



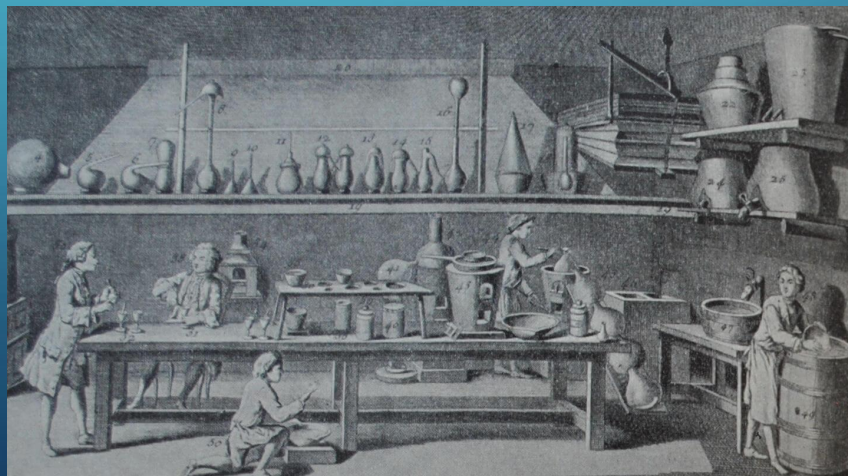
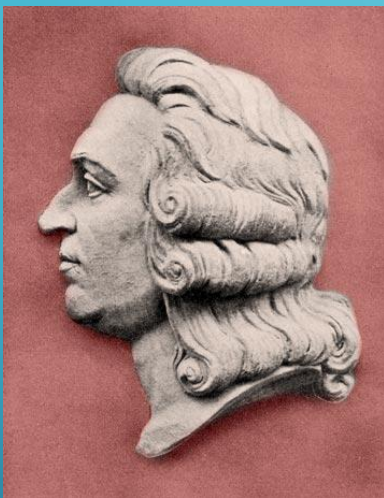
ХИМИЯ ФУНКЦИОНАЛЬНЫХ МАТЕРИАЛОВ

АДСОРБЦИОННЫЕ МАТЕРИАЛЫ. ЦЕОЛИТЫ

ЧТО ЭТО?

