



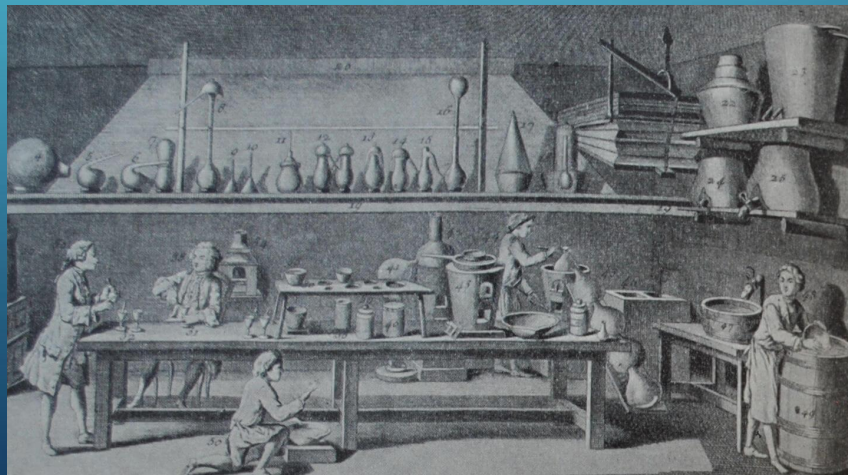
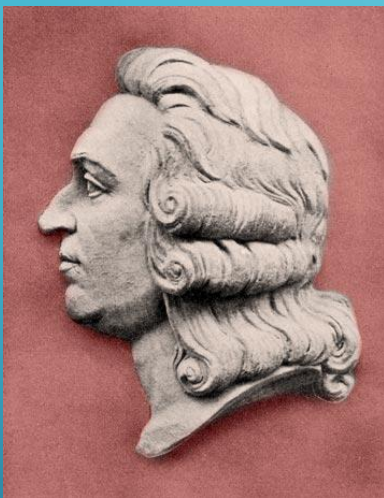
ХИМИЯ ФУНКЦИОНАЛЬНЫХ МАТЕРИАЛОВ

АДСОРБЦИОННЫЕ МАТЕРИАЛЫ. ЦЕОЛИТЫ

ЧТО ЭТО?

