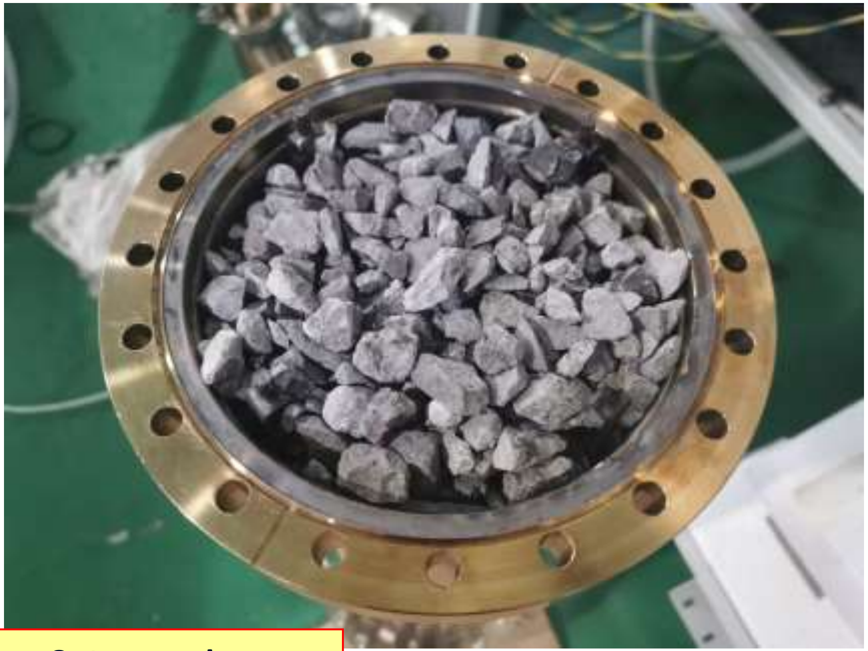
ALPHA Flux Test



Zeolites BEFORE & AFTER Flux Test

X13 Zeolite

8 7 6 5 4 3 2 1

REVISIONS LOG					
REV.	DATE	ECN	AUTH	DR	CK
-	12/2020	ECN 200106		RDONG	

D

Molecular Sieve JZ-ZMS9

Description:

JZ-ZMS9 is Sodium aluminosilicate, It could absorb the molecular which diameter is not more than 9 angstroms.

Applications:

1. Purification of gas in air separation plant, removal of H2O, CO2 and hydrocarbons.
2. Dehydration and desulfurization (removal of H2S and mercaptan, etc.) of natural gas,LNG, liquid alkanes (propane, butane, etc.).
3. Deep drying of general gases (e.g. compressed air, permanent gas).
4. Drying and purification of synthetic ammonia.
5. Desulfurization and deodorization of Aerosol.
6. CO2 removal from pyrolysis gas.

Specification:

Properties	Unit	sphere		cylinder	
Diameter	mm	1.6-2.5	3-5	1/16"	1/8"
Static Water Adsorption	≥%	26.5	26.5	26	26
CO2 Adsorption	≥%	18	17.5	17.5	17.5
Bulk Density	≥g/ml	0.64	0.62	0.62	0.62
Crushing Strength	≥N/Pc	25	80	25	65
Attrition Rate	≤%	0.1	0.1	0.4	0.4
Package Moisture	≤%	1.5	1.5	2.0	2.0

Standard Pakage:

sphere: 140kg/steel drum
cylinder: 125kg/steel drum

JiuZhou **Shanghai Jiuzhou Chemicals Co., Ltd**

NOTE:
PROPERTIES: SPHERE
DIAMETER : 3-5MM

Attention:

The product as desiccant cannot be exposed in the open air and should be stored in dry condition with air-proof package.

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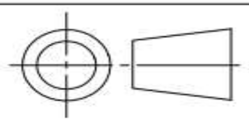
E-mail: marketing@jiuzhouchemicals.com **Website:** www.jiuzhouchemicals.com

C B

NO DEVIATIONS, SUBSTITUTIONS, OR EXCEPTIONS

HELLER INDUSTRIES INC



THIRD ANGLE PROJECTION

DIMENSIONS ARE IN MILLIMETERS
UNLESS OTHERWISE SPECIFIED
TOLERANCES ARE:
(ALL) DECIMAL PLACES: ±0.38
ANGULAR: ±1°

BREAK ALL SHARP CORNERS (0.13 - 0.25)
TOLERANCE ZONE PROJECTION ± 25.4
ALL MACHINED SURFACES 3.2
DO NOT SCALE DRAWING

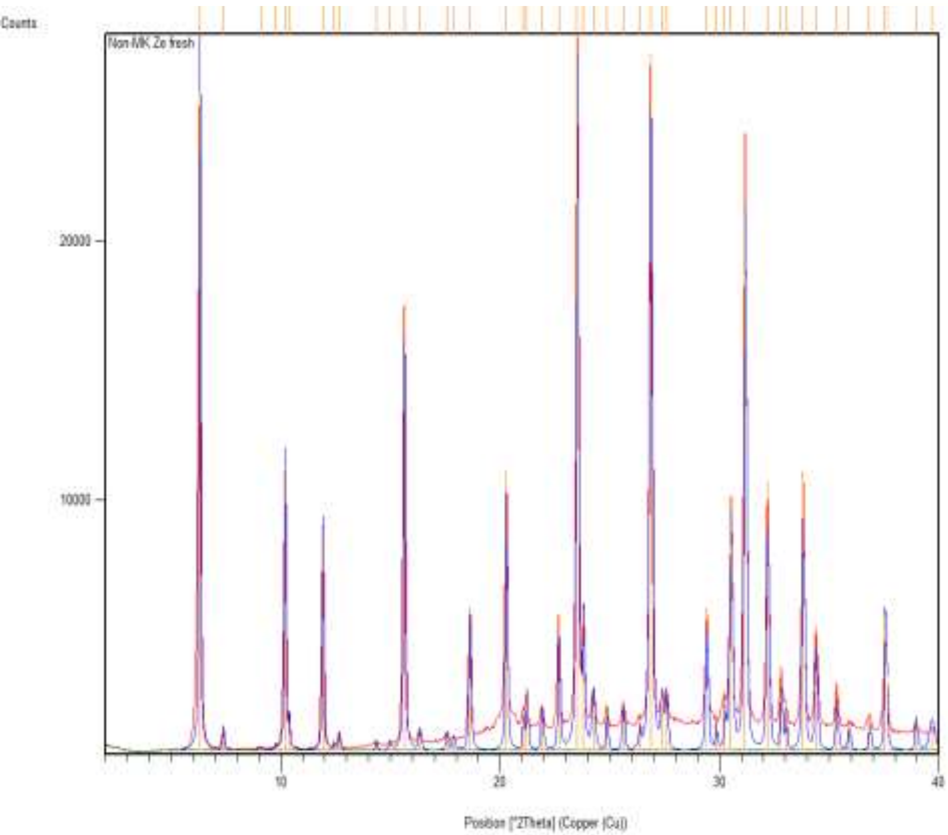
QUANTITY:	
SO. No:	
COMP. DATE:	NEXT ASSY / QTY

MATERIAL: SEE NOTES	DESCRIPTION/TITLE: JZ-ZMS9 ZEOLITE, 13X GRADE		
FINISH	DRAWN BY: RDONG	DATE: 12/19/2020	
	APPROVED BY: RAVIT	DATE: 2/24/2021	
PROJECT/MFG No:	SIZE: A	2210186	REVISION: int
SCALE	LAST SAVED BY: rpotineni	3/31/2021	SHEET 1 OF 1

A

8 7 6 5 4 3 2 1

XRD – Fresh Zeolite – X13



Candidates:

No.	Ref. Code	Score	Compound Name	Chemical Formula
1	00-005-0586	22	Calcite, syn	Ca C O3
2	00-033-1161	15	silica	Si O2
3	00-046-1045	15	Quartz, syn	Si O2
4	00-010-0173	12	alumina	Al2 O3
5	00-024-0072	7	Hematite	Fe2 O3
6	01-073-1667	6	Bornite	Cu5 Fe S4
7	00-006-0329	4	Praseodymium Oxi...	Pr O1.83
8	01-075-0134	3	Uranium Oxide	U O2
9	00-005-0628	1	Halite, syn	Na Cl
10	01-077-2041	1	Sodium Erbium Flu...	Na Er F4

Zeolites are microporous, aluminosilicate minerals commonly used as commercial adsorbents and catalysts.

