LTL

LTL.1 Zeolite framework type and topology

The designation of the FTC refers to **L**inde **T**ype **L**, a synthetic aluminosilicate with composition $K_6Na_3Al_9Si_{27}O_{72} \cdot 21H_20$, first synthesized and described in [68Bre1, ref. cited after 89New1, 68Bre2]. The crystal structure was solved by Barrer and Villiger [69Bar1] in space group *P* 6/*mmm*. A natural counterpart of zeolite L, the mineral perlialite, was found in russian alkaline rocks [84Men1, 86Kon1, refs. cited after 90Art1] and structurally characterized by Artioli and Kvick [90Art1]. The framework structure (Fig. LTL.1.1) consists of 12-ring channels (**lel** units, Fig. LTL.1.3) formed by *lil* ($4^{12}4^68^612^2$) units linked by pillars (**ofr** units) of alternating *can* ($4^66^36^2$) and *hpr* (4^66^2) units, and 8-ring channels (**kbi** units) formed by alternating *ste* (4^28^4) and *kaa* (6^28^2) units as shown in Fig. LTL.1.2.

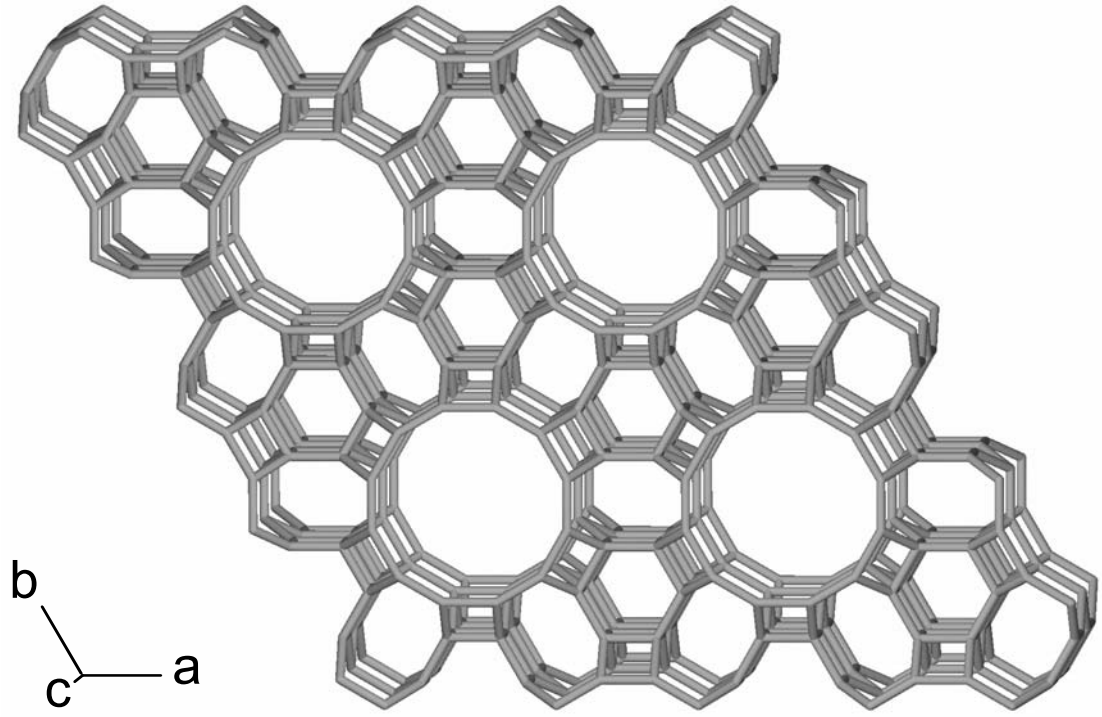
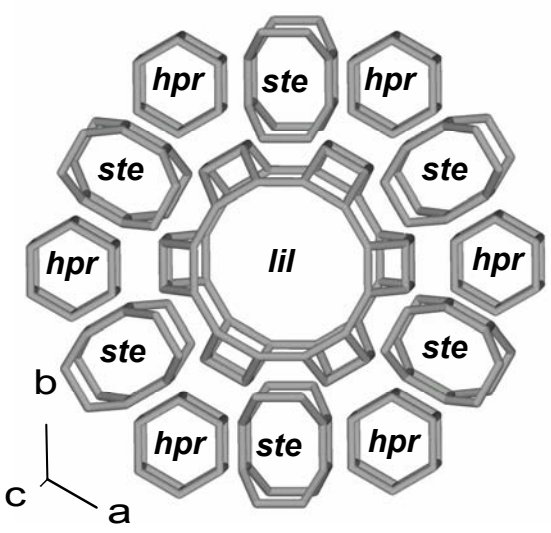
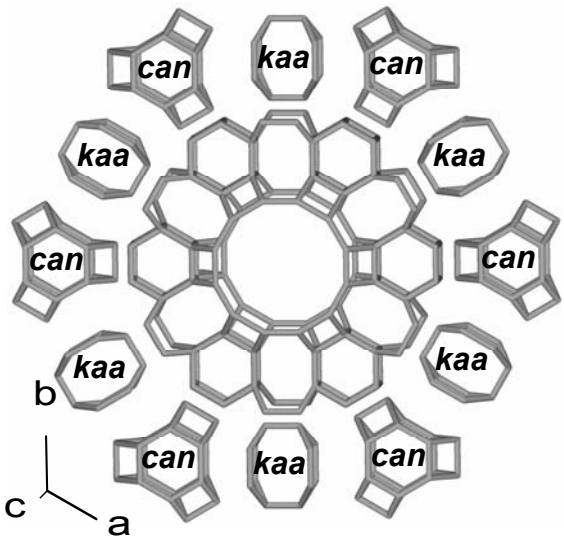