1758

Алекс Фредерик Кронштедт

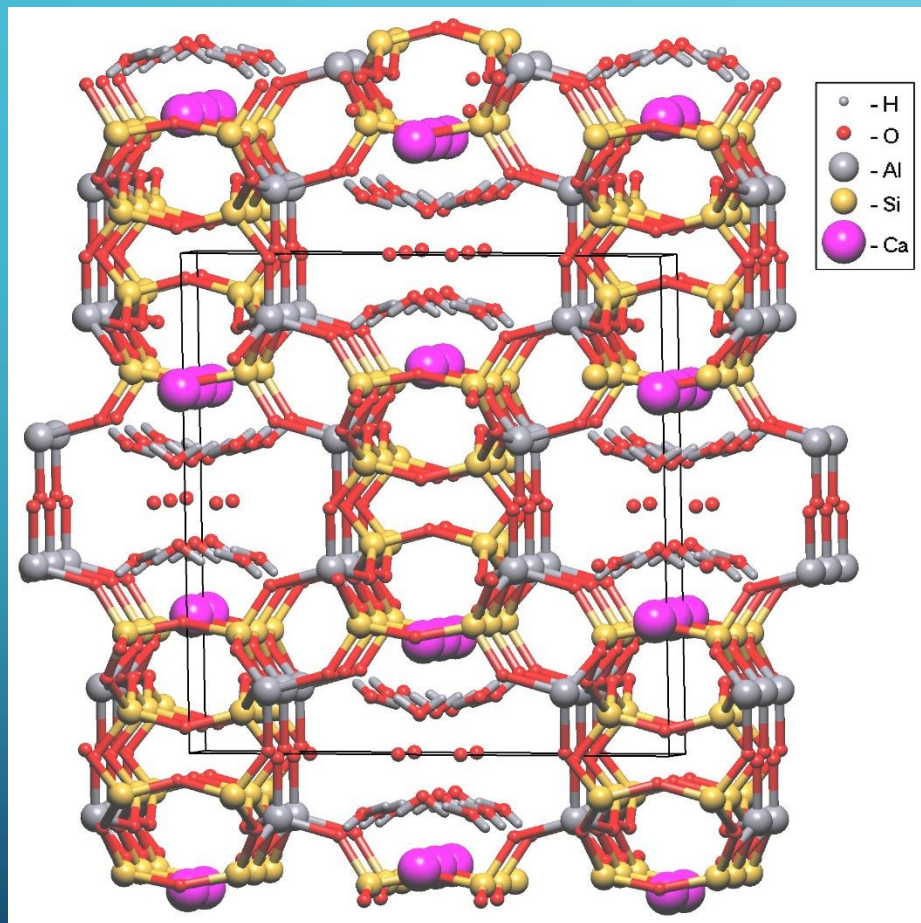


Zein - кипеть
Литос - камень



СТИЛЬБИТ

Структура



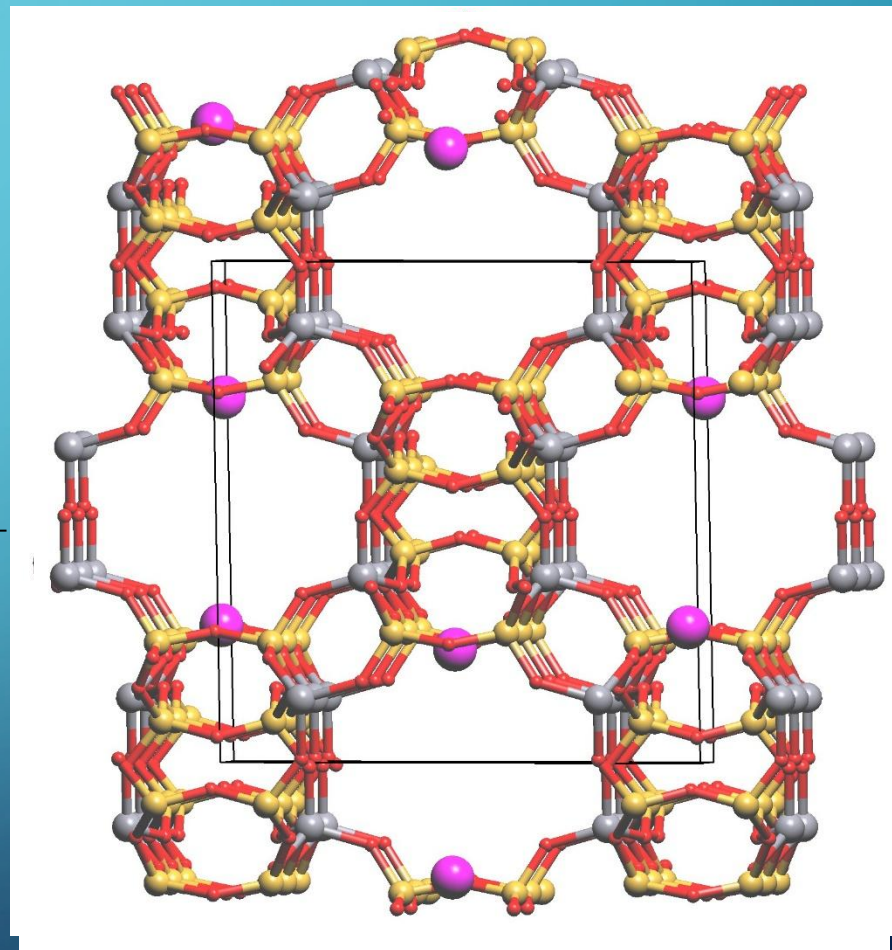
$-H_2$



$\xleftarrow{H_2}$

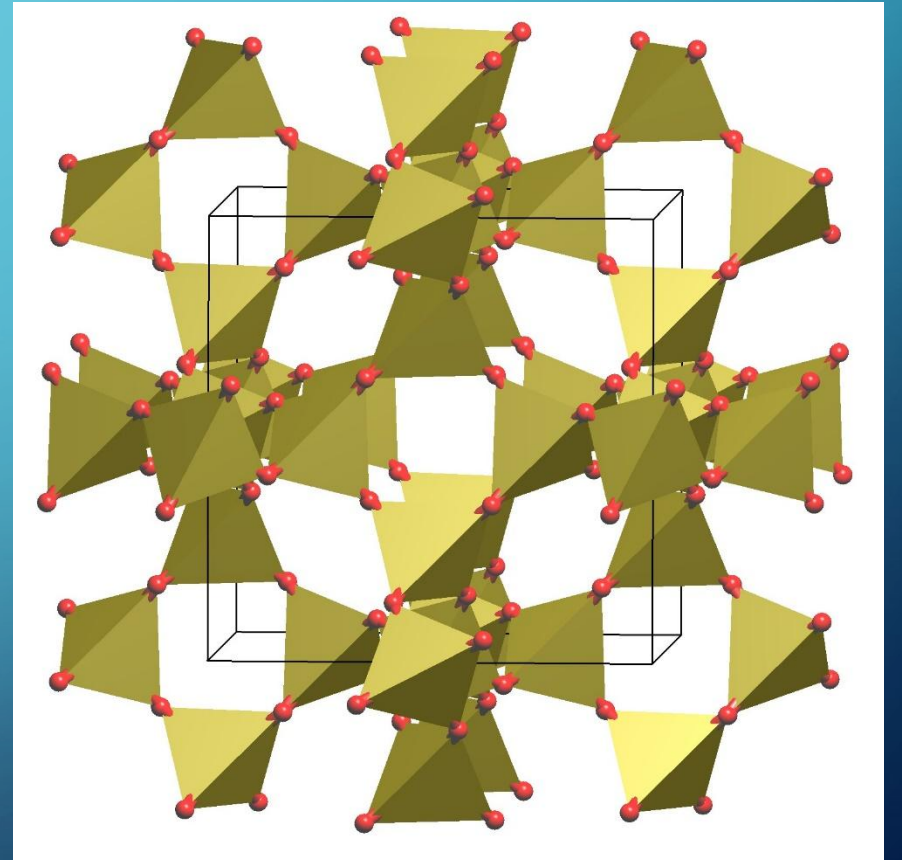
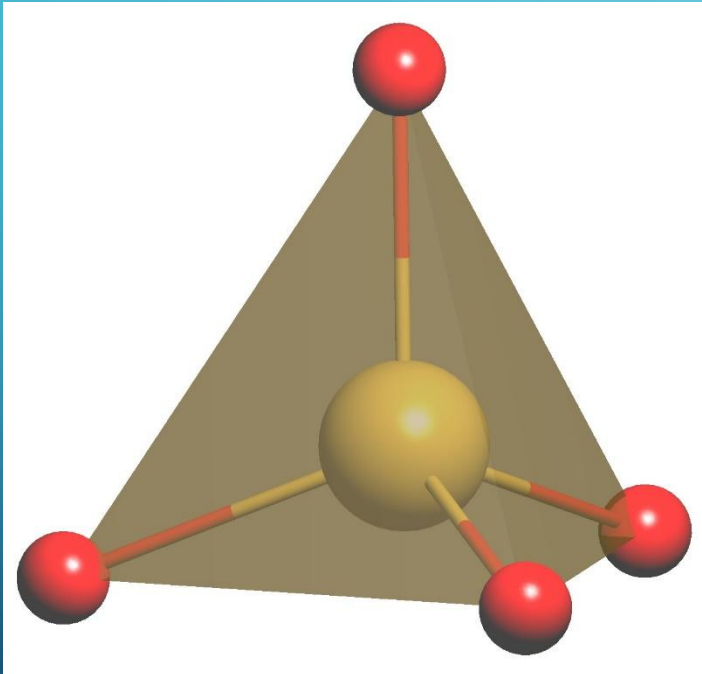


H_2



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]