1758

Алекс Фредерик Кронштедт

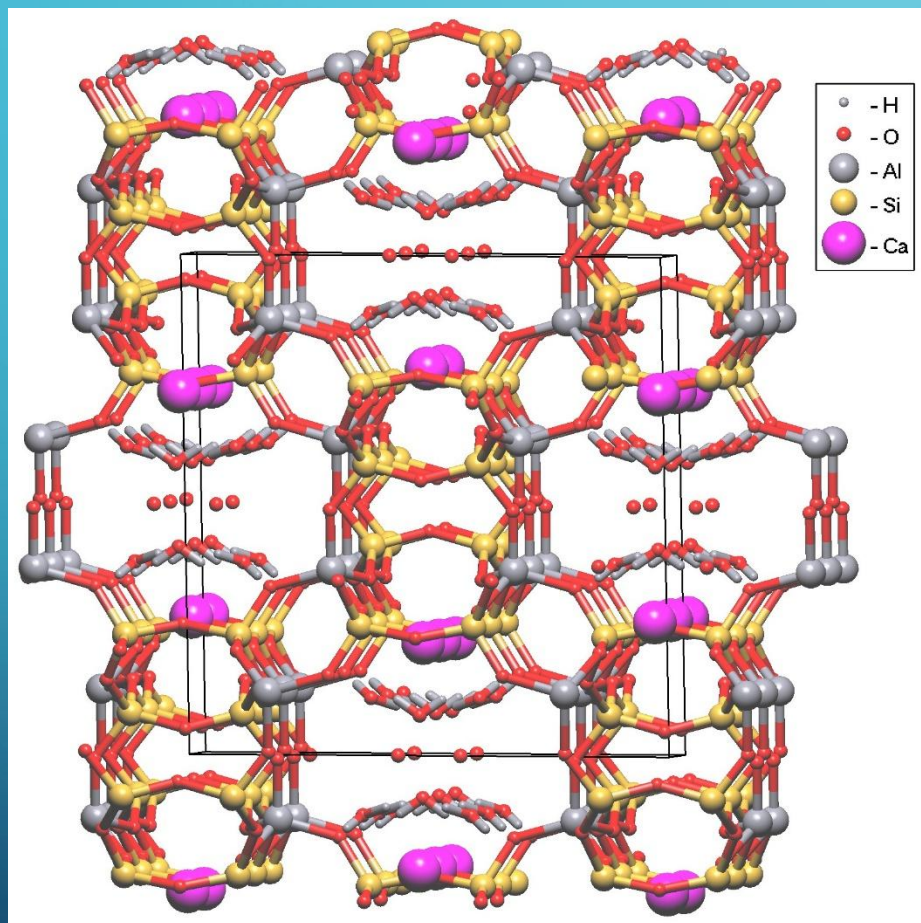


Zein - кипеть
Литос - камень



СТИЛЬБИТ

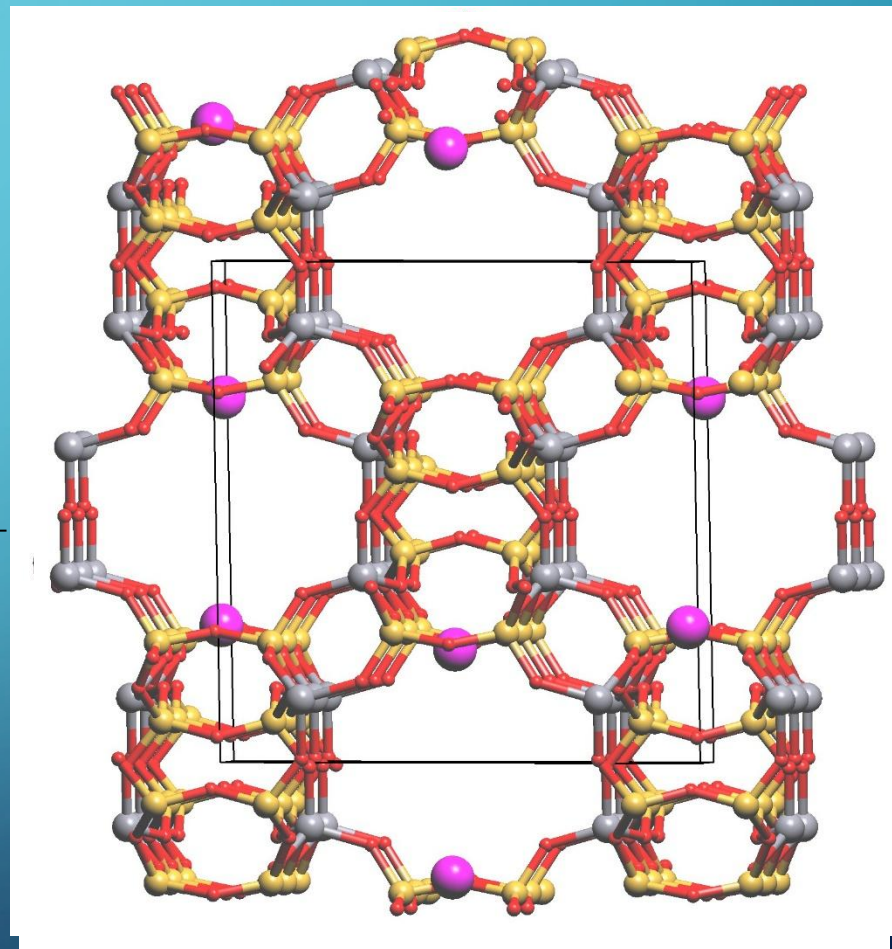
Структура



$-H_2$

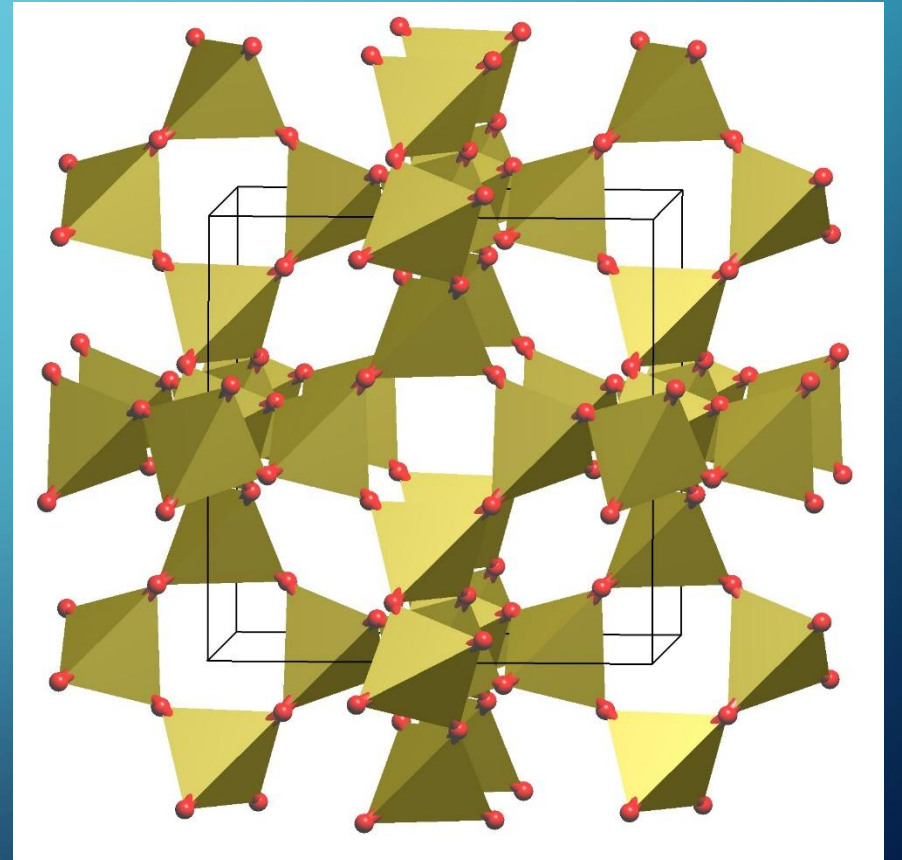
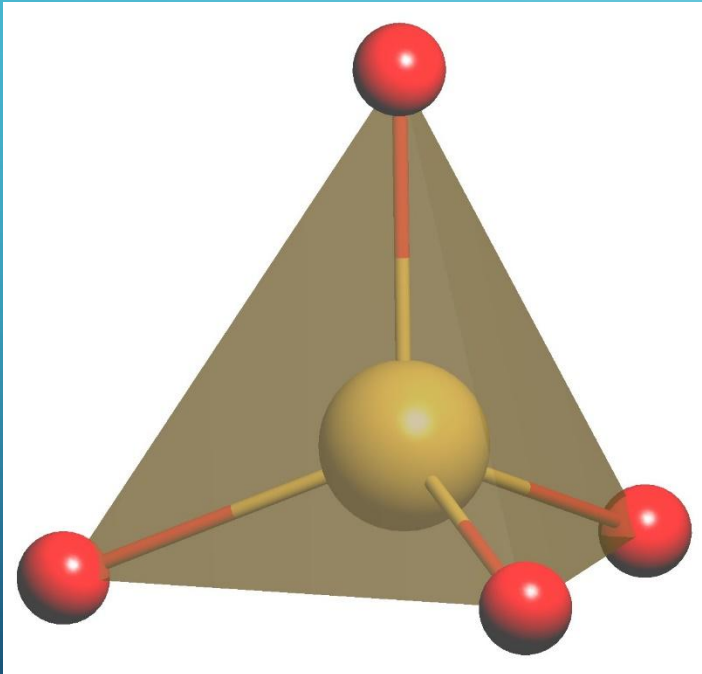


H_2



Структура

Si, Al, Be, Mg, P, Ti, Mn, Fe, Zn, Ga,
Ge, Co, Ni, Cu



Состав

ToposPro Build - 5. 3. 1. 2 - [C:\Users\20\ICSD\Цеолиты]