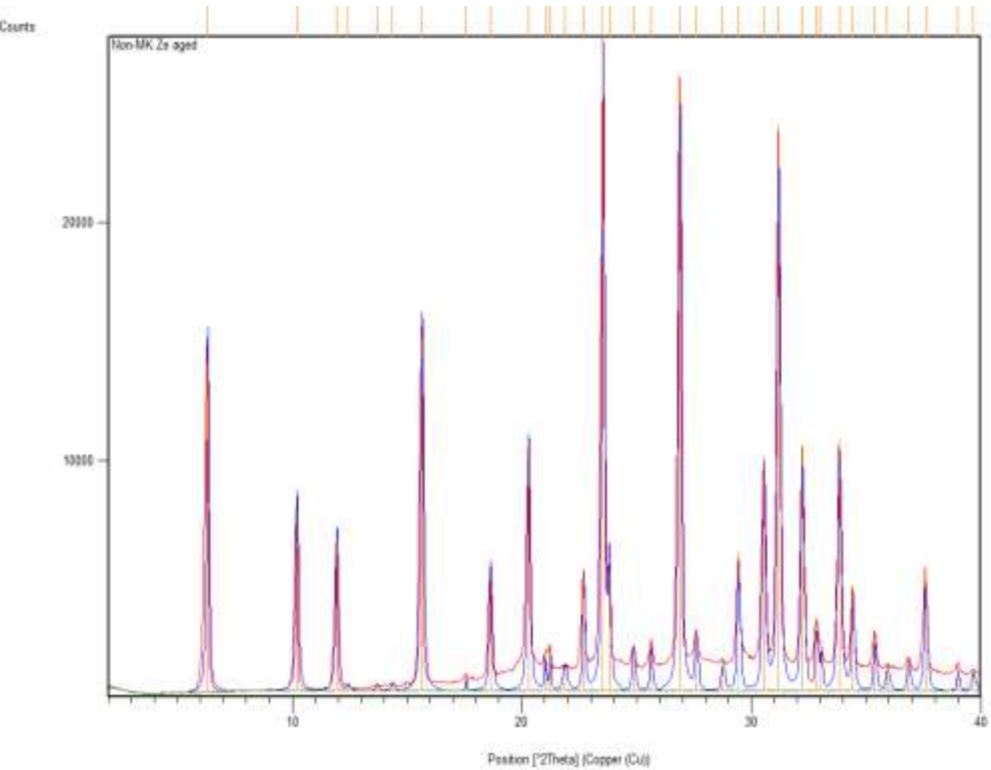
- Presence of Calcite is considered significant

- Zeolite extrudate size ~4mm

- Si –Al ratio ~3 to 1

- Pore size unknown

XRD – Aged Zeolite – X13   time in service - unknown



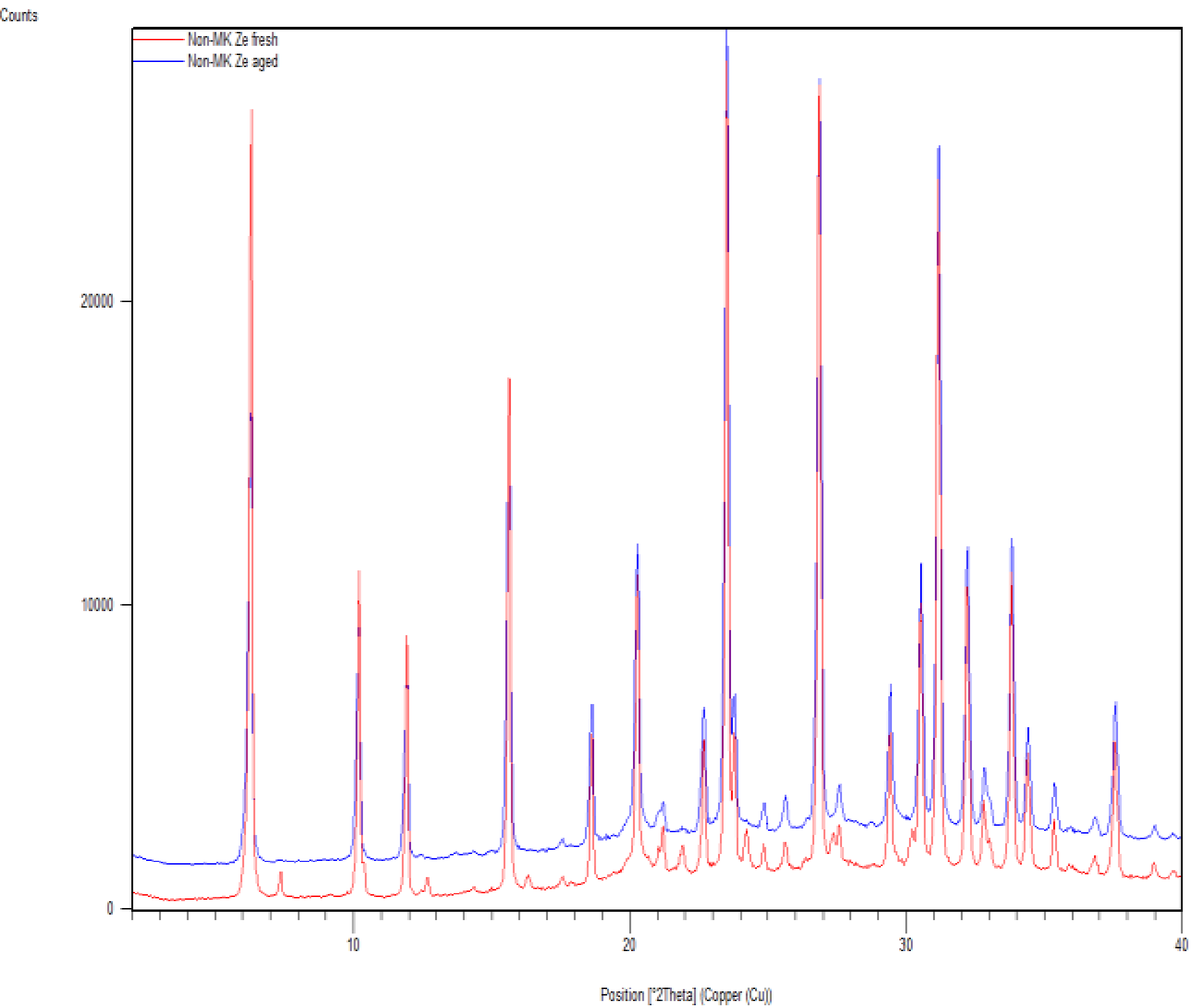
Selected Candidate: 00-005-0586

No.	Ref. Code	Score	Compound Name	Chemical Formula
1	00-005-0586	28	Calcite, syn	Ca C O3
2	00-033-1161	17	silica	Si O2
3	00-046-1045	17	Quartz, syn	Si O2
4	00-010-0173	16	alumina	Al2 O3
5	00-024-0072	13	Hematite	Fe2 O3
6	00-024-1977	13	Sucrose	C12 H22 O11
7	01-073-1667	7	Bornite	Cu5 Fe S4
8	00-033-0664	7	burnt ochre	Fe2 O3
9	00-006-0329	4	Praseodymium Oxide	O1.83
10	01-075-0134	4	Uranium Oxide	U O2
11	01-077-2041	1	Sodium Erbium Flu...	Na Er F4
12	00-005-0628	1	Halite, syn	Na Cl

Sucrose, a disaccharide, (C12H22O11), from monomers. glucose and fructose likely originated in a condensation reaction from flux and thixotropic agents. Aged zeolite is 6.0mm in diameter, having adsorbed CO2 and water.

Burnt Ochre is a family of earth pigments, which includes yellow ochre, red ochre, purple ochre, sienna, and umber. The major ingredient of all the ochres is iron(III) oxide-hydroxide, known as limonite, which gives them a yellow color. Yellow ochre, FeO(OH)·nH 2O, is a hydrated iron hydroxide (limonite) also called gold ochre.

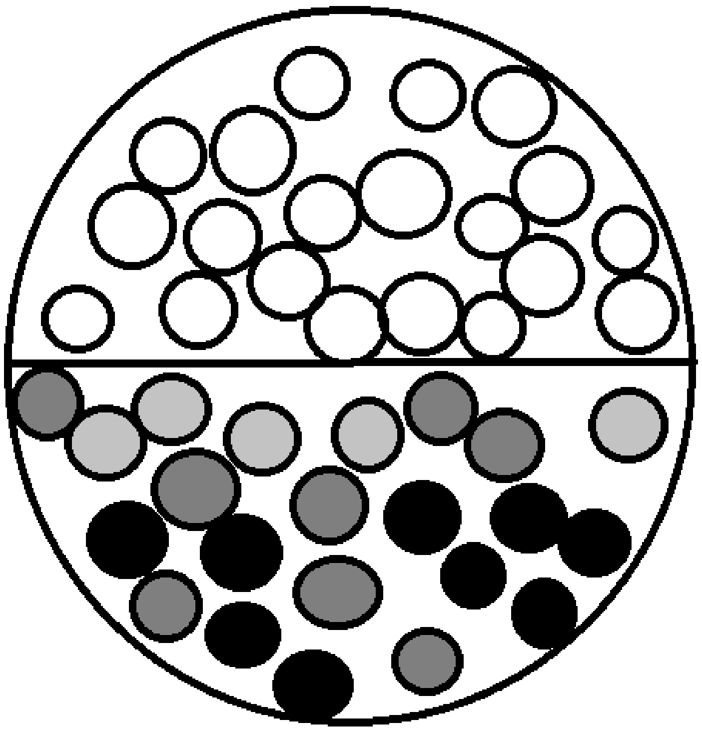
XRD comparative spectral overlap – X13 Zeolite – Fresh vs Aged



Aged and fresh samples with near identical structures, same zeolite

Structural features observed in the fresh sample, no longer evident in the aged sample

