Fig. 39A-1-054. ESR of Cu ²⁺ : Table 39A-1-024; see also ESR of Cr ³⁺ : see	88Bai, 77Fuj 82Bai 76Shi 84Mis 78Fuj, 85Bra 79Mat 90Yu

ESR of Tl ²⁺ : see		92Gui, 92Gri
14b	X-ray diffuse scattering: Fig. 39A-1-055, Fig. 39A-1-056. Strong streaks were observed along the a^* axis at temperatures just above Θ_f .	77Has
15a	Striped domain structure was observed by dew method. Observation by the method of X-ray topography: see	64Str 83Kla, 95Bha
16	Observation of phase boundary by X-ray topography: see	95Bha