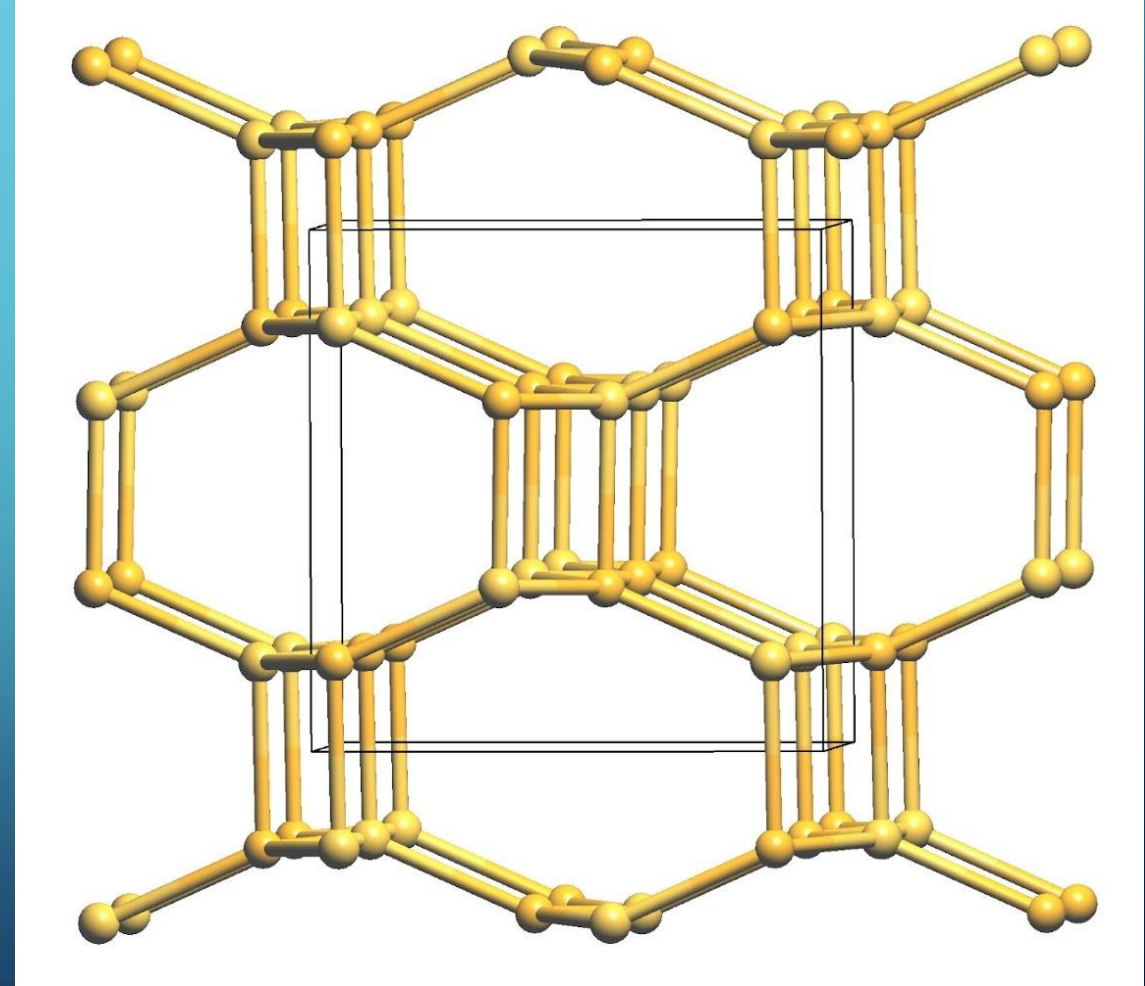
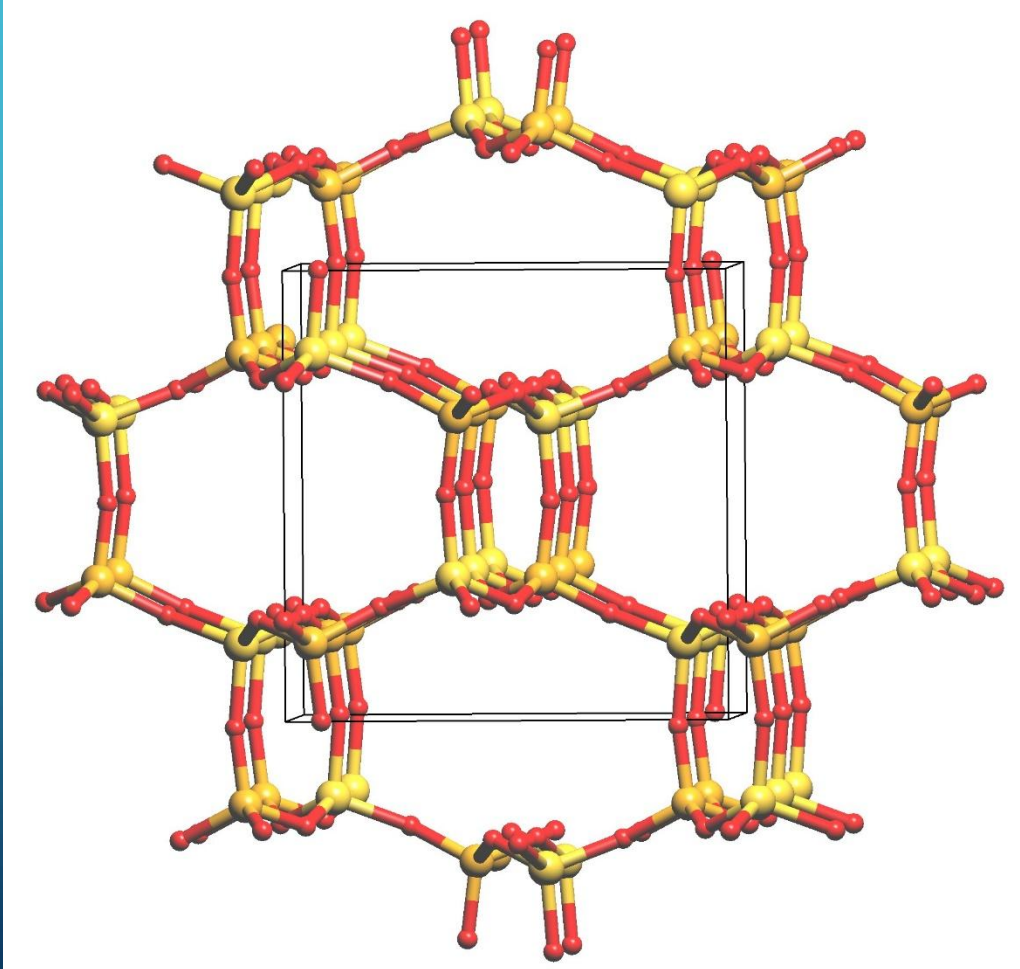
System Compound Filter Database Program Results Window Cancel Help

Compounds

K13.5(Si10Al10O40)(OH)3(H2O)13
Ca1.64K2(Si10.67Al5.33O32)(H2O)12
KCa0.92Mg0.82(Si13.52Al4.48O36)(H2O)9.84
K12(Al12Si12O48)(H2O)20
Mn4.5Na3Al12Si12O48(C2H2)4.5
Co.333Na.333(AlSiO4)(H2O)2.92
Ca0.07(Al0.1629Si0.8375O2)
K2.76Mg2Ca0.84(Si36O72)(OH)8.44(H2O)23.94
Mn4.5Na3(Si12Al12O48)
Na5(Al5Si5O20)(H2O)9
Na88(Al88Si104O384)(H2O)172.1
Na(AlSiO4)
Ca28(Al57Si135O384)
Ca43.3Al76.8Si115.2O384
K54.7Al54.7Si137.3O384
Na11Al11Si13O48S16
Na11Al11Si13O48(NH3)32
Ti11Al11Si13O48
Ti11Al11Si13O48(H2O)20
Ca40Al80Si112O384(H2O)116
(Ba13.42(Al30Si66O192))(BaCl2)8.22
(Ba5.12(Al30Si66O192))(BaBr2)7.92
Na17.28Ba8.88(Al30.048Si65.952O192)Cl3.84(H2O)70
Na6(Al6Si10O32)(H2O)12
Na11Fe10(Si15Al4)O384(H2O)164
H11Na29Cu7(Al56Si136O384)(H2O)250
H11Na21Cu12(Al56Si136O384)(H2O)250
H10Al11Fe115(Al56Si136O384)(H2O)250

1678:0:26

3D каркас



Database of Zeolite Structures

IZA-SC All Codes

Advanced Search ▾

Tools ▾

Other Links ▾

Home > [Codes](#)

[Help](#) [Credits](#)

Zeolite Framework Types

Search for a Framework Type Code

Enter one character to search for a code or
two or more to search for a code or material name

or select one from the tables below:

Fully ordered
Type Materials *

ABW	ACO	AEI	AEL	AEN	AET	AFG	AFI	AFN	AFO	AFR	AFS	AFT	AFV	AFX
AFY	AHT	ANA	APC	APD	AST	ASV	ATN	ATO	ATS	ATT	ATV	AVL	AWO	AWW
BCT	BEC	BIK	BOF	BOG	BOZ	BPH	BRE	BSV	CAN	CAS	CDO	CFI	CGF	CGS
CHA	-CHI	-CLO	CON	CSV	CZP	DAC	DDR	DFO	DFT	DOH	DON	EAB	EDI	EEL
EMT	EON	EPI	ERI	ESV	ETL	ETR	EUO	EWS	EZT	FAR	FAU	FER	FRA	GIS
GIU	GME	GON	GOO	HEU	IFO	IFR	-IFT	-IFU	IFW	IFY	IHW	IMF	IRN	IRR
-IRY	ISV	ITE	ITG	ITH	ITR	ITT	-ITV	ITW	IWR	IWS	IWV	IWW	JBW	JNT
JOZ	JRY	JSN	JSR	JST	JSW	KFI	LAU	LEV	LIO	-LIT	LOS	LOV	LTA	LTF
LTJ	LTL	LTN	MAR	MAZ	MEI	MEL	MEP	MER	MFI	MFS	MON	MOR	MOZ	MSE
MSO	MTF	MTN	MTT	MTW	MVY	MWF	MWW	NAB	NAT	NES	NON	NPO	NPT	NSI
OBW	OFF	OKO	OSI	OSO	OWE	-PAR	PAU	PCR	PHI	PON	POS	PSI	PUN	RHO
-RON	RRO	RSN	RTE	RTH	RUT	RWR	RWY	SAF	SAO	SAS	SAT	SAV	SBE	SBN
SBS	SBT	SEW	SFE	SFF	SFG	SFH	SFN	SFO	SFS	SFW	SGT	SIV	SOD	SOF
SOR	SOS	SSF	SSY	STF	STI	STT	STW	-SVR	SVV	SWY	SZR	TER	THO	TOL
TON	TSC	TUN	UEI	UFI	UOS	UOV	UOZ	USI	UTL	UWY	VET	VFI	VNI	VSV
WEI	-WEN	YFI	YUG	ZON										

Partially disordered
Type Materials

*BEA
*CTH
*-EWT
*-ITN
*MRE
*SFV
*-SSO
*STO
*-SVY

Строительные единицы

Database of Zeolite Structures

IZA-SC All Codes Framework Material 3D Drawing Powder Pattern CIF PDF References

Home Codes Framework Characteristic Units Help Credits

Framework Type FAU

Framework

Cell Parameters: cubic F d -3 m (# 227)
 $a = 24.3450 \text{ \AA}$ $b = 24.3450 \text{ \AA}$ $c = 24.3450 \text{ \AA}$
 $\alpha = 90.000^\circ$ $\beta = 90.000^\circ$ $\gamma = 90.000^\circ$
 Volume = 14428.8 \AA^3
 RPLS = 0.0009

Framework density (FD_{SI}): 13.3 T/1000 \AA^3
Topological density: TD₁₀ = 579 TD = 0.476190

Ring sizes (# T-atoms): 12 6 4



Channel dimensionality: Topological (pore opening > 6-ring): 3-dimensional

Maximum diameter of a sphere:
 that can be included 11.24 \AA
 that can diffuse along a: 7.35 \AA b: 7.35 \AA c: 7.35 \AA

Accessible volume: 27.42 %

Secondary Building Units: 6-6 or 6-2 or 6 or 4-2 or 1-4-1 or 4

Composite Building Units:

Natural Tiling: t-fau t-hpr t-toc

Year code assigned 1978
 Data last updated Jul 1, 2007

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FAU $Fd\bar{3}m$

$$2[4^6.6^2] + [4^6.6^8] + [4^{18}.6^4.12^4]$$

1453

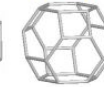
TILES

Face symbol:

$[4^6.6^2]$

$[4^6.6^8]$

$[4^{18}.6^4.12^4]$



V, E, F:

(12, 18, 8)

(24, 36, 14)

(48, 72, 26)

Symmetry:

$\bar{3}m$

$\bar{4}3m$

$\bar{4}3m$

Wyckoff:

16c

8a

8b

Label:

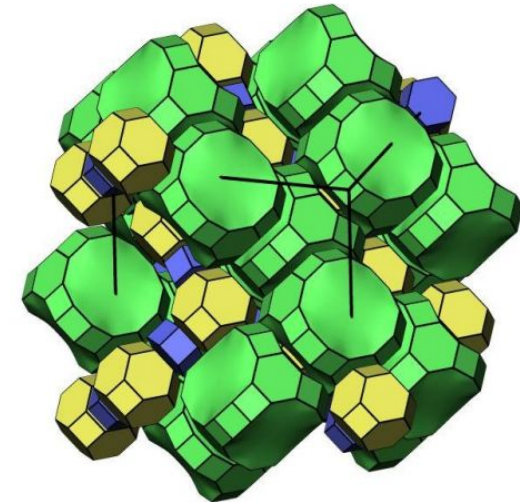
t-hpr

t-toc

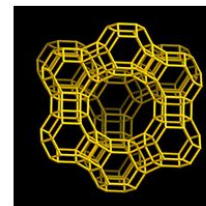
t-fau

Special features: simple

TILING



Framework images
 (click on icon for larger image)



Viewed along [111]



viewed along [110]



Polyhedral model viewed along [110]



an 'artist impression' of a catalytic reaction

Framework Type MFI

Type Material [?]

Material Name: ZSM-5

Chemical Formula[§]: $[\text{Na}^+_n (\text{H}_2\text{O})_{16}] [\text{Al}_n \text{Si}_{96-n} \text{O}_{192}] \text{-MFI}$, $n < 27$

Unit Cell[§]: orthorhombic $P n m a$ (# 62)

$a' = 20.0700 \text{ \AA}$	$b' = 19.9200 \text{ \AA}$	$c' = 13.4200 \text{ \AA}$
$\alpha' = 90.000^\circ$	$\beta' = 90.000^\circ$	$\gamma' = 90.000^\circ$

Framework density: [?] 17.9 T/1000 \AA^3

Channels: [?] $\{[100] 10 \ 5.1 \times 5.5 \leftrightarrow [010] 10 \ 5.3 \times 5.6\}^{***}$

Dimensionality [?]

Sorption (molecular cross section > 3.4 \AA): 3-dimensional
 Topological (pore opening > 6-ring): 3-dimensional

References:

Kokotailo, G.T., Lawton, S.L., Olson, D.H. and Meier, W.M.
 "Structure of synthetic zeolite ZSM-5"
Nature, **272**, 437-438 (1978)

[§] Olson, D.H., Kokotailo, G.T., Lawton, S.L. and Meier, W.M.
 "Crystal Structure and Structure-Related Properties of ZSM-5"
J. Phys. Chem., **85**, 2238-2243 (1981)

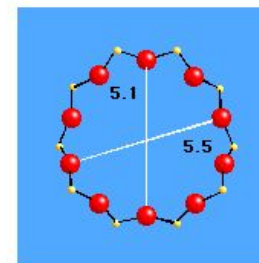
van Koningsveld, H., van Bekkum, H. and Jansen, J.C.
 "On the location and disorder of the tetrapropylammonium (TPA) ion in zeolite ZSM-5 with improved framework accuracy"
Acta Crystallogr., **B43**, 127-132 (1987)

Name and Code derivation:

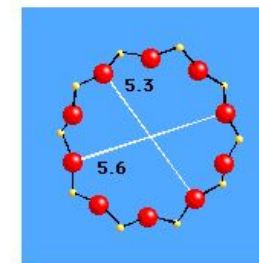
Zeolite Socony Mobil - five
 → ZSM-5 (five)
 → MFI

[§] Chemical Formula and Unit Cell taken from the reference marked with this sign

Limiting Rings



10-ring viewed along [100]