X13 Zeolite Bed Contaminant Profile



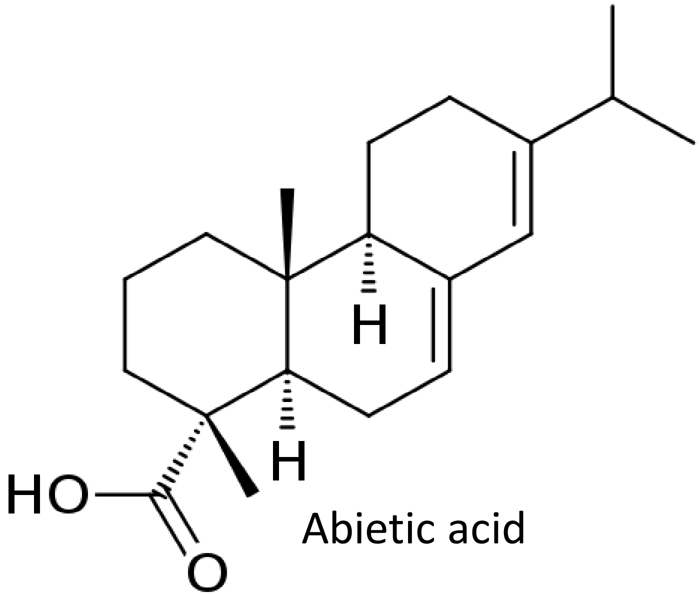
Mal-distribution of contaminants reportedly reside at the bottom region of the incoming zeolite bed

Suggesting non uniform flow and ineffective use of zeolite bed

Inlet flow straightener, eg, wire mesh may mitigate problem. Wire mesh matrix segments could improve zeolite life and performance

Irrespective of matrix design, inlet flow straightening may be necessary in a traditional monolith, metal, ceramic, extrudate

Flux composition



Abietic acid

Rosin (resin) content is upward of 50-60% of a typical flux compound.

Abietic acid is the primary carboxylic acid in flux that serves to remove oxide formation from surfaces.

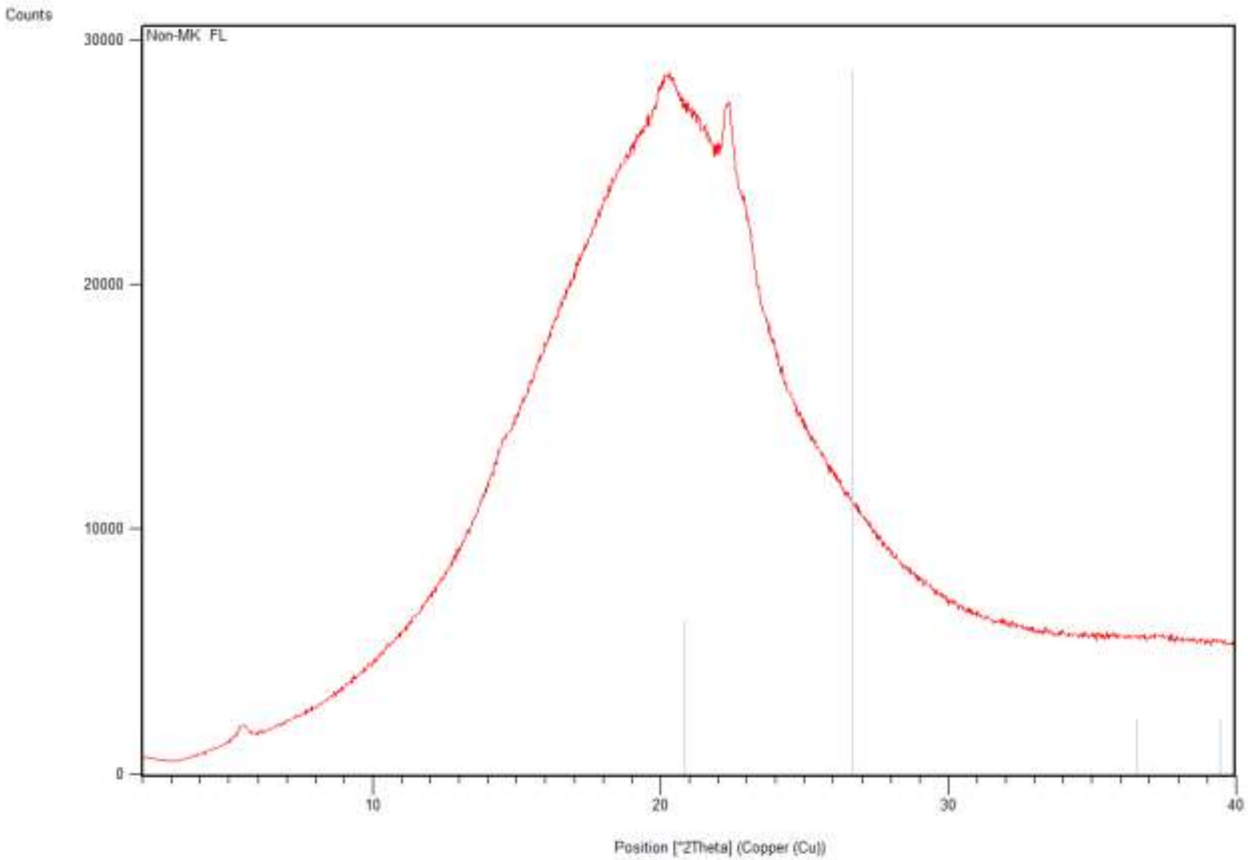
Rheological modifiers

Solvent – linear glycol

Small molecules

Pyrolysis or devolatilization of flux occurs at elevated temperatures in inert or (02) deprived environment.
In general, pyrolysis of organic substances produces volatile products and leaves a carbon-rich solid residue. Pyrolysis, which leaves carbon compounds as the primary residue, carbonization. Pyrolysis is considered the first step in the processes of gasification or combustion.

XRD – Flux compound - Fresh



Candidates:

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1	00-033-1161	4	silica	Si O2
2	00-046-1045	3	Quartz, syn	Si O2
3	00-005-0586	2	Calcite, syn	Ca C O3

Sample is largely amorphous suggesting high surface area and high surface energy

Highly viscous

Low crystallinity

Low or non-existent porosity

Flux composition:

- Small molecule
- Rheological Additives
- Abietic acid
- Rosin/resin

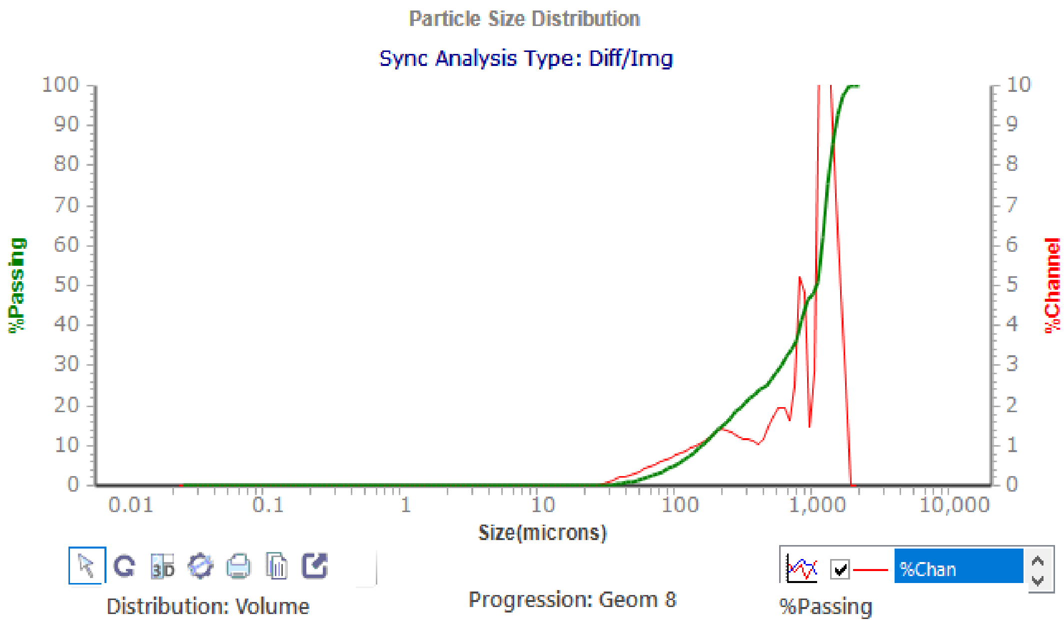
CaCO3 and SiO2 binders
Disaccharide formed in the furnace

PSD-FLUX PSD by Microtrac FlowSync with nonpolar solvent Isopar-G Analyzed following 60s sonication

Summary Data | Tabular Data | Notes/Warnings | Raw Data | Setzero | Size/Shape Data

Summary		Percentiles		Size Percent		Peaks Summary		
Data	Value	%Tile	Size(um)	Size(um)	%Tile	Dia(um)	Vol%	Width
MV(um):	828.2	10.00	143.7			1166	53.7	350
MN(um):	59.63	20.00	280.0			741.7	14.1	136.9
MA(um):	361.0	30.00	536.0			466.6	10.3	181.1
CS:	1.66e-2	40.00	749.8			154.6	21.9	176.3
SD:	528.9	50.00	979.6					
		60.00	1072					
Mz:	822.2	70.00	1142					
si:	472.2	80.00	1227					
Ski:	-0.37268	90.00	1358					
Kg:	0.733	95.00	1460					