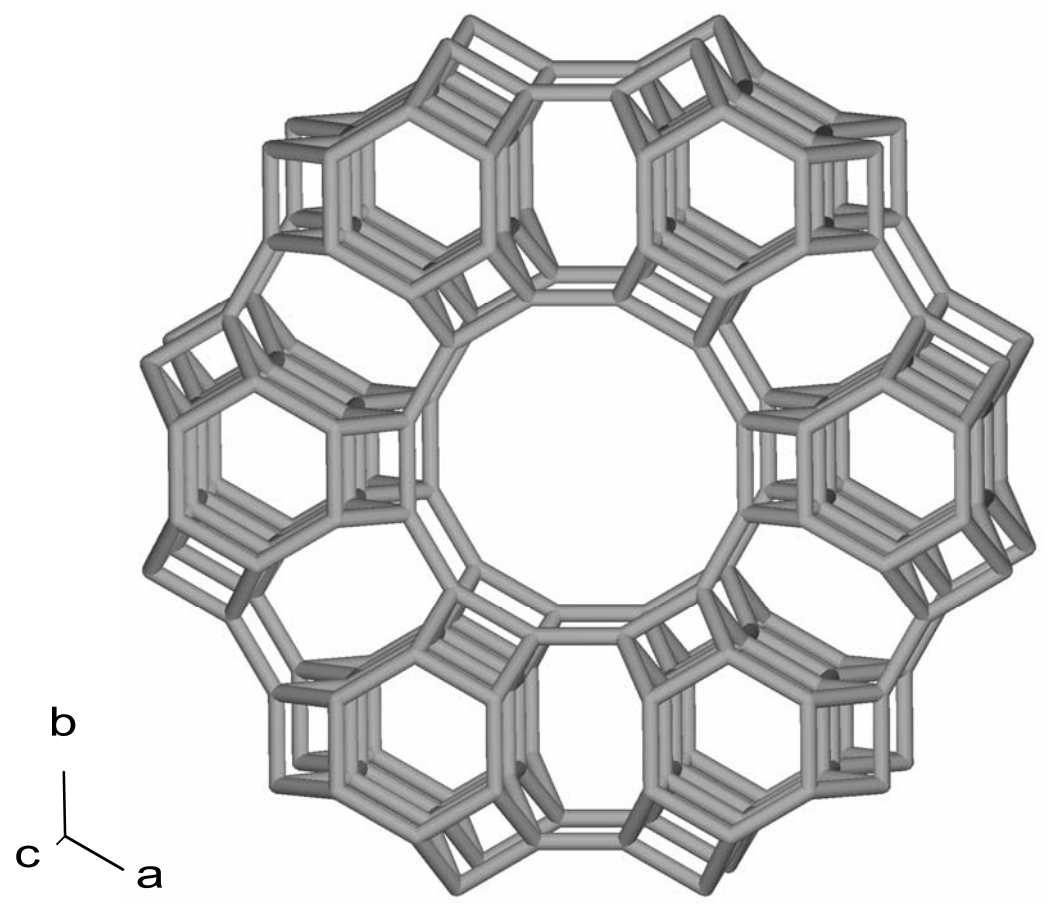
Fig. LTL.1.1. The framework structure of LTL-type compounds in the highest possible topological symmetry *P* 6/*mmm* (LTL1989a01, 89New1). View parallel [001] rotated by 5° about [100] and [120].