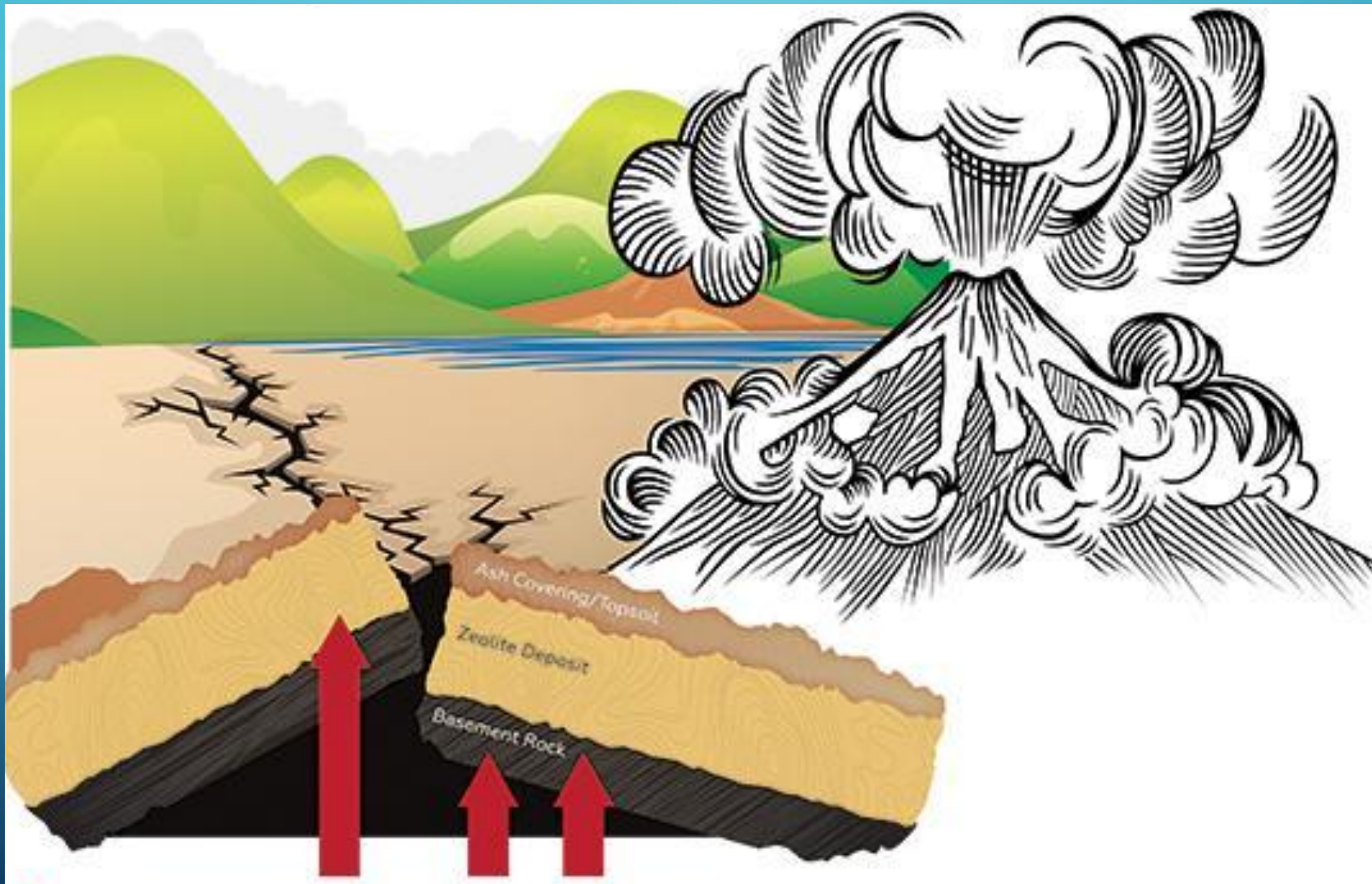


10-ring viewed along [010]