Bar->Line
Large->Small
Restore Graph
Undo Keep
Retained



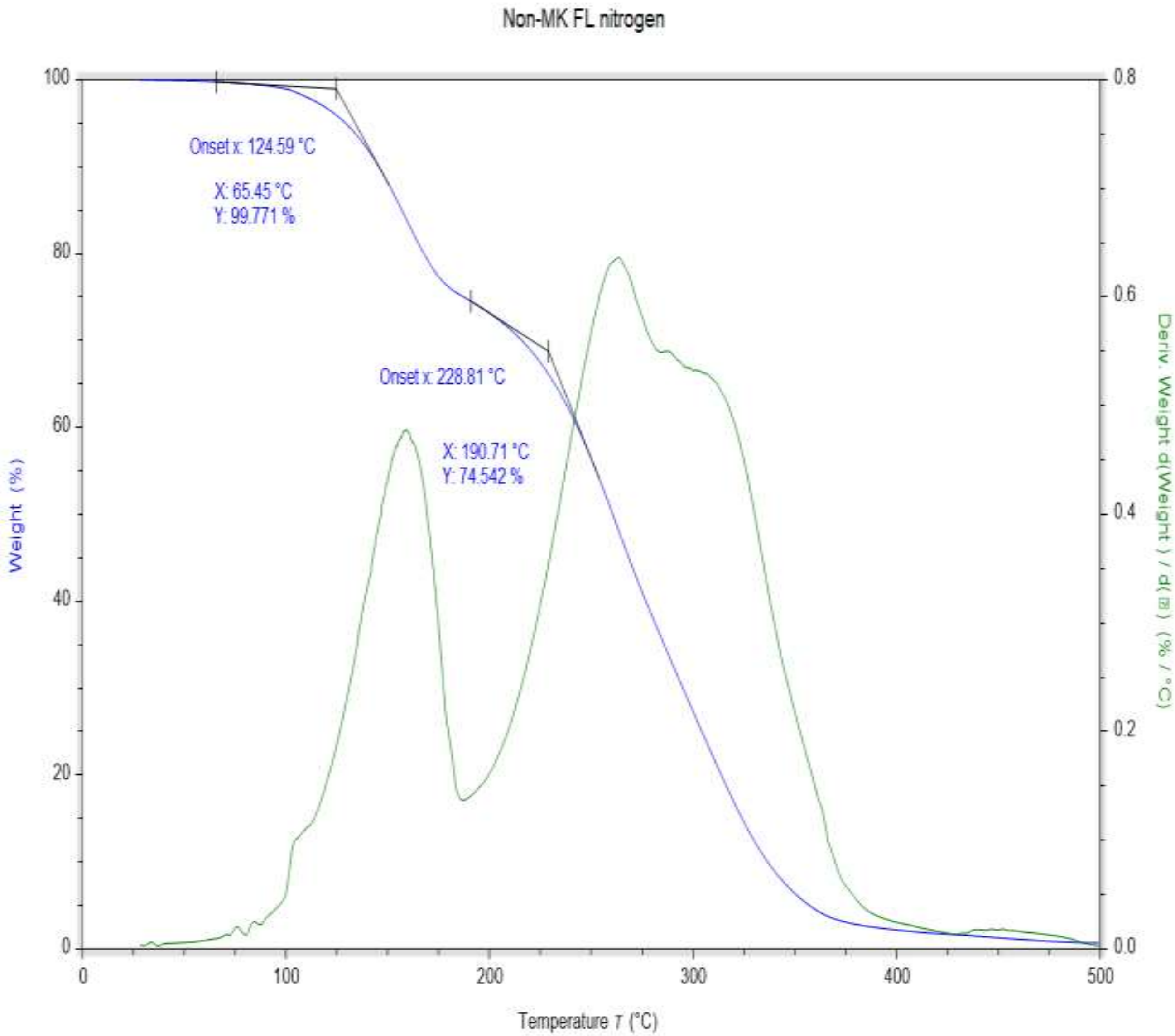
Wide PSD distribution ~144U to 1460U

Sample polymer-like mildly soluble in Isopar-G

Classification of Flux may improve deposition furnace contaminant profile

Flux

TGA/DTA in N2 : Ramp 5.0c/min to 500c

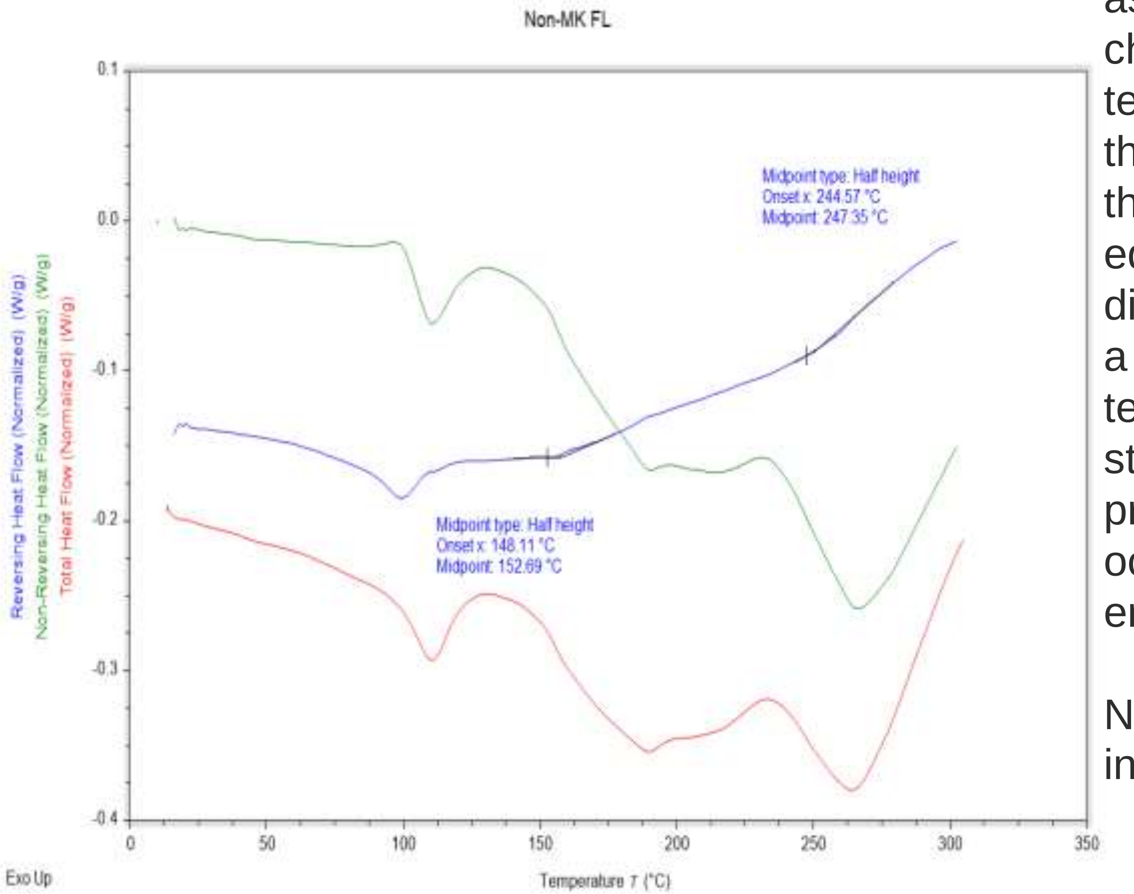


Onset
~65C – 500C

2 exotherms
1 endotherm

Flux Characterized by DSC - Differential Scanning Calorimetry ~300C

No.	Description
1	Equilibrate 10.00 °C
2	Isothermal 5.00 min
3	Data On
4	Modulate Temperature Amplitude 0.5000 °C , Period 60.0 s
5	Ramp 5.00 °C/min to 400.00 °C



DSC monitors changes in the heat effects associated with physical transitions and chemical reactions as a function of temperature. The DSC principle assumes that under constant pressure conditions the change of heat in any transition is equivalent to the change of enthalpy. The difference in heat flow to the sample and a reference is recorded as a function of temperature. DSC allows the user to study the kinetics of the physical processes and chemical reactions that occur during biodegradation, including enthalpy changes.