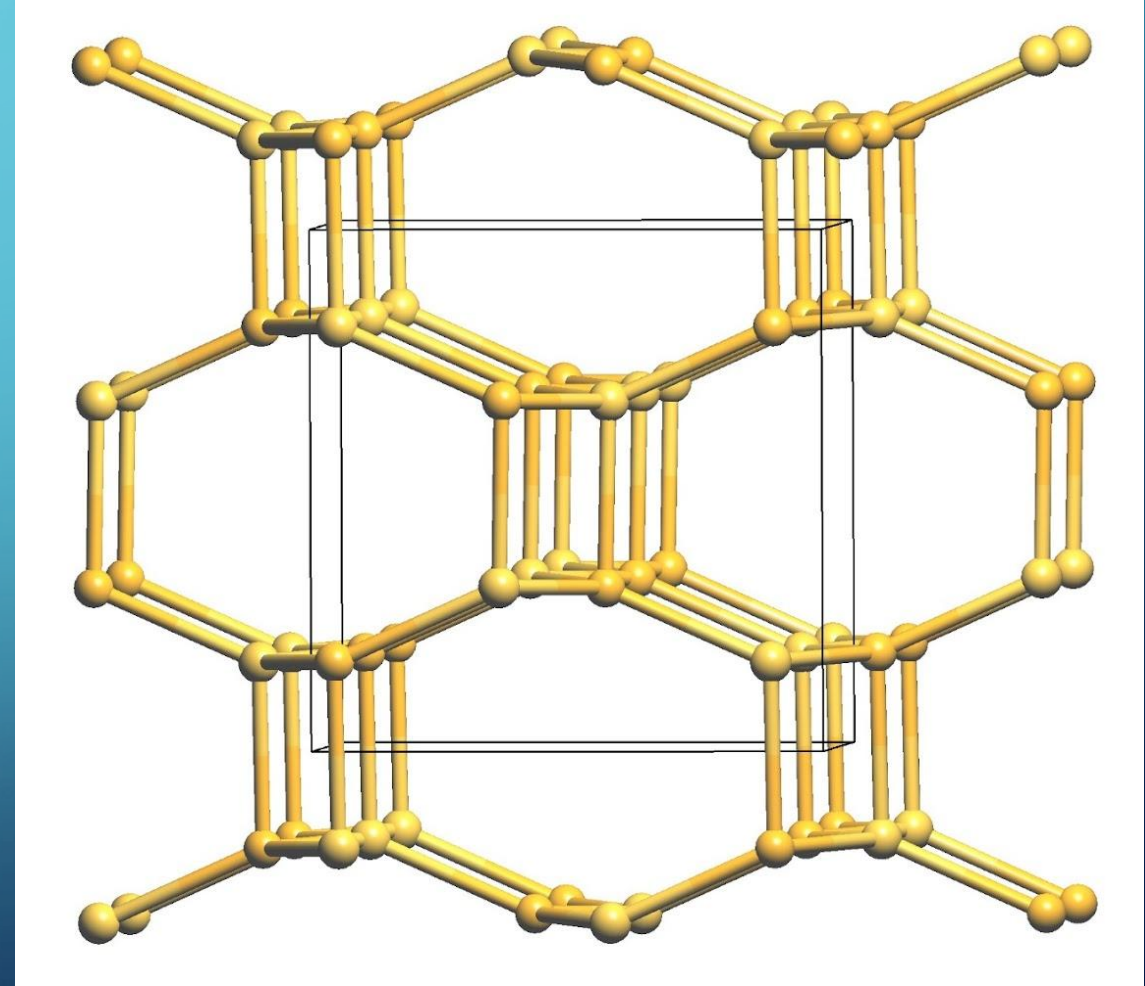
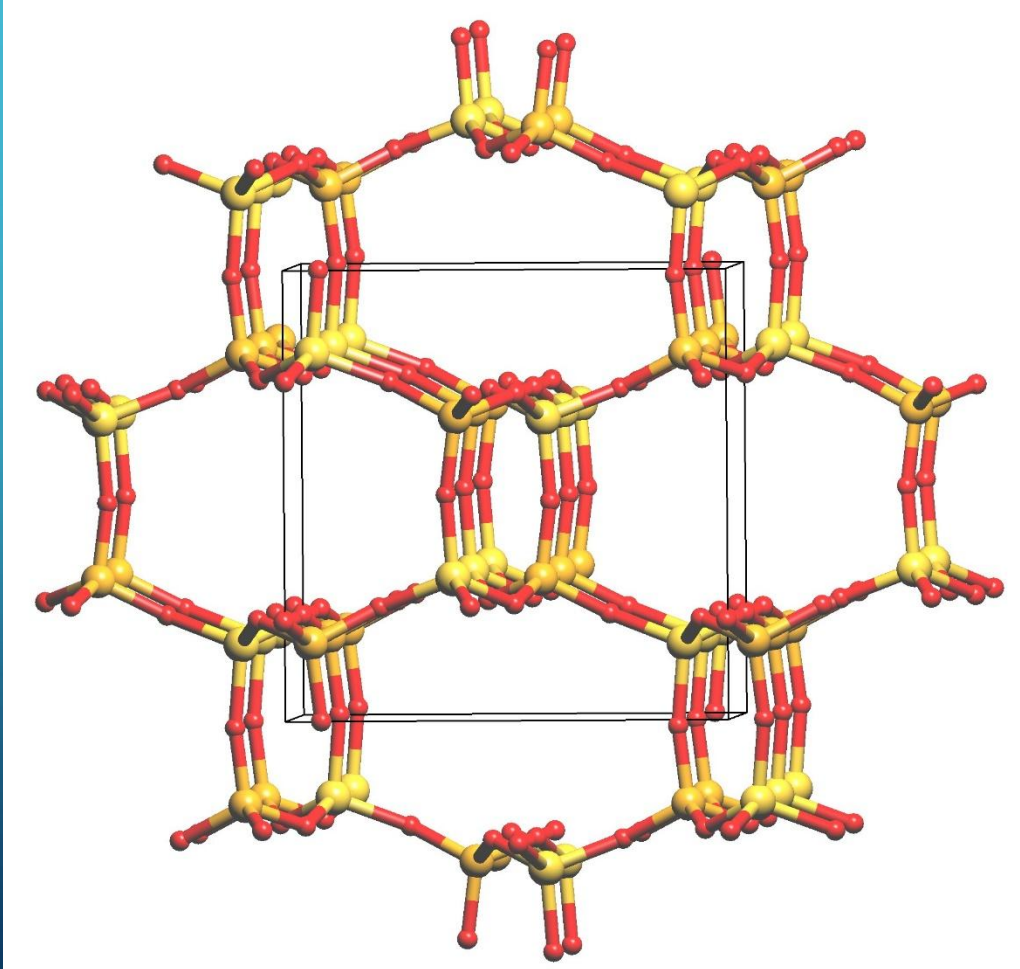
System Compound Filter Database Program Results Window Cancel Help

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:

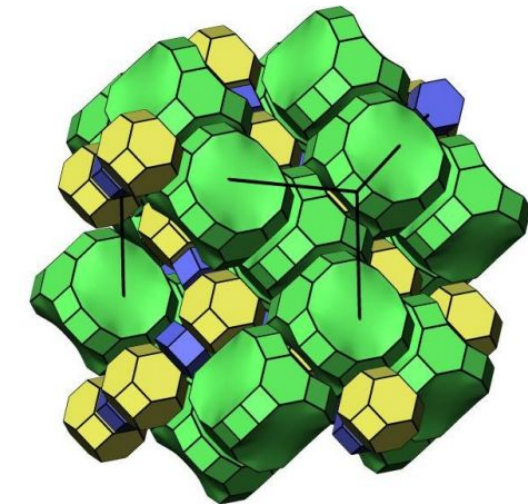
t-hpr

t-toc

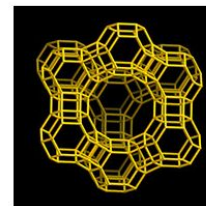
t-fau

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)

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

Framework density: ? 17.9 T/1000 Å³

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

Dimensionality ?