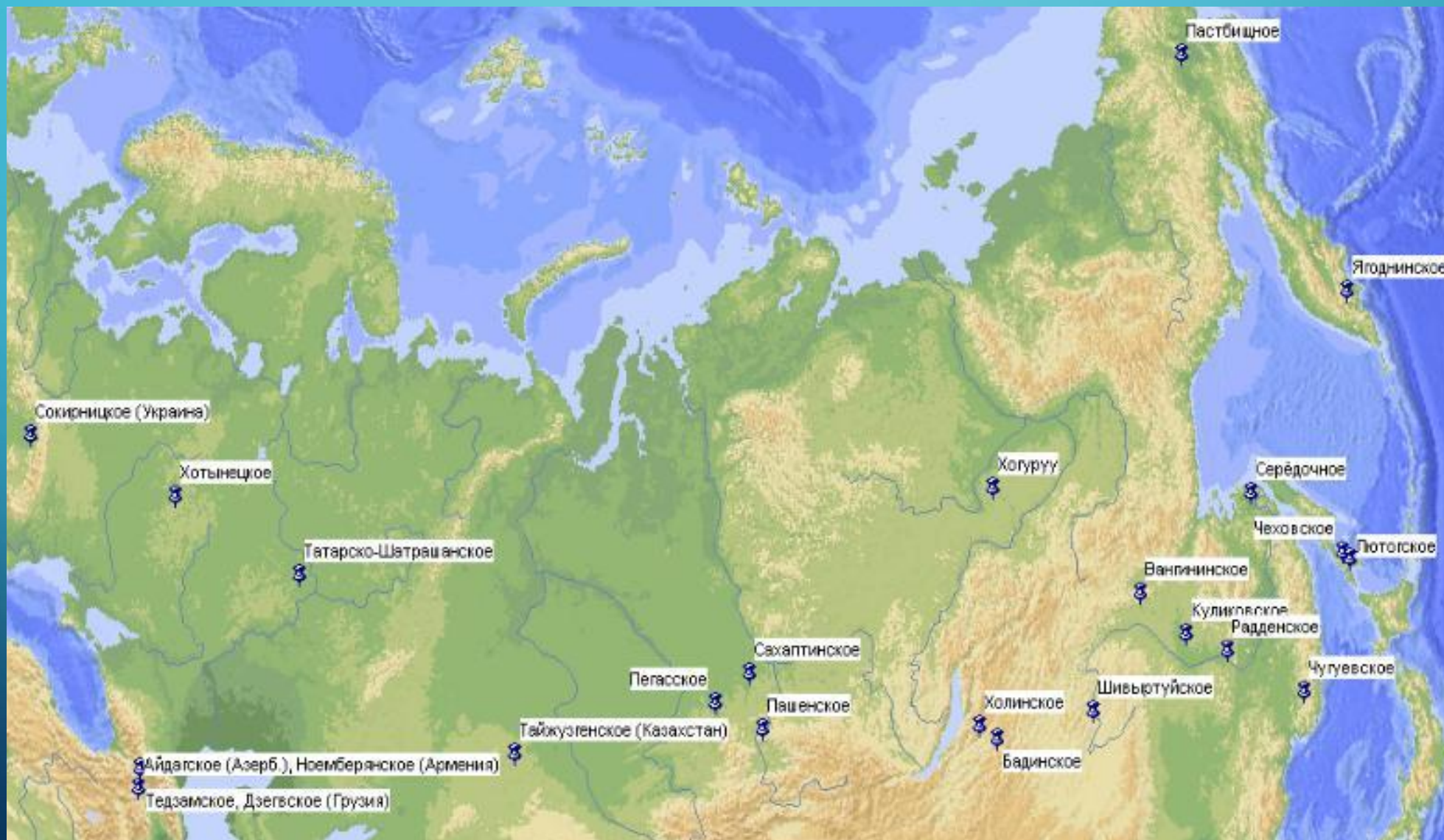
ZSM-5

Zeolite
 Socony
 Mobil-five

Цеолиты: образование



Цеолиты: месторождения



Натуральные цеолиты



анальцим



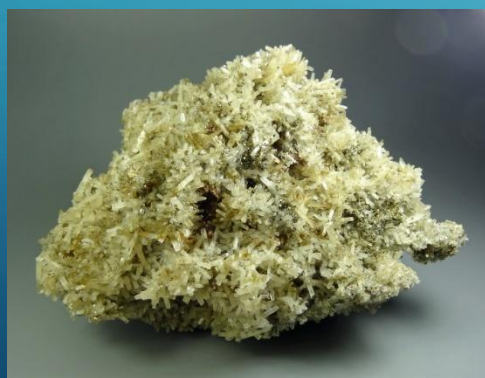
шабазит



гейландит



клиноптилолит



натролит



содалит



стильбит



филипсит

Применение: строительство



4 000 000 T

2 500 000 T

Цеолиты: синтез

- Концентрации растворов
- pH
- Скорость смешивания
- Время перемешивания
- Температура
- Скорость кристаллизации
- Время кристаллизации



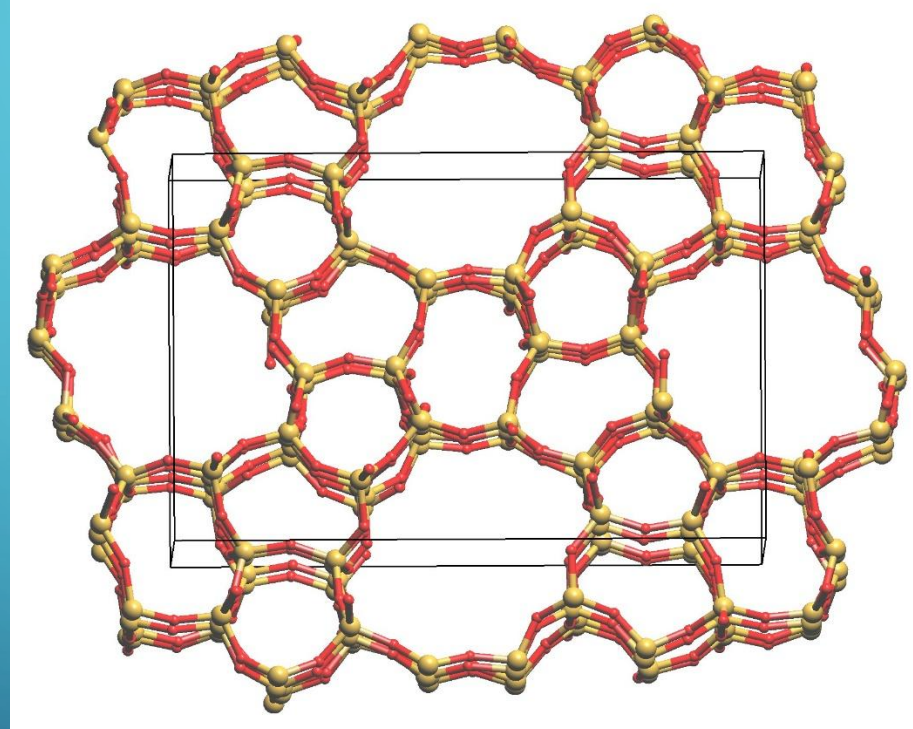
Применение: катализ

Цеолит Y (FAU) 300 000 т



Применение: катализ

Metanol to Gasoline (MTG) Process



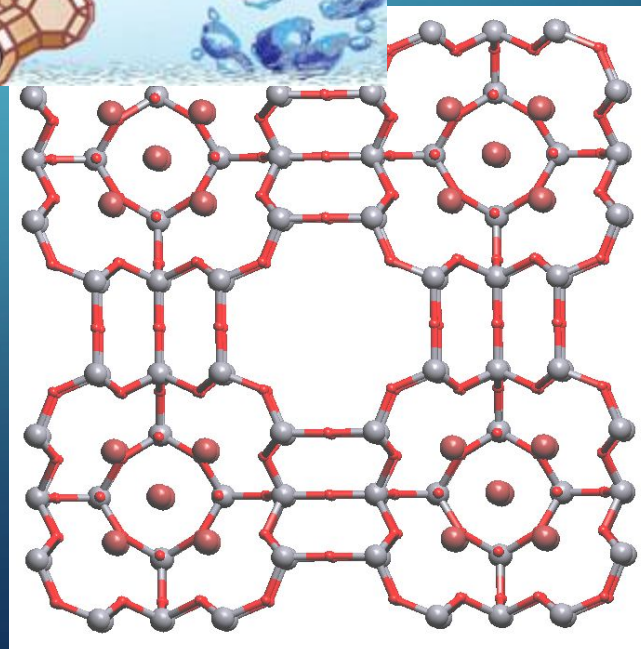
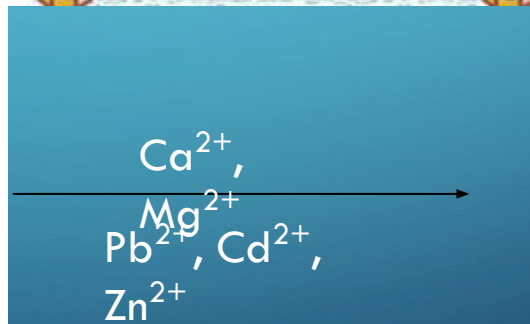
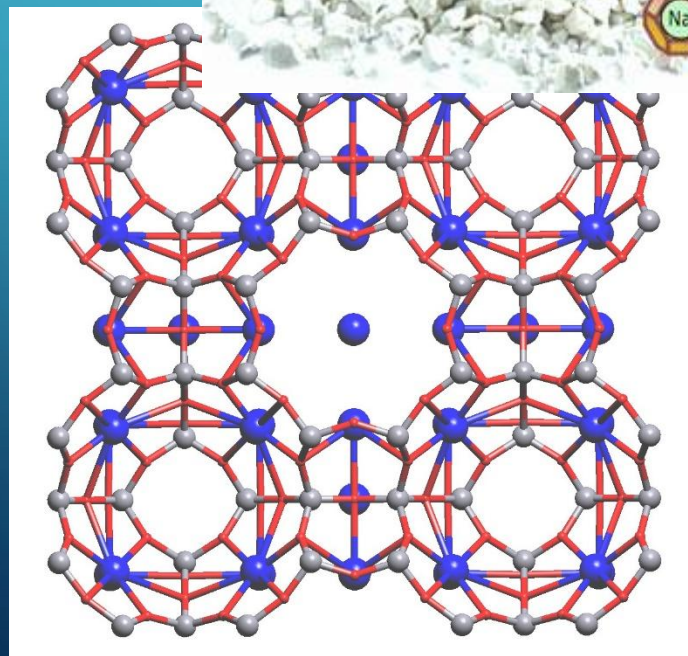
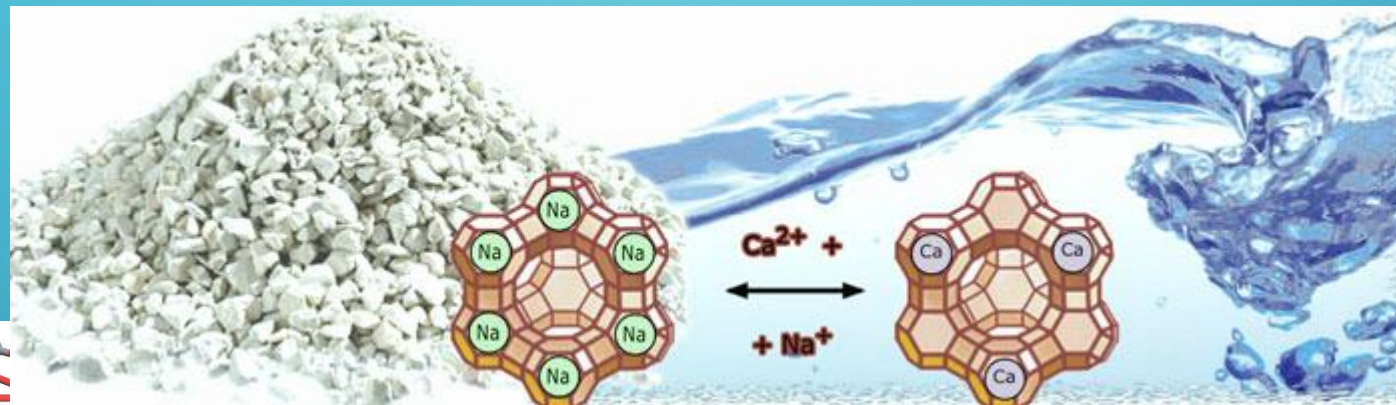
H-ZSM-5
MFI