Not clear why heat in sample shows an increase with increasing T,

Characterization in Progress

SEM

- flux – (particles, contaminants, features)
- aged zeolite - (pore size, contaminants)

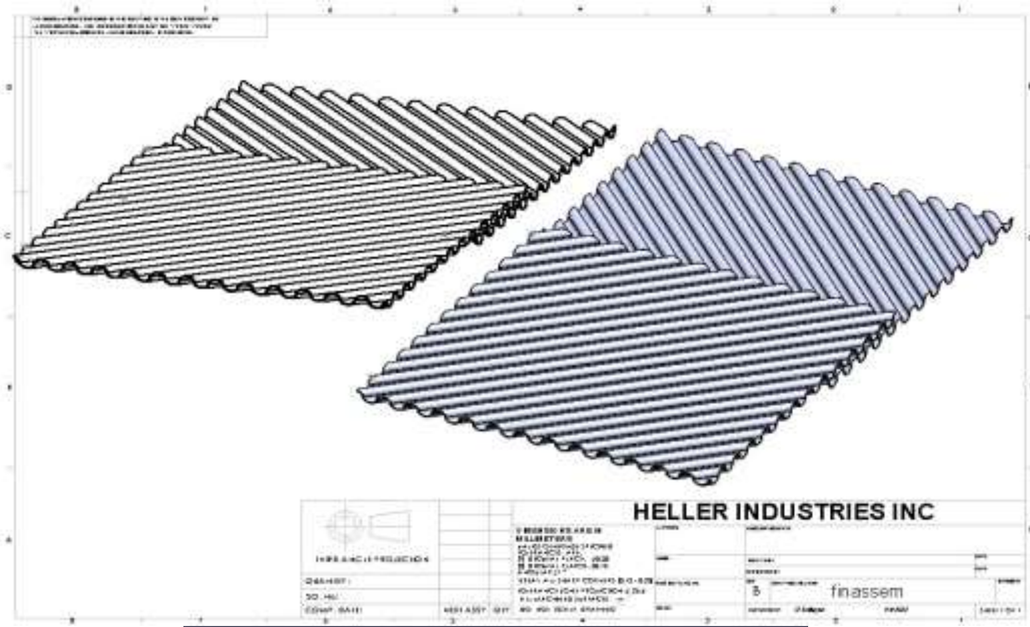
TGA/air

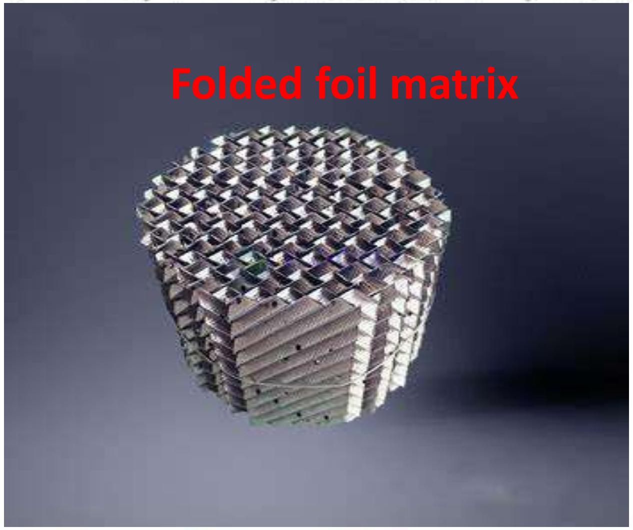
- flux - (how air and flow influence oxidation of HC’s)

Porosity (N)

- SA and micropore measurement
- Comparative, fresh and aged zeolite

H1 Cross Flow Metal Substrate Development – High Mass Transfer

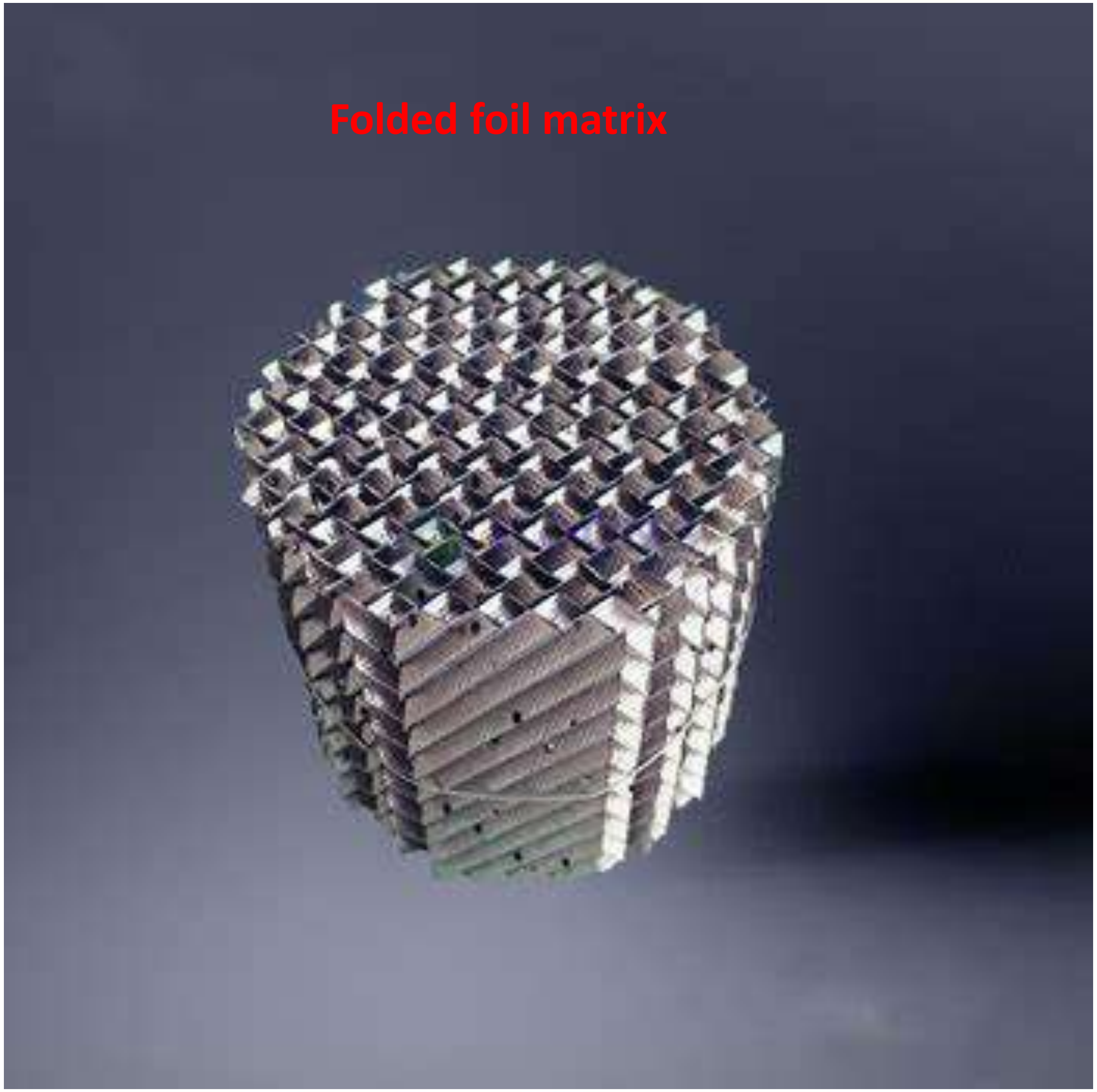




Material: fecralloy-OCr21A16
Gauge: 50 micron
Corrugation height: 0.98mm
Channel angle: 45 degree
Foil width: 106.30mm
Finished diameter: 138mmOD
5.433”D x 4.185”L
97.02” = V (total cat V = ~3.2L)
No mantle

Nonionic wash
Foil roll with nodal matrix braze
Heat treat: 920C/2hrs/Air
Corrugation height 0.98mm
Corrugation width   2.1mm
4 wraps of flat foil on perimeter
Tolerance: +/- 0.38mmD
Tolerance: +/- 0.13mmL

H1 Cross Flow Metal Substrate Development – High Mass Transfer Substrate



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Corrugation height 0.98mm
Corrugation width   2.1mm
4 wraps of flat foil on perimeter
Tolerance: +/- 0.38mmD
Tolerance: +/- 0.13mmL

Technology	Substrate	Type	Dimensions	Quantity Requested	Quantity Received	Date Requested	Invoice Receive Date	PO
Trap-baseline (no coating)	wire mesh		5.66D" x 0.5"L	10	10	22-May	6/3/2022	PO337516/3
Trap-LPA (TH-100)	wire mesh		5.66D" x 0.5"L	10	10	22-May	6/3/2022	PO337516/3
H-Beta	metal monolith	straight channel	138mmD x 106.3mmL	3		6/2 & 7/15/22	NA	
H-Beta w/10% Cu	metal monolith	straight channel	138mmD x 106.3mmL	3		6/2 & 7/15/22	NA	
Cu-Y	metal monolith	straight channel	138mmD x 106.3mmL	3		6/2 & 7/15/22	NA	
ZSM-5	metal monolith	straight channel	138mmD x 106.3mmL	3		6/2 & 7/15/22	NA	
SCR	metal monolith	straight channel	138mmD x 106.3mmL	3		6/2 & 7/15/22	NA	
Cu-ZSM-5	metal monolith	straight channel	138mmD x 106.3mmL	3		6/2 & 7/15/22	NA	
DOC/DPF 5g/2:1:0	Cordierite	DOC/DPF	143.8*152/300	1				
DOC/GPF 5g/2:1:0	Cordierite	DOC/GPF	118.4*127/300	1		6/22/2022	PO375534	
CuSCR/GPF	Cordierite	CuSCR/GPF	118.4*127/300	1				
DOC/DPF 5g/2:1:0	Cordierite	DOC/DPF	143.8*152/300	1				
DOC/GPF 5g/2:1:0	Cordierite	DOC/GPF	118.4*127/300	1		7/15/2022	PC01153	
CuSCR/GPF	Cordierite	CuSCR/GPF	118.4*127/300	1				
H-Beta	Cordierite	floThru-300/400 cpsi	TBD	1		25-Jul		
H-Beta w/10% Cu	Cordierite	floThru-300/400 cpsi	TBD	1		25-Jul		
Cu-Y	Cordierite	floThru-300/400 cpsi	TBD	1		25-Jul		
ZSM-5	Cordierite	floThru-300/400 cpsi	TBD	1		25-Jul		
SCR	Cordierite	floThru-300/400 cpsi	TBD	1		25-Jul		
Cu-ZSM-5	Cordierite	floThru-300/400 cpsi	TBD	1		25-Jul		
DOC-DPF	Cordierite	floThru-300/400 cpsi	TBD	1		25-Jul		