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

References:

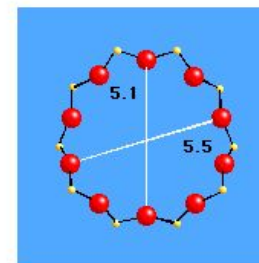
- Kokotailo, G.T., Lawton, S.L., Olson, D.H. and Meier, W.M.
 "Structure of synthetic zeolite ZSM-5"
Nature, **272**, 437-438 (1978)
- § Olson, D.H., Kokotailo, G.T., Lawton, S.L. and Meier, W.M.
 "Crystal Structure and Structure-Related Properties of ZSM-5"
J. Phys. Chem., **85**, 2238-2243 (1981)
- 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:

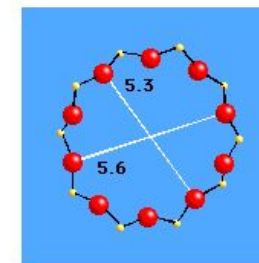
Zeolite Socony Mobil - five
 → ZSM-5 (five)
 → MFI

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

Limiting Rings



10-ring viewed along [100]

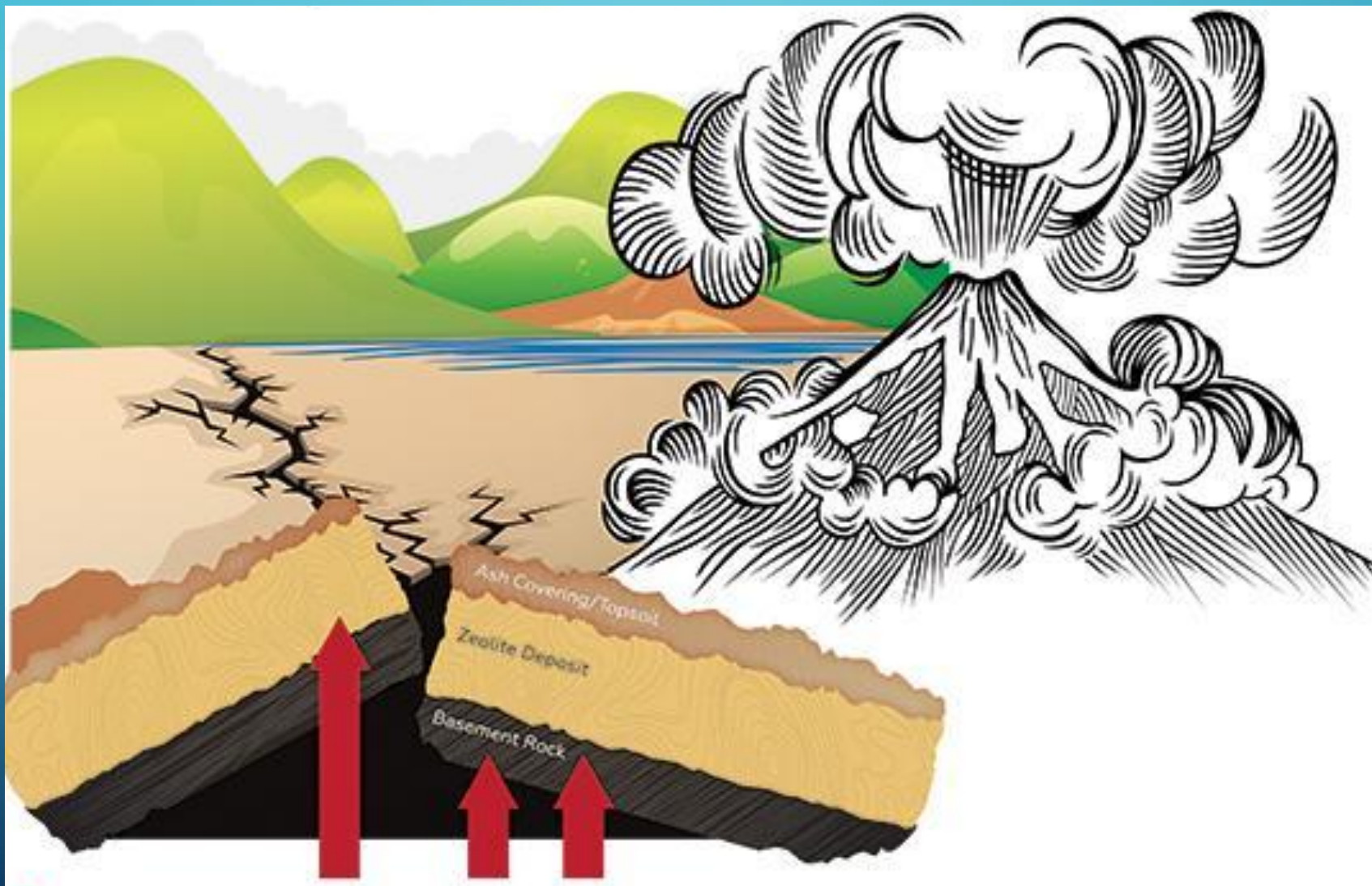


10-ring viewed along [010]