«Производство полимеров» поли-пара-ксилилен

Применение: катионообмен

Цеолит А (LTA)

1,400 000 т



Применение: катионообмен



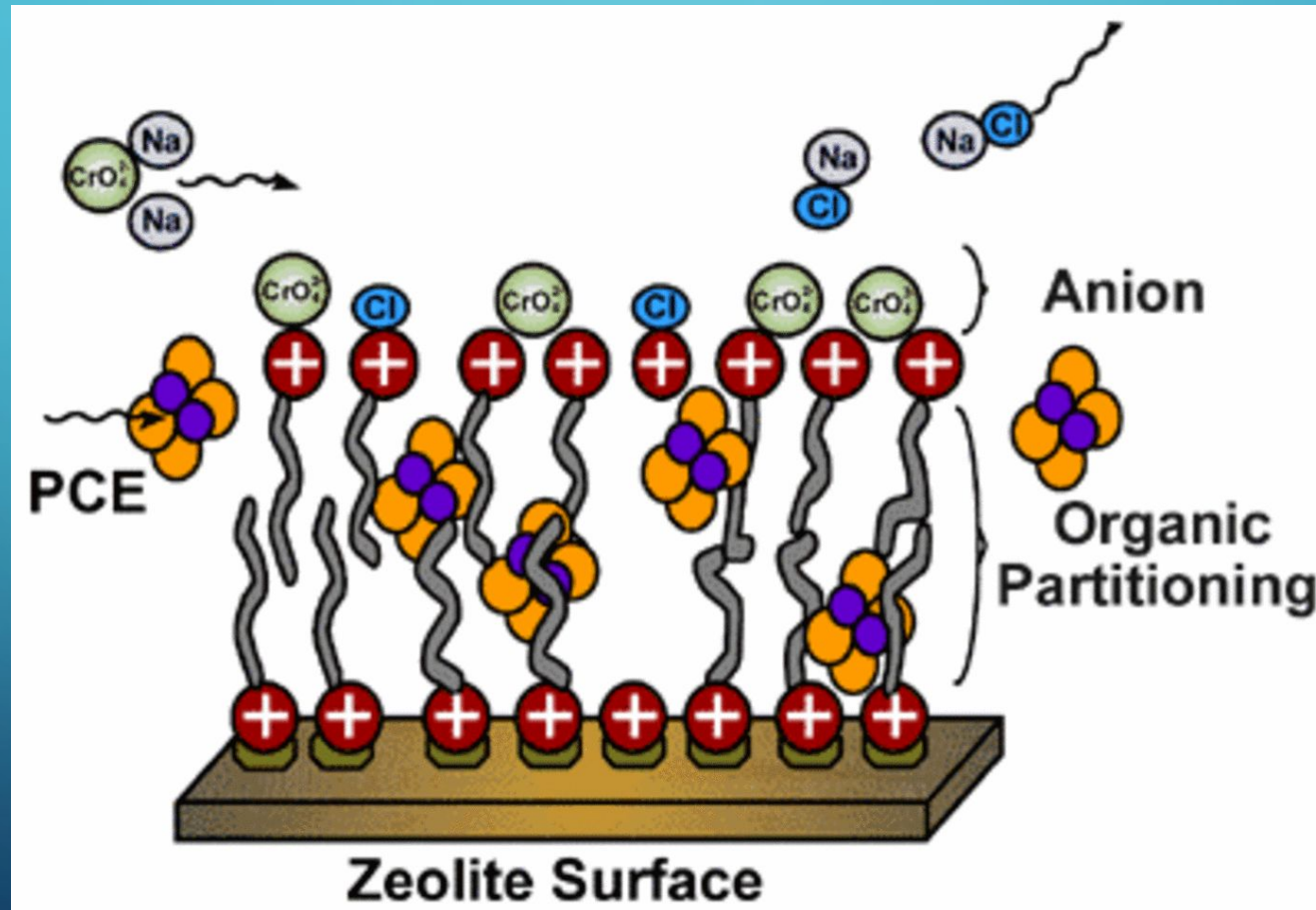
ЛИНОПТИЛОЛИТ
(HEU)