Zeolyst-Zeolites: Test Candidates for Flux and Formic Applications

Source	Material	Pore SizeD	BET SA	Si-Al Ratio
Zeolyst	CBV-400	24.5A	730	5.1
Zeolyst	CBV-5524G	5.5A	425	50.1
Zeolyst	CBV-2314		425	23.1
Zeolyst	CBV-720	24.28A	780	30.1

Note:

- 2 Y zeolites and 2 ZSM-5 zeolites
- (CBV-2314, CBV-5524 are ZSM-5)
- (CBV-400, CBV-720 are Y Zeolites)
- CBV 5524G and CBV 2314 must be calcined at 500C for 1 hour in air to activate H form

Molecular Weight Distribution of Residue in Flux Reactor Cold Traps

GPC (Gel Permeation Chromatography) Eurofins

GPC separates organic compounds based on the size, (atomic radii), specifically by hydrodynamic volume

Size determination and separation are achieved through packed porous beads in a chromatographic column. Organics can be characterized by molecular wt and average molecular wt within a column.

Gels are used as the stationary phase for GPC. The pore size of a gel are carefully controlled in order to achieve a given separation. Other desirable properties of the gel forming agent are the absence of ionizing groups and, in each solvent, low affinity for the substances to be separated

The column used for GPC is filled with a microporous packing material. The column is filled with the gel.

XRF result: Wash-coat scrapped from commercial metal monolith

TEST REPORT

试验结果 Test Result			
委托人	张元	Sample submission date	2022-06-20

XRFUQ 数据					
Pat number	Sample description		Component	Test value %	Test method
2205770	Scratching powder		Al_2O_3	65.593	ECTC/I-AL-080
			CaO	0.120	
			CeO_2	10.768	
			Cr_2O_3	0.342	
			Fe_2O_3	2.898	
			La_2O_3	1.771	
			MgO	0.052	
			MnO	1.881	
			Na_2O	0.322	
			P_2O_5	0.600	
			SO_3	0.652	
			SiO_2	14.203	

Precious metals deemed too low in concentration to resolve signal to noise interference in providing accurate measurement

Wash-coat loading deemed very low

Wash-coat reported to be very difficult to remove from substrate, suggesting low porosity, low wash coat loading

99.202% wash-coat materials, with PM & contaminant balance

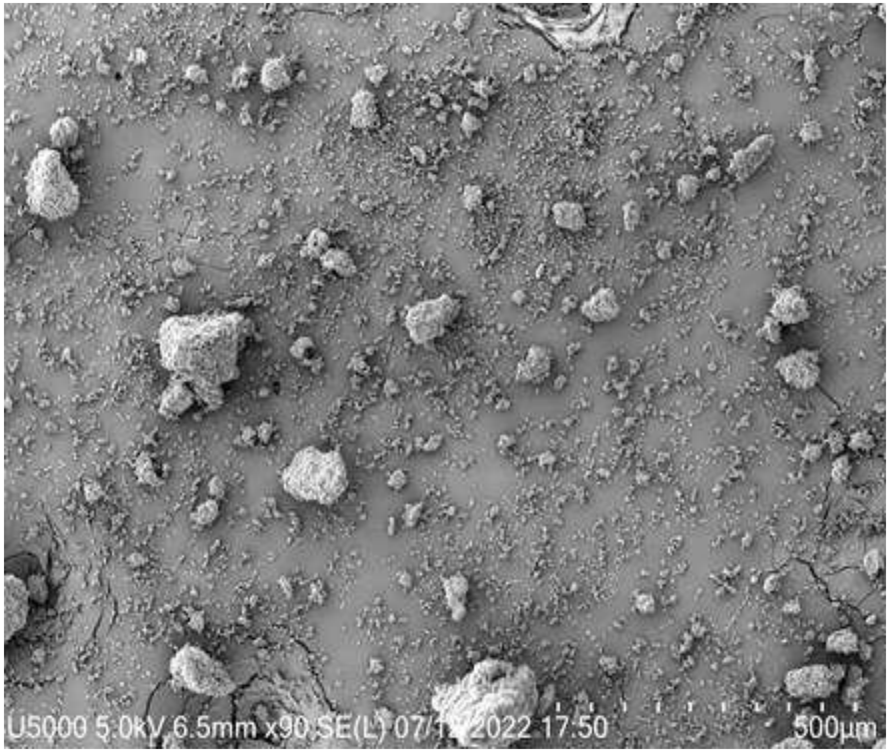
ICP results suggest low PM and wash-coat content

	Dark, before regeneration			Light, after regneration		
Component	mg/brick	mg/in³	g/in³	mg/brick	mg/in³	g/in³
Pd	28.58	0.325883694	0.000325884	30.451	0.347217788	0.000347218
Pt	29.32	0.334321551	0.000334322	22.838	0.26041049	0.00026041
Al	3288.1	37.49258837	0.037492588	4783.968	54.54923603	0.054549236
Ba	2.15	0.024515393	2.45154E-05	2.53	0.028848347	2.88483E-05
Ca	14.53	0.165678449	0.000165678	35.341	0.402976055	0.000402976
Cr	20.87	0.237970353	0.00023797	16.894	0.192633979	0.000192634
Fe	240.73	2.744925884	0.002744926	273.328	3.116624857	0.003116625
Mg	1.15	0.013112885	1.31129E-05	2.115	0.024116306	2.41163E-05
Mn	446.67	5.093158495	0.005093158	479.181	5.46386545	0.005463865
Ni	81.84	0.9331813	0.000933181	363.32	4.142759407	0.004142759
La	626.84	7.147548461	0.007147548	599.95	6.840935006	0.006840935
Ce	749.98	8.551653364	0.008551653	1020.632	11.63776511	0.011637765
			0.063064538			**0.087007389**

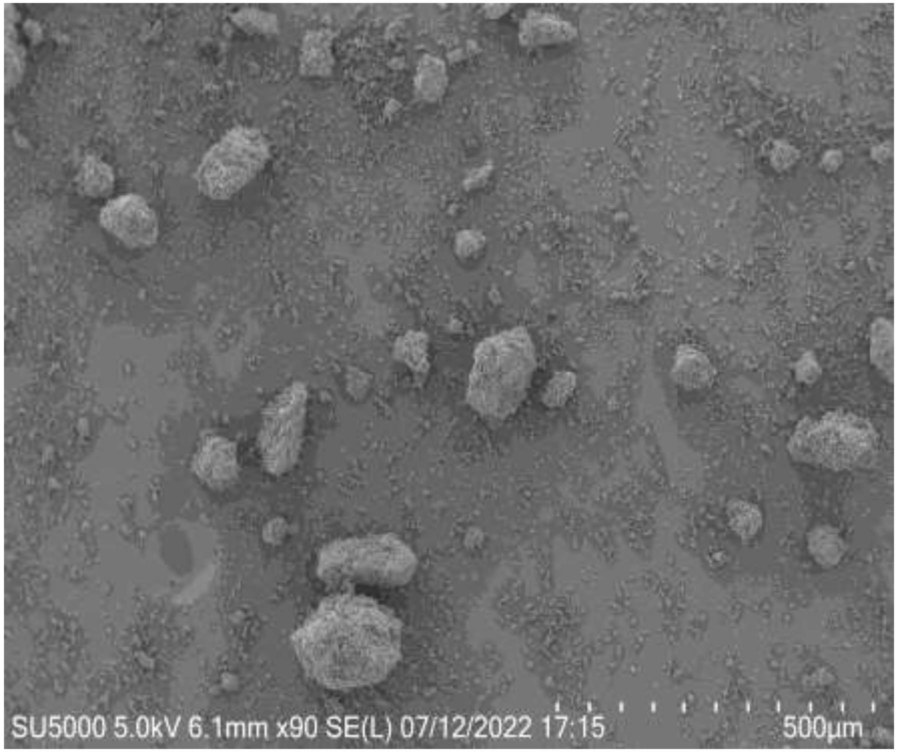
SEM - Scanning Electron Microscopy for Aged Zeolite

Bulk analysis - Morphology technique - back scattered electrons penetration at various depths
Irregular Particle Morphology
Pore size, contamination profile not determined