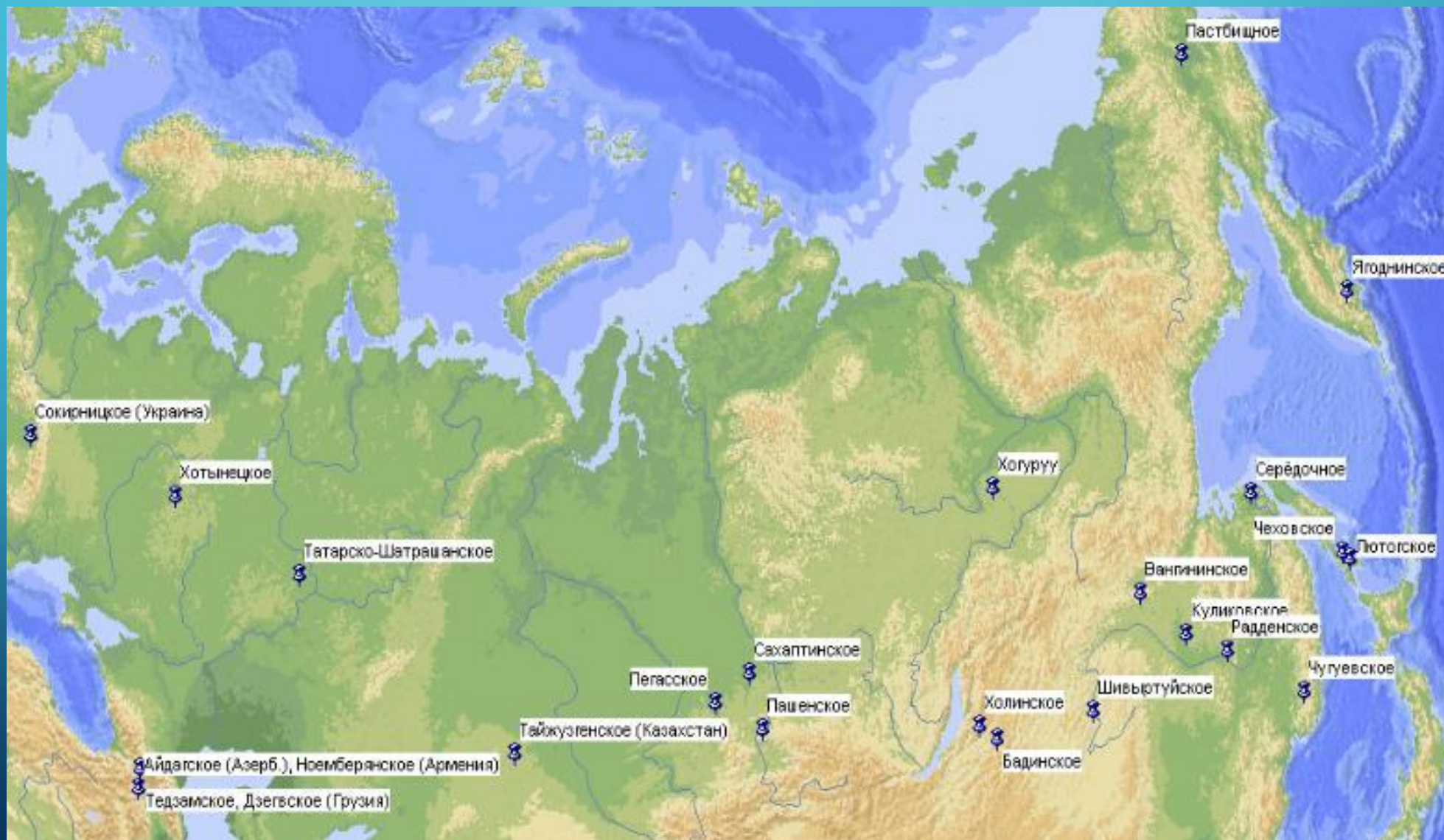
ZSM-5

Zeolite
 Socony
 Mobil-five

Цеолиты: образование



Цеолиты: месторождения



Натуральные цеолиты



анальцим



шабазит



гейландит



клиноптилолит



натролит



содалит



стильбит



филипсит

Применение: строительство

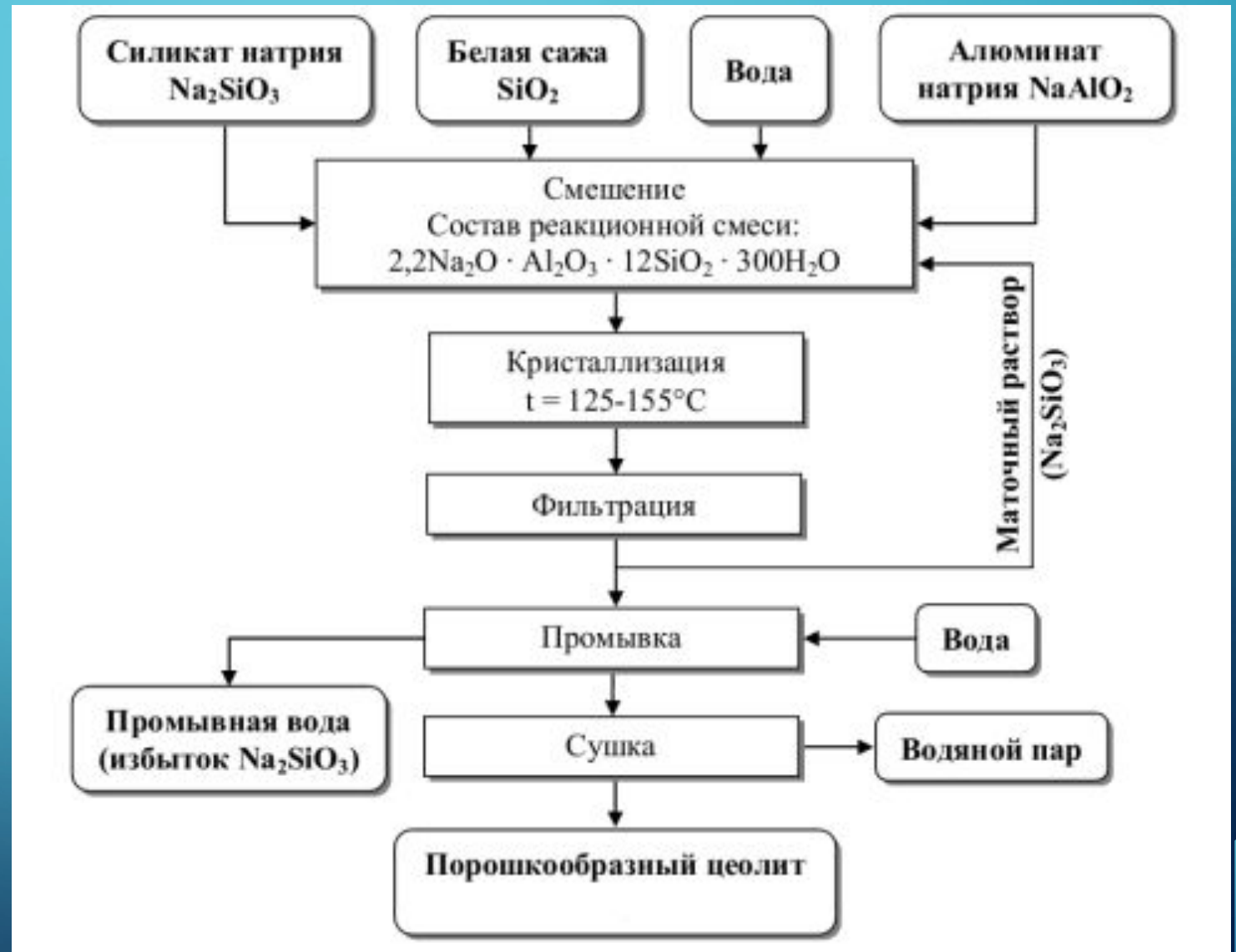


4 000 000 T

2 500 000 T

Цеолиты: синтез