a Linkage of *ste* and *hpr* units enclosing the *lil* unit.



b Second layer formed by *can* and *kaa* units.



c The assemblage shown in b) with front and rear layers of *can* and *kaa* units.

Fig. LTL.1.2. Building scheme of LTL-type compounds. View parallel [001] rotated by 6° about [210] and [010]. Figures are on different scales.

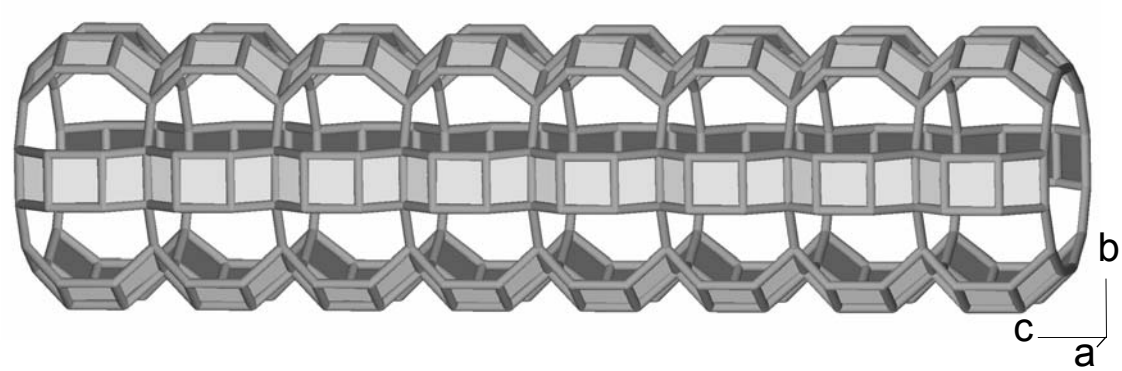


Fig. LTL.1.3. 12-ring channel (**lel** unit) formed by *lil* units. 4-rings are drawn nontransparently. View parallel [210] rotated by 6° about [001] and 12° about [010].

LTL.2 Compounds and crystal data

Table LTL.2.1 Chemical data.

FD = framework density CE = cation exchange TT = thermal treatment REF = reference
SM = source of material SR = sorbate T = temperature of thermal treatment [K]