Fresh 90x

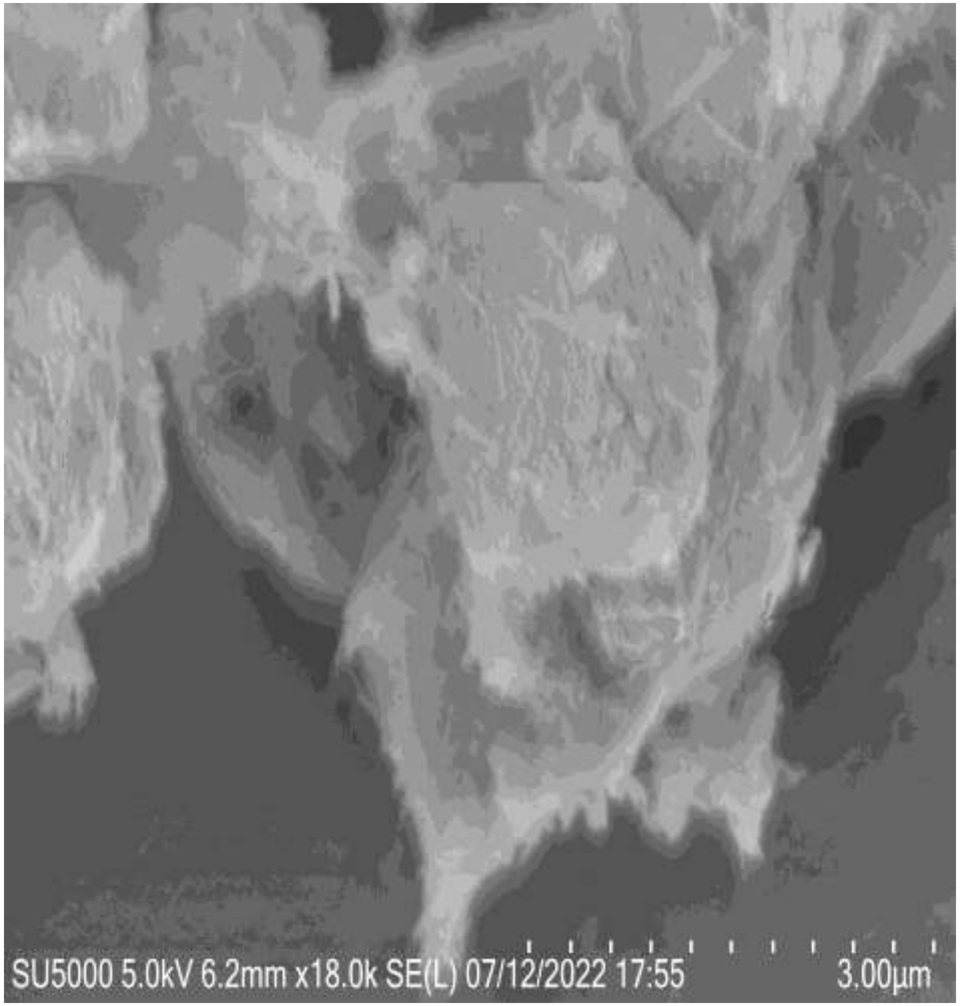


Aged 90x

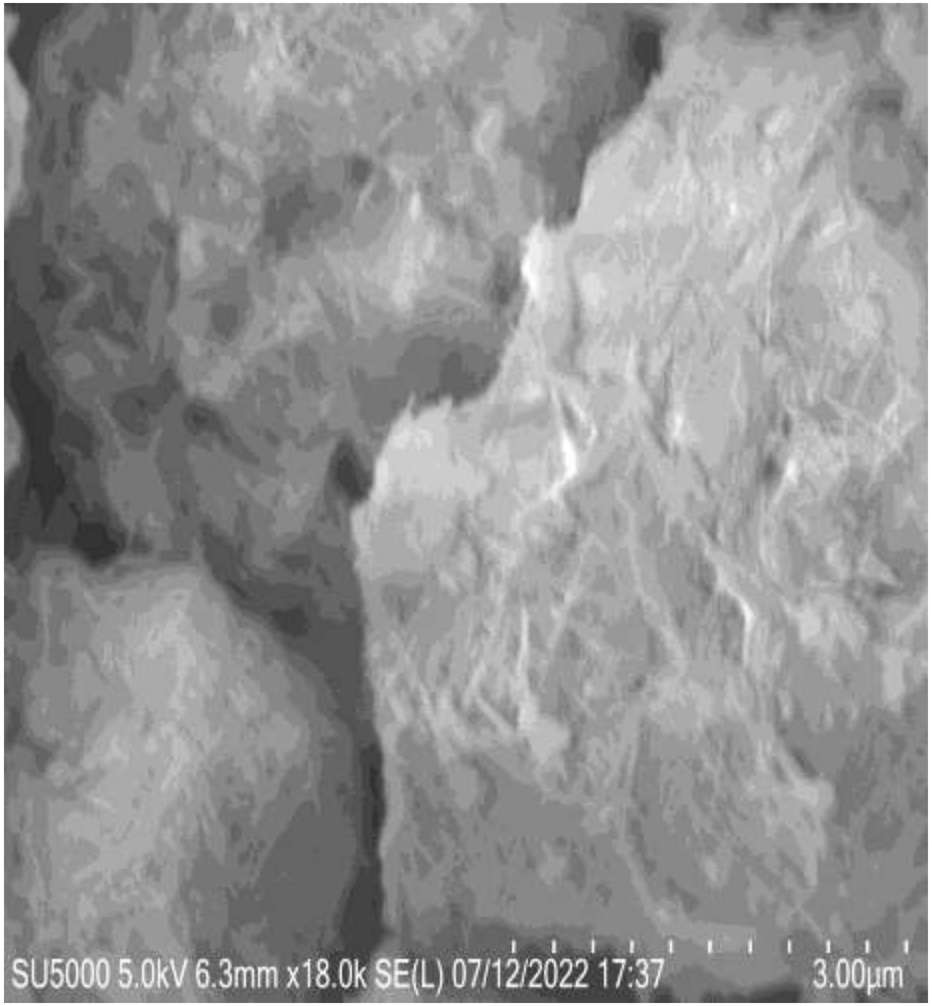


SEM – X13 Zeolite 18KX

Fresh

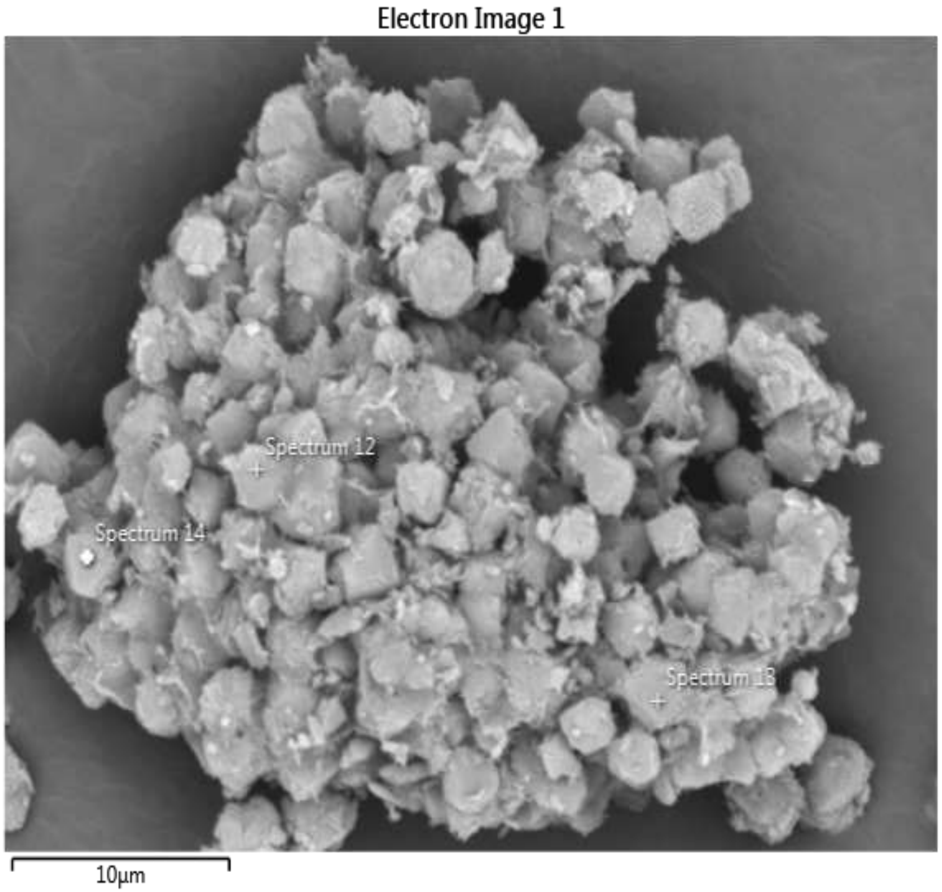


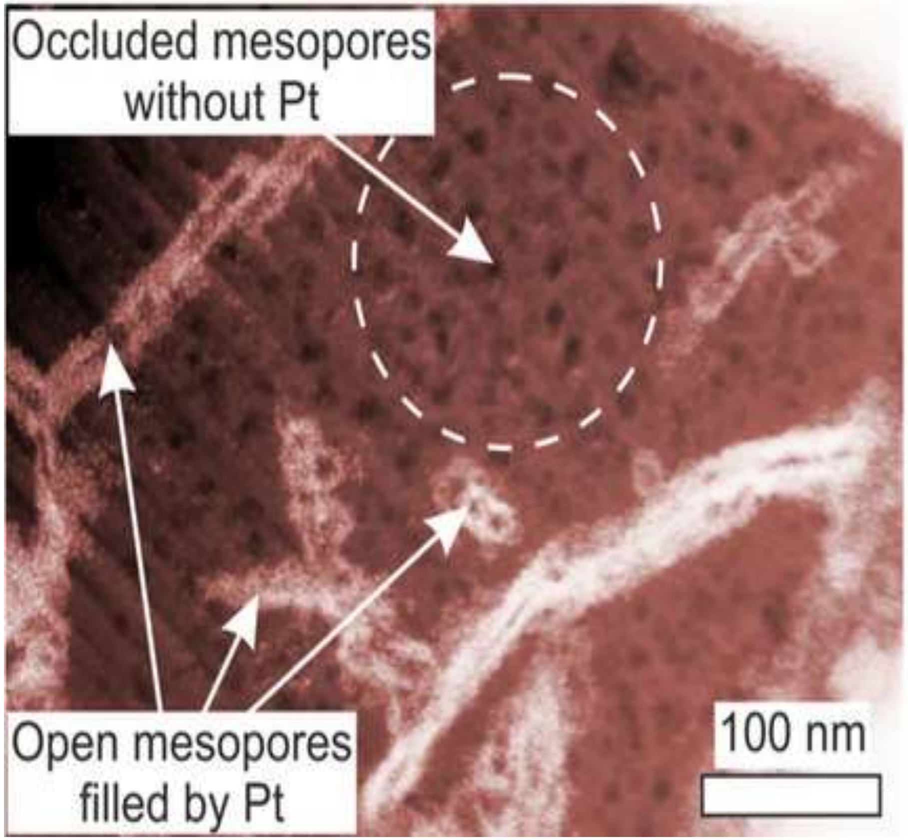
Aged