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



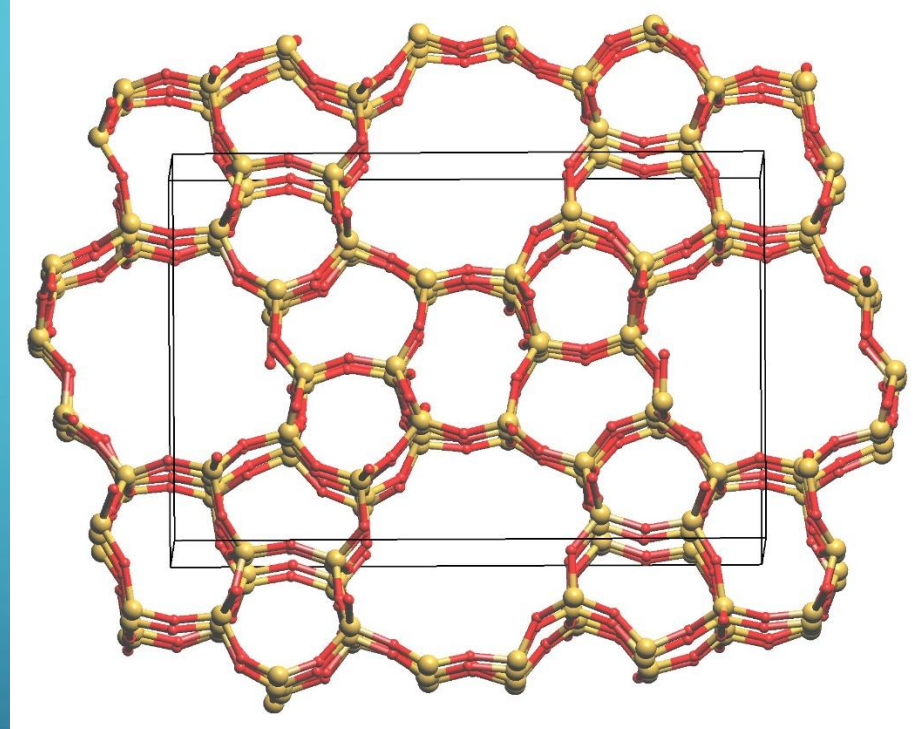
Применение: катализ

Цеолит Y (FAU) 300 000 т



Применение: катализ

Metanol to Gasoline (MTG) Process



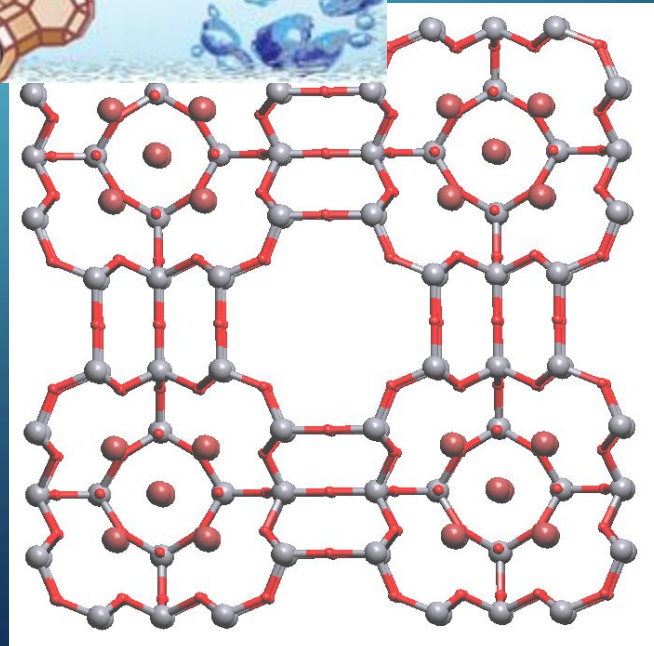
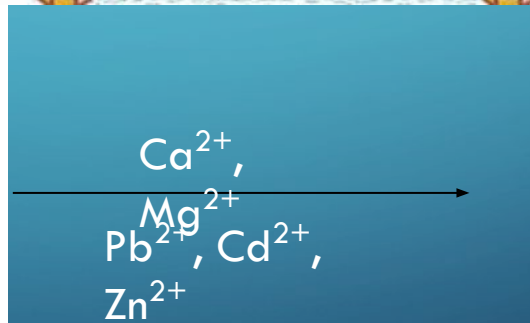
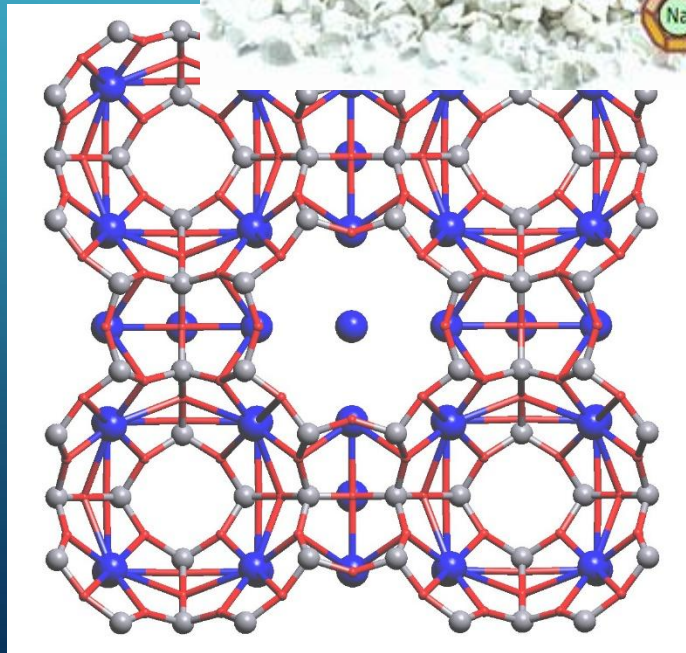
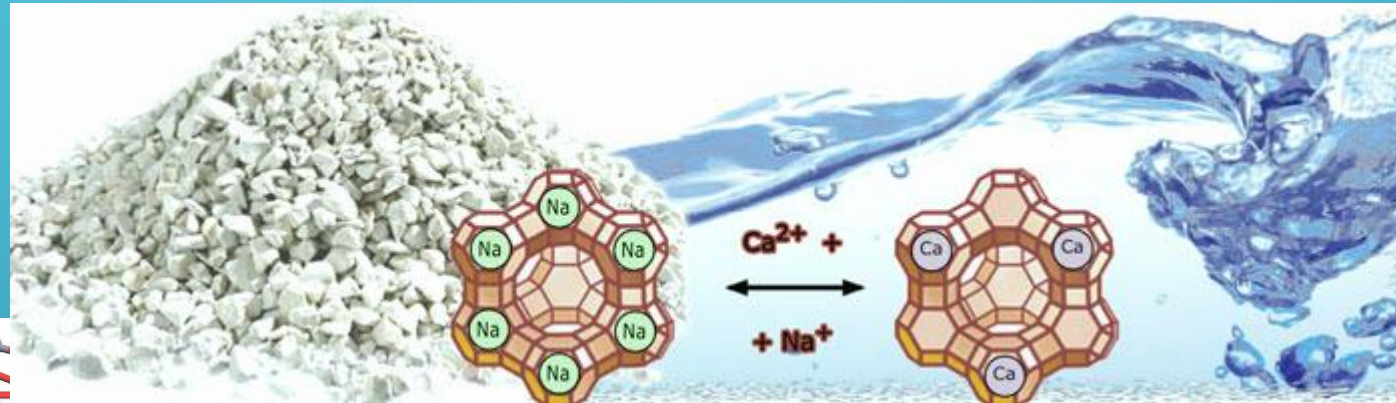
H-ZSM-5
MFI