code	chemical composition	FD	SM	CE	SR	TT	T	REF
P* 6/*m m m								
LTL1969a01	$K_6Na_3 \cdot Al_9Si_{27}O_{72} \cdot 21H_2O$	16.3	S	-	H_20	-	-	69Bar1
LTL1972a01	$K_{2.7}Ba_{7.65} \cdot Al_{18}Si_{18}O_{72} \cdot 23H_2O$	15.8	S	-	H_20	-	-	72Bae1
LTL1985a01	$K_{10.3} \cdot Ga_{10.3}Si_{25.7}O_{72}$	15.9	S	-	-	D	n.s.	85Wri1
LTL1985a02	$K_{10.3} \cdot Ga_{10.3}Si_{25.7}O_{72} \cdot 1.5C_5D_5N$	15.9	S	-	pyridine	D	n.s.	85Wri1
LTL1986a01	$K_9 \cdot Ga_9Si_{27}O_{72}$	16.1	S	-	-	D	673	86New1, 86New2
LTL1988a01	$Si_{36}O_{72}$	16.4		-	-	-	-	88van1
LTL1989a01	$K_9 \cdot Al_9Si_{27}O_{72}$	16.3	S	-	-	D	673	89New1
LTL1989a02	$K_9 \cdot Al_9Si_{27}O_{72}$	16.3	S	-	-	D	673	89New1
LTL1989a03	$K_9 \cdot Al_9Si_{27}O_{72} \cdot 1.12C_6D_6$	16.3	S	-	benzene	D	673	89New1
LTL1990a01	$K_8Tl_4 \cdot Al_{12}Si_{24}O_{72} \cdot 20H_2O$	16.1	M[1])	-	H_20	-	-	90Art1
LTL1990a02	$K_8Tl_4 \cdot Al_{12}Si_{24}O_{72} \cdot 20H_2O$	16.0	M[1])	-	H_20	-	-	90Art1
LTL1990b01	$K_{4.62}Na_{6.12} \cdot Al_9Si_{27}O_{72} \cdot 19H_2O$[2])	16.4	S	Na	H_20	-	-	90Sat1
LTL1990b02	$K_{4.70}Sr_{1.43} \cdot Al_9Si_{27}O_{72} \cdot 12H_2O$[2])	16.4	S	Sr	H_20	-	-	90Sat1
LTL1990b03	$Ba_{1.13}K_{5.22} \cdot Al_9Si_{27}O_{72} \cdot 18H_2O$[2])	16.4	S	Ba	H_20	-	-	90Sat1
LTL1990b04	$Cs_{3.68}K_{5.63} \cdot Al_9Si_{27}O_{72} \cdot 8H_2O$[2])	16.2	S	Cs	H_20	-	-	90Sat1
LTL1992a01	$K_{9.50} \cdot Al_{9.5}Si_{26.5}O_{72} \cdot 25.5H_2O$	16.4	S	-	H_20	-	-	92Hir1
LTL1992a02	$K_{5.14}H_{4.36} \cdot Al_{9.5}Si_{26.5}O_{72} \cdot 25.5H_2O$	16.3	S	-	H_20	-	-	92Hir1
LTL1992a03	$K_{2.25}H_{7.25} \cdot Al_{9.5}Si_{26.5}O_{72} \cdot 25.5H_2O$	16.2	S	-	H_20	-	-	92Hir1
LTL1993a01	$K_{9.59} \cdot Al_{6.45}Fe_{3.18}Si_{26.37}O_{72} \cdot 20.53H_2O$	16.1	S	-	H_20	-	-	93Pic1
LTL1994a01	$K_9 \cdot Al_9Si_{27}O_{72}$	16.2	S	-	-	D	n.s.	94And1
LTL1994a02	$K_{10} \cdot Al_9Si_{27}O_{72}$	16.3	S	K	-	D	n.s.	94And1

[1]) perlialite [2]) Si : Al = 3 : 1 assumed

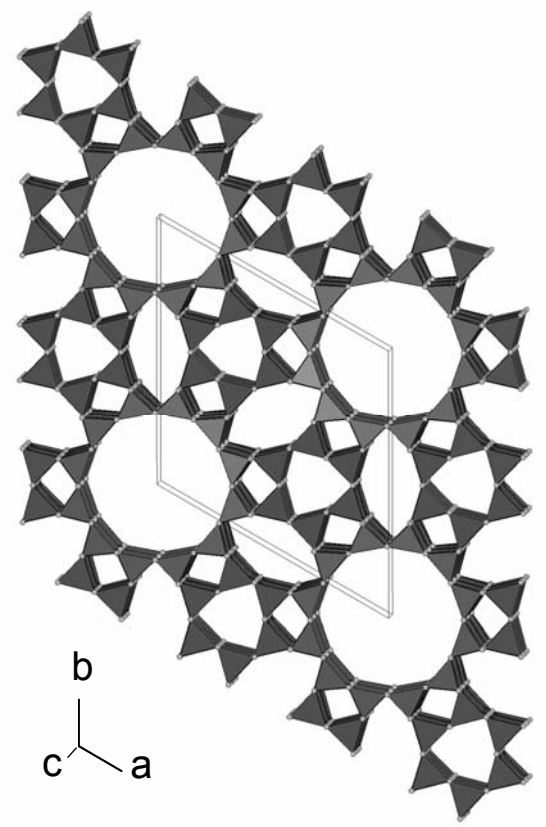
Table LTL.2.1 (continued).