500 000 т

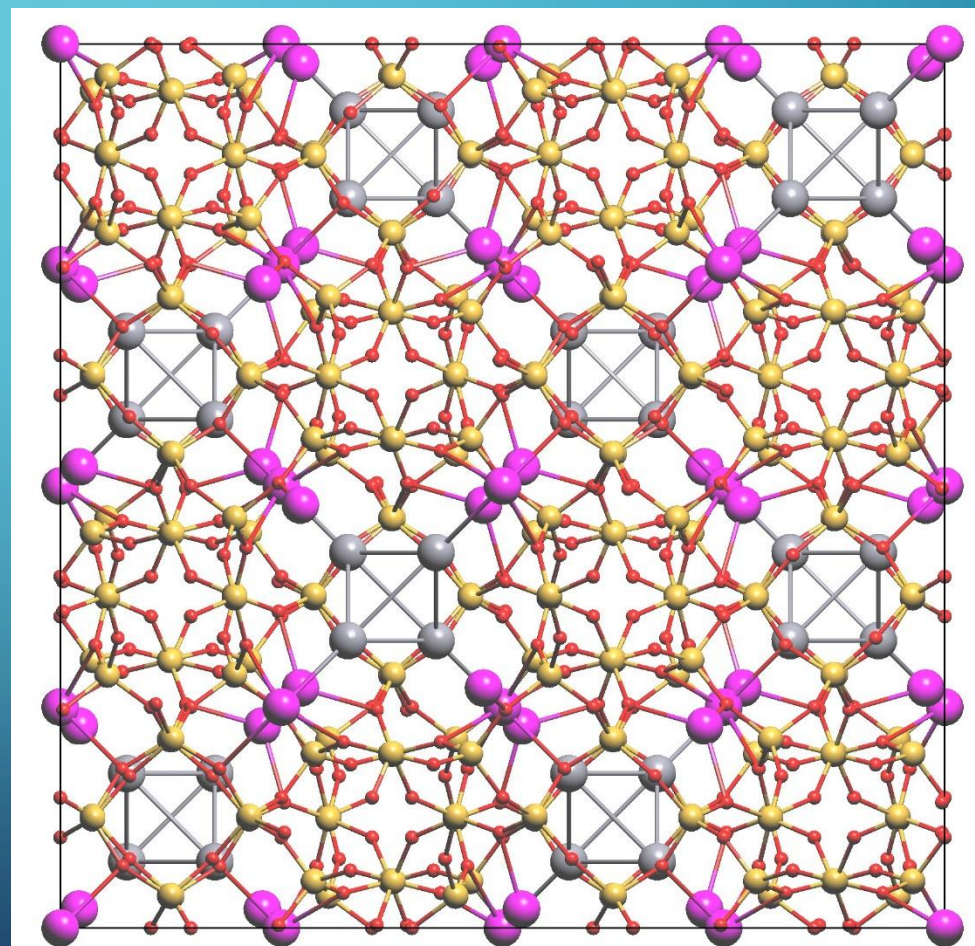
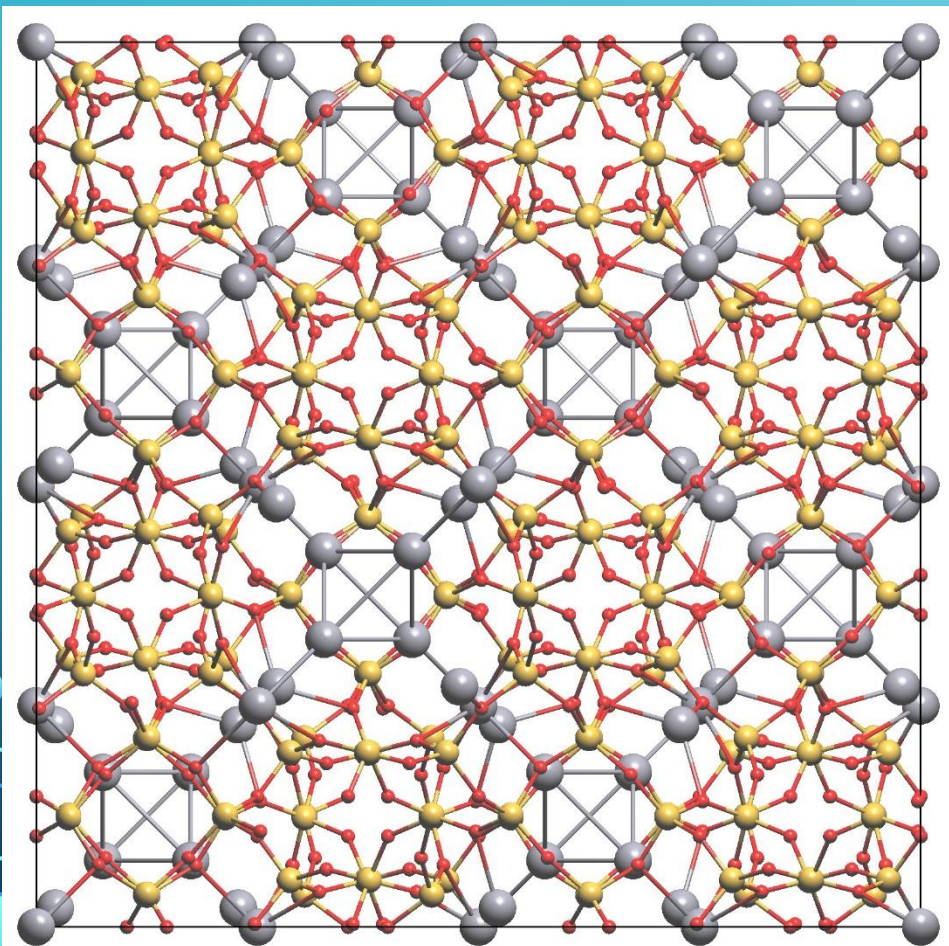
^{134}Cs , ^{137}Cs , ^{90}Sr

Применение: адсорбция

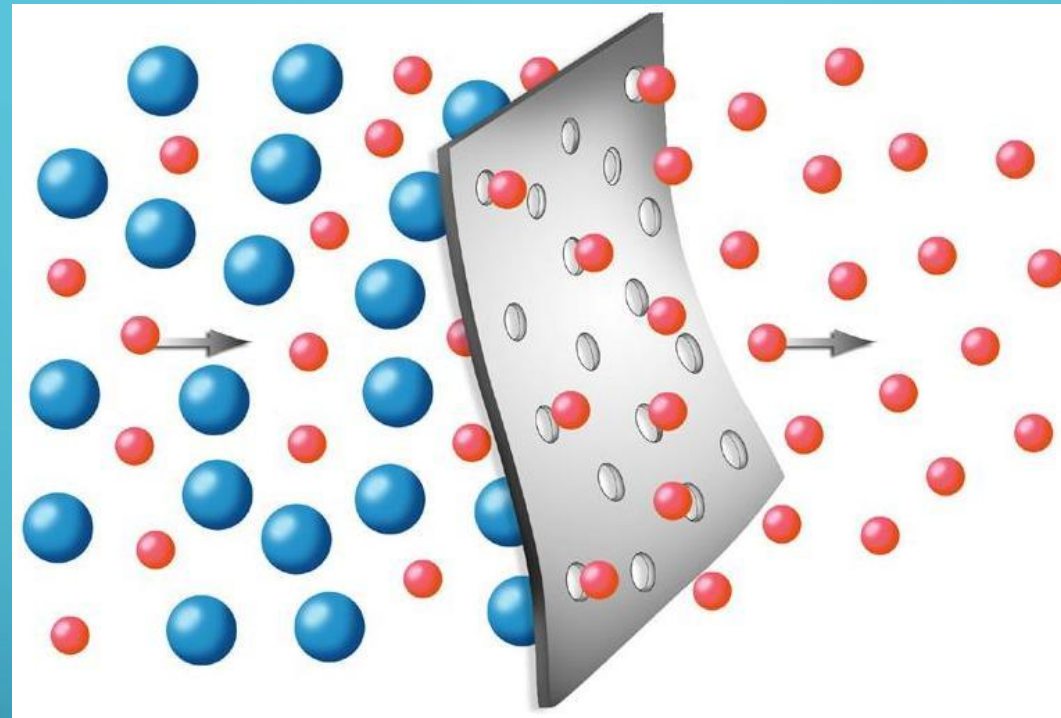
Клиноптилолит (HEU)



Применение: адсорбция



Применение: молекулярные сита



Осушение

Удаление углеводородов

Разделение газов

Применение: медицина



Применение: сельское хозяйство