«Производство полимеров» поли-пара-ксилилен

Применение: катионообмен

Цеолит А (LTA)

1,400 000 т



Применение: катионообмен



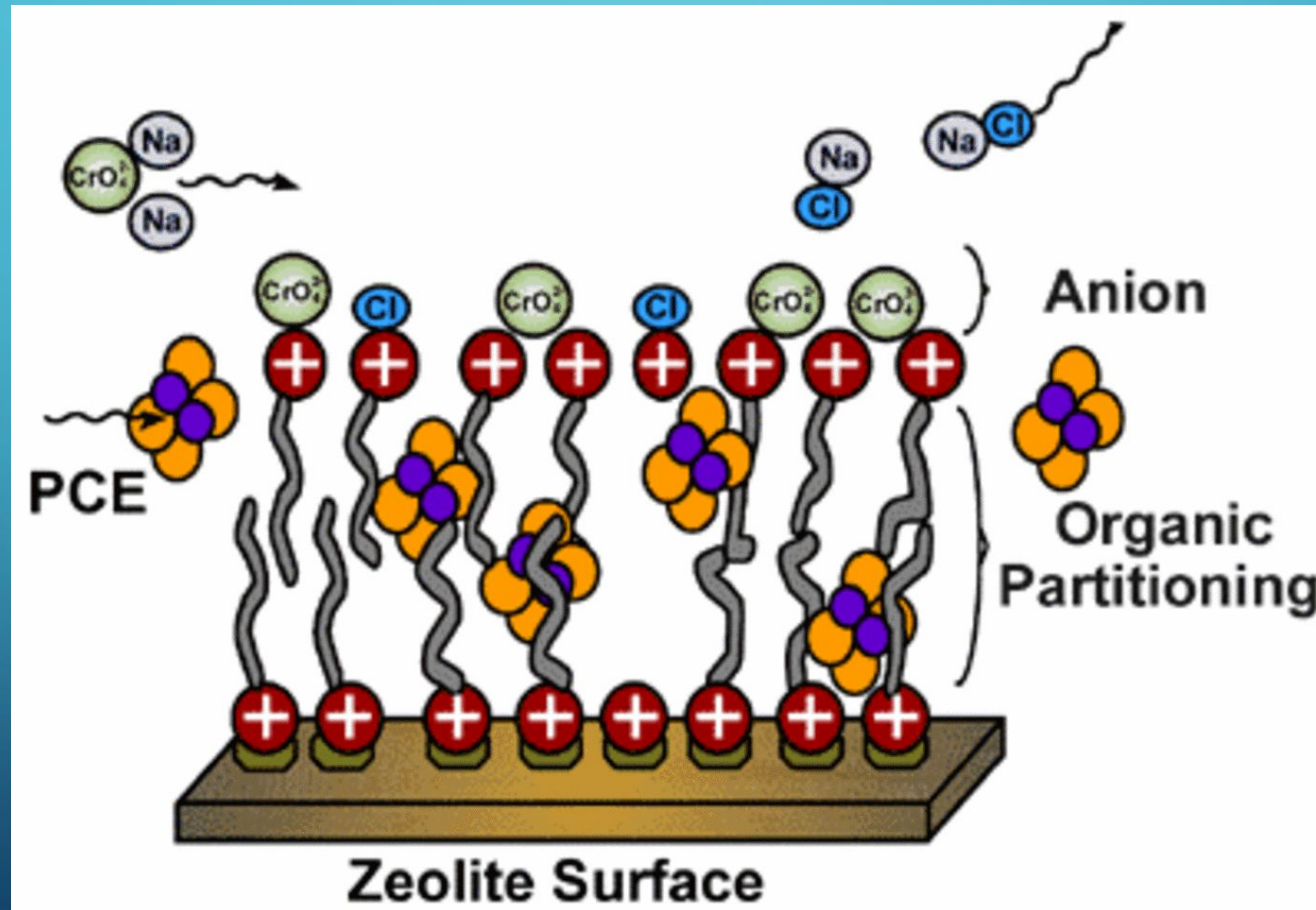
ЛИНОПТИЛОЛИТ
(HEU)