code	chemical composition	FD	SM	CE	SR	TT	T	REF
LTL1997a01	$K_9 \cdot Al_9Si_{27}O_{72}$	16.2	S	-	-	D	723	97And1
LTL1997a02	$K_{10} \cdot Al_9Si_{27}O_{72}$	16.3	S	K	-	D	723	97And1
LTL1997a03	$K_{12} \cdot Al_9Si_{27}O_{72}$	16.4	S	K	-	D	723	97And1
LTL1997a04	$K_{14} \cdot Al_9Si_{27}O_{72}$	16.4	S	K		D	723	97And1

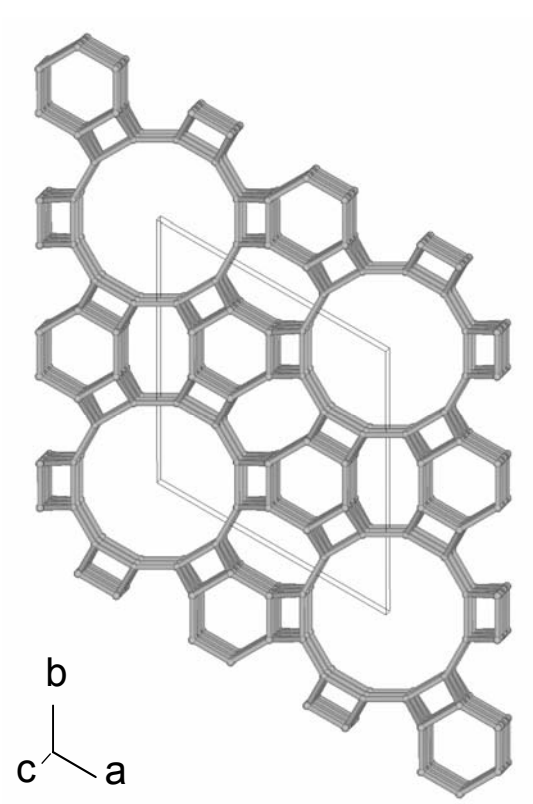
Table LTL.2.2 Structural parameters of LTL-type compound.

code	*a* [Å]	*c* [Å]	*V* [Å^3]	*T* [K]	reference
P* 6/*m m m					
LTL1969a01	18.40(4)	7.52(3)	2205	n.s.	69Bar1
LTL1972a01	18.701(2)	7.501(1)	2272	n.s.	72Bae1
LTL1985a01	18.6673(1)	7.4956(1)	2262	4	85Wri1
LTL1985a02	18.6314(7)	7.5081(4)	2257	4	85Wri1
LTL1986a01	18.580(4)	7.4894(8)	2239	n.s.	86New1, 86New2
LTL1988a01	18.3	7.58	2198	-	88van1
LTL1989a01	18.466(3)	7.4763(6)	2208	298	89New1
LTL1989a02	18.490(1)	7.4781(7)	2214	78	89New1
LTL1989a03	18.460(2)	7.4798(9)	2207	78	89New1
LTL1990a01	18.5432(4)	7.5310(3)	2243	n.s.	90Art1
LTL1990a02	18.5548(4)	7.5313(3)	2246	n.s.	90Art1
LTL1990b01	18.358(3)	7.521(1)	2195	n.s.	90Sat1
LTL1990b02	18.358(2)	7.523(1)	2196	n.s.	90Sat1
LTL1990b03	18.361(3)	7.525(1)	2197	n.s.	90Sat1
LTL1990b04	18.411(3)	7.558(1)	2219	n.s.	90Sat1
LTL1992a01	18.367(8)	7.5227(3)	2198	n.s.	92Hir1
LTL1992a02	18.403(8)	7.5345(3)	2210	n.s.	92Hir1
LTL1992a03	18.426(3)	7.5451(5)	2218	n.s.	92Hir1
LTL1993a01	18.4797(5)	7.5456(2)	2232	n.s.	93Pic1
LTL1994a01	18.483(1)	7.4938(4)	2217	n.s.	94And1
LTL1994a02	18.4503(5)	7.4852(2)	2207	n.s.	94And1
LTL1997a01	18.4830(6)	7.4938(4)	2217	RT	97And1
LTL1997a02	18.4498(3)	7.4851(2)	2207	RT	97And1
LTL1997a03	18.3893(3)	7.4828(2)	2191	RT	97And1
LTL1997a04	18.3628(4)	7.5170(3)	2195	RT	97And1