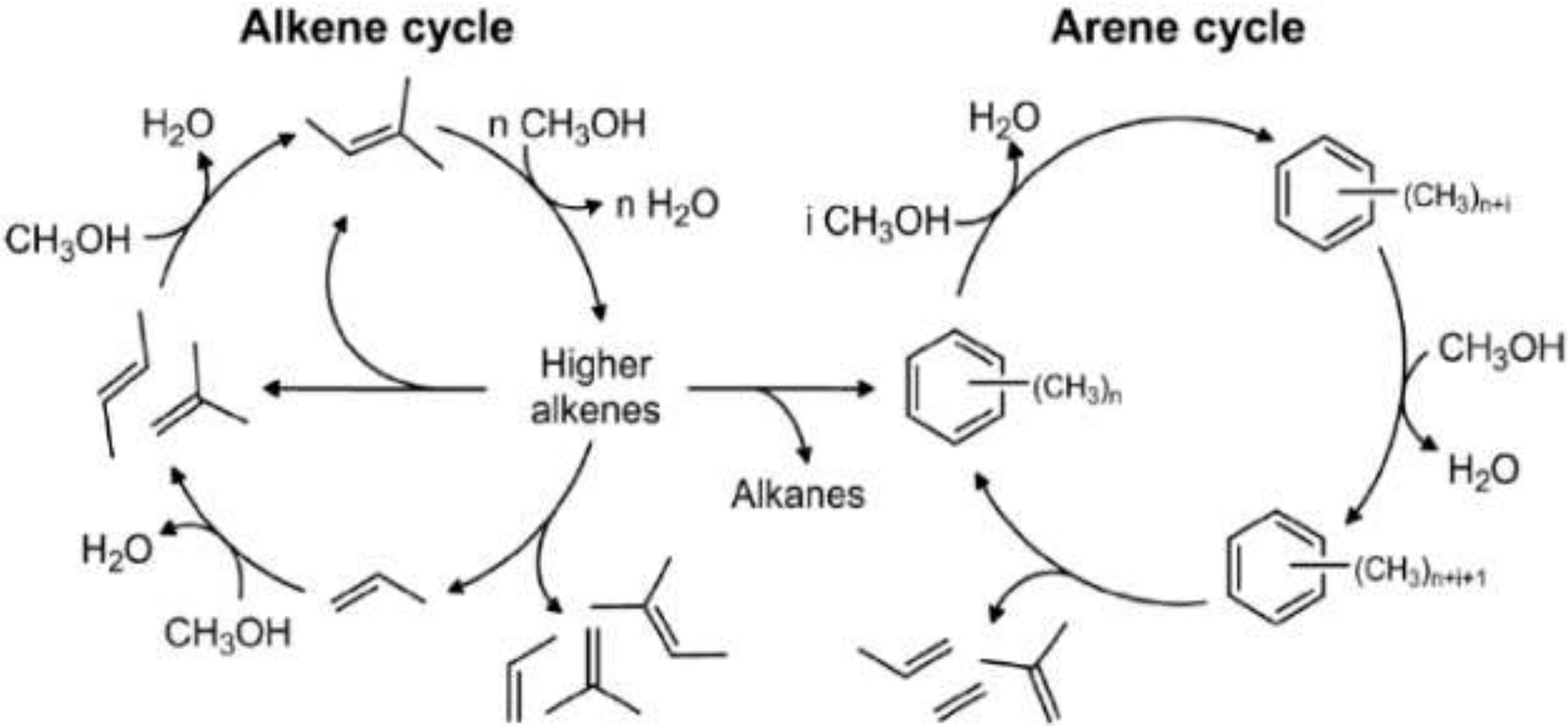
Primary zeolite particles ~ 1 microns D
Zeolite pores ~ 1-10A D

X13 3KX



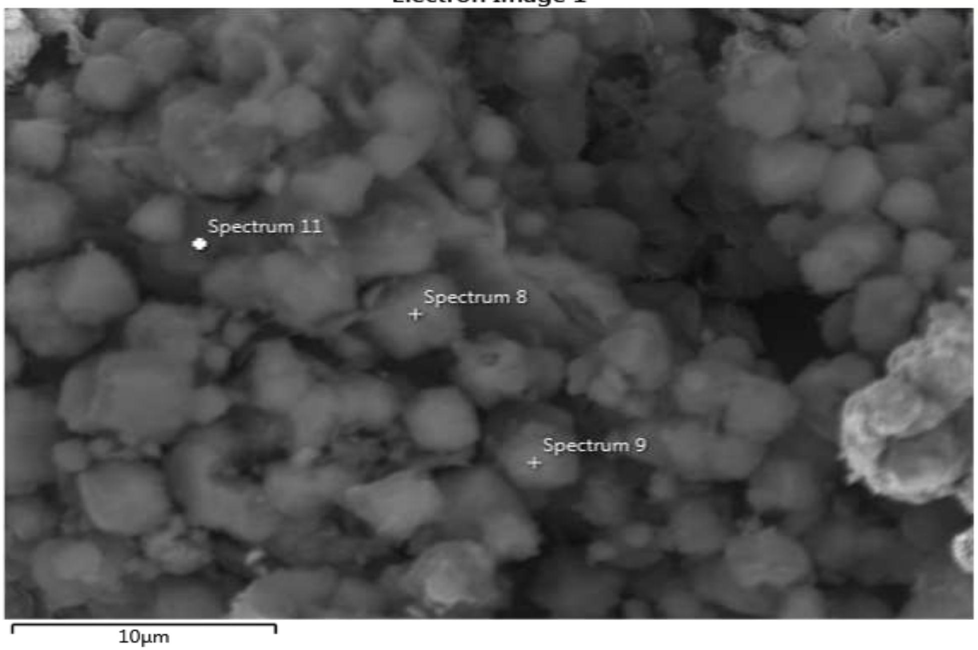


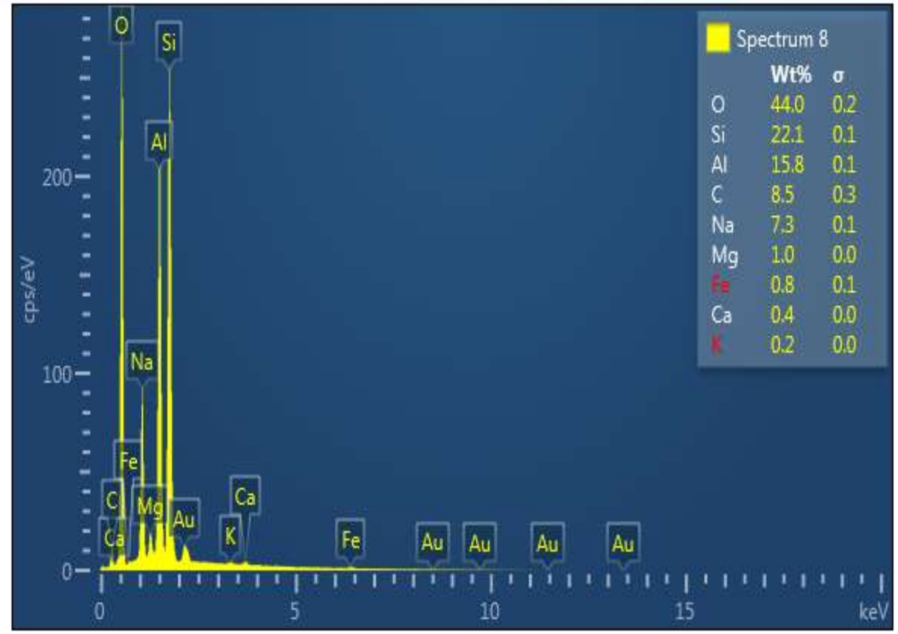
Zeolite HC Cracking Kinetics - Condensation (Exothermic) Rx