500 000 т

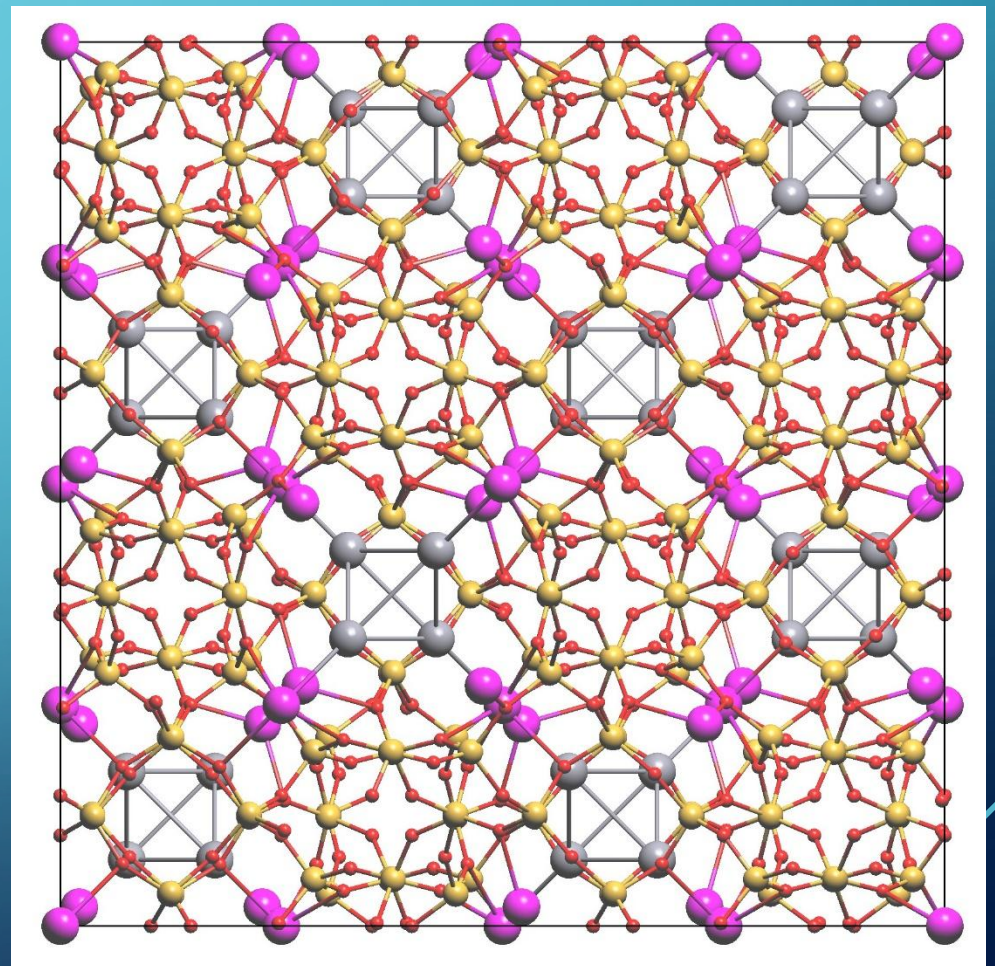
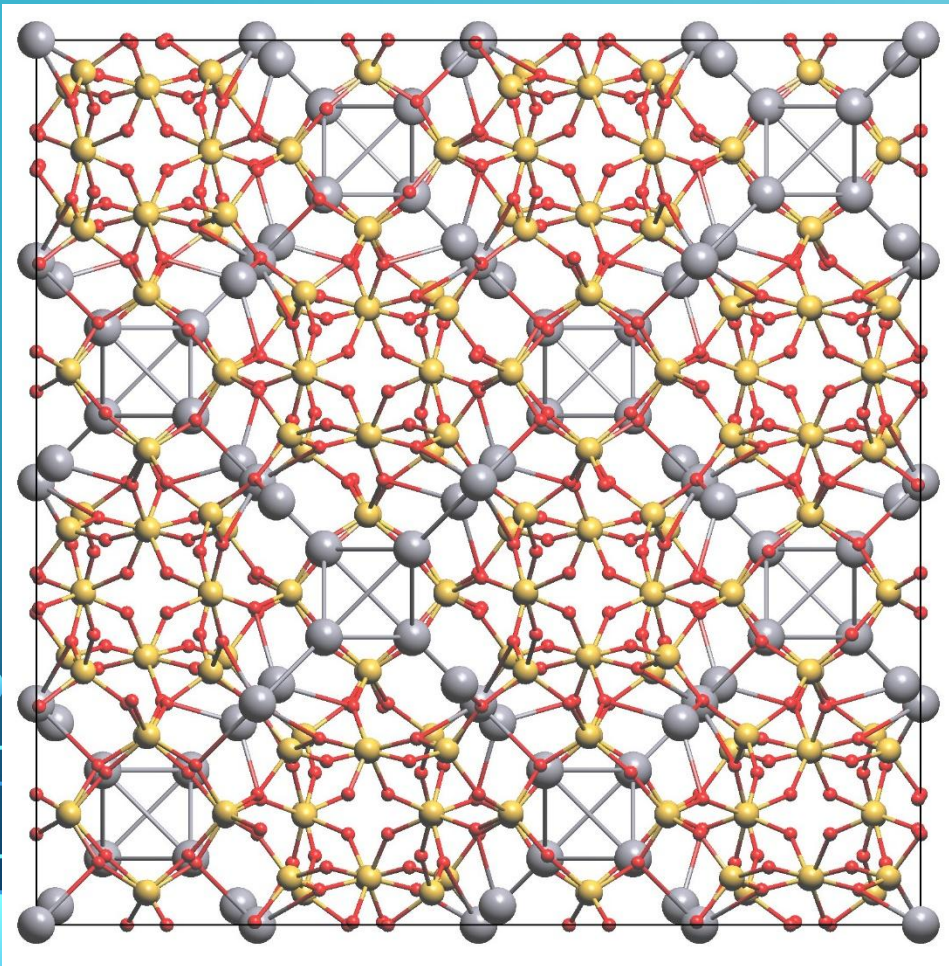
^{134}Cs , ^{137}Cs , ^{90}Sr

Применение: адсорбция

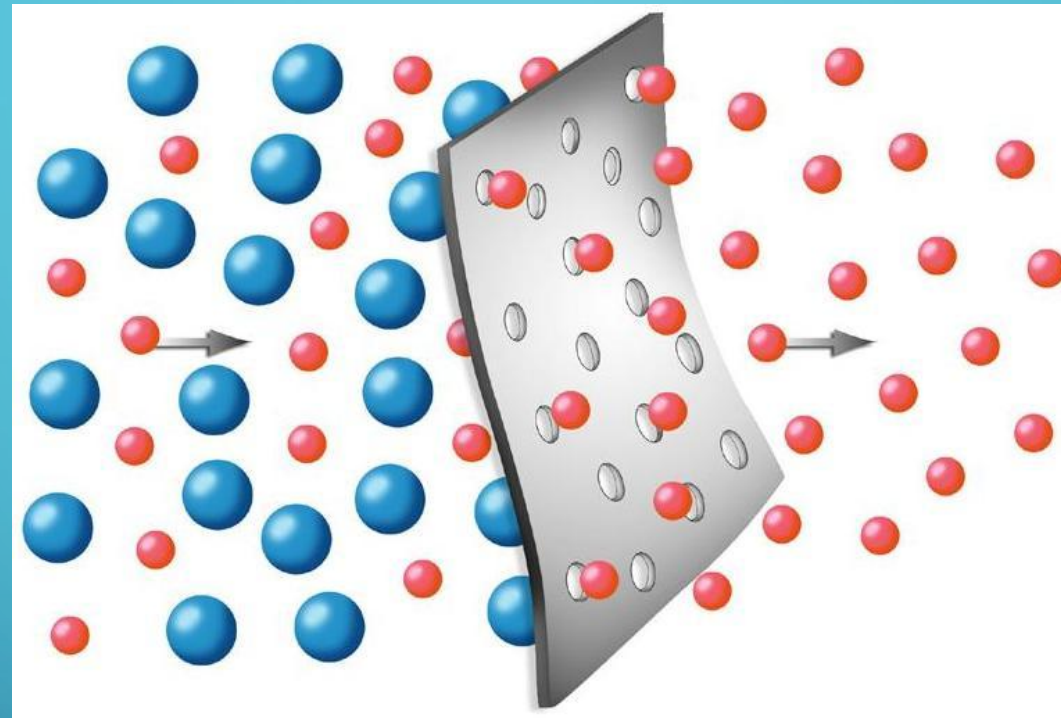
Клиноптилолит (HEU)



Применение: адсорбция



Применение: молекулярные сита



Осушение

Удаление углеводородов

Разделение газов

Применение: медицина



Применение: сельское хозяйство