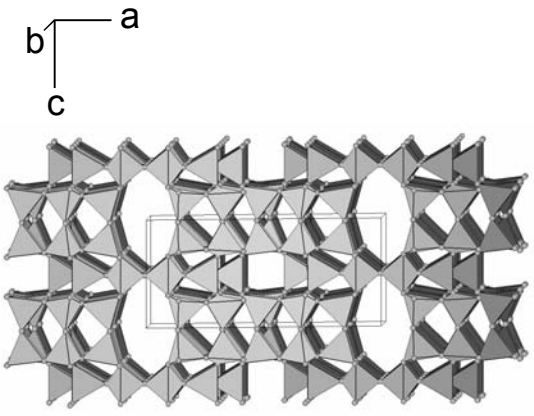
LTL.3 Framework structure of the LTL-I compound (*P*6/*m m m*, IT #191)



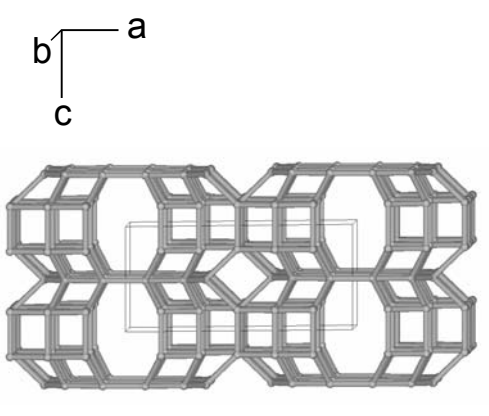
a View parallel [001] rotated by 2° about [210] and [010] .



b Ball and stick model corresponding to a).



c View parallel [010] rotated by 2° about [210] and [001] .



d Ball and stick model corresponding to c).

Fig. LTL.3.1 Projections of the LTL-I crystal structure of $K_9 \cdot Al_9Si_{27}O_{72}$ (LTL1989a01, 89New1).

Table LTL.3.1 Atomic coordinates and site definitions for $K_9 \cdot Al_9Si_{27}O_{72}$ (LTL1989a01, 89New1).

atom	*x*	*y*	*z*	*B* [Å^2]	site symmetry	Wyckoff position	no. of atoms in unit cell
(Si,Al)1	0.1660(3)	0.4989(3)	0.2121(4)	1.4(1)	1	24(r)	18 / 6
(Si,Al)2	0.0943(4)	0.3584(4)	½	1.4(1)	*m* . .	12(q)	9 / 3
O1	0.1022(3)	0.4142(3)	0.3183(4)	2.6(1)	1	24(r)	24
O2	0.1442(3)	0.4772(3)	0	2.6(1)	*m* . .	12(p)	12
O3	0.2657(2)	2*x*	0.2560(6)	2.6(1)	. *m* .	12(o)	12
O4	0.4251(2)	2*x*	0.2751(6)	2.6(1)	. *m* .	12(o)	12
O5	0.1659(2)	2*x*	½	2.6(1)	*m m* 2	6(m)	6
O6	0	0.2754(4)	½	2.6(1)	*m* 2 *m*	6(k)	6
K2	1/3	2/3	½	3.4(2)	$\bar{6}$ *m* 2	2(d)	2
K3	0	½	½	3.4(2)	*m m m*	3(g)	3
K4	0	0.3197(9)	0	3.4(2)	*m* 2 *m*	6(j)	4.78(9)
K5	0	½	0	3.4(2)	*m m m*	3(f)	0.16(6)

Table LTL.3.2 Selected interatomic distances and angles for $K_9 \cdot Al_9Si_{27}O_{72}$ (LTL1989a01, 89New1).

	T - O [Å]	T - O - T [°]		T - O [Å]	T - O - T [°]
(Si,Al)1 - O1	1.619(5)	142.5(4)	(Si,Al)2 - O5	1.624(7)	149.6(4)
(Si,Al)1 - O2	1.636(3)	151.6(4)	(Si,Al)2 - O6	1.647(7)	132.6(5)
(Si,Al)1 - O4	1.643(8)	141.8(5)	(Si,Al)2 - O1	1.667(4)	142.5(4)
(Si,Al)1 - O3	1.659(6)	136.5(4)	(Si,Al)2 - O1	1.667(4)	142.5(4)
Mean	1.639	143.1	mean	1.651	141.8

LTL.4 Chemical composition

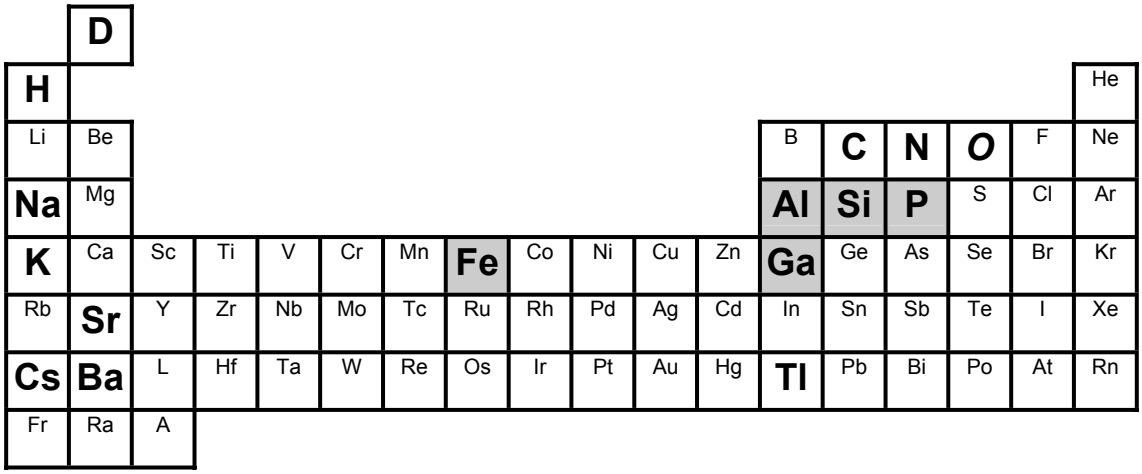


Fig. LTL.4.1 Chemical elements (highlighted) occurring in LTL-type compounds. Framework cations are in grey fields.

LTL.5 Flexibility and apertures

The overall spread of values of the individual T-O-T angles of LTL-type silicoaluminates ranges only from ca. 130° to 155°, with a mean value of 142°. This is very close to the mean value observed in the sample of 2436 T-O-T values for silicoaluminates zeolite frameworks generally, which is 141° [95Bau1]. Too little is known about frameworks of the LTL-type to be able to speak about their flexibility.
The 12-ring in the LTL framework is slightly narrower than in the FAU-type framework and barely exceeds 7 Å.

LTL.6 Other information

Aromatics are formed in an industrial process from straight-chain alkanes by dehydrocyclization using platinum clusters in basic LTL-type zeolites [98Jen1 and literature cited therein, see also 2004Bha1]. LTL-type zeolites are of interest for photochemical applications [2003Has1, 2000Pau1, 87Per1].

LTL.7 References

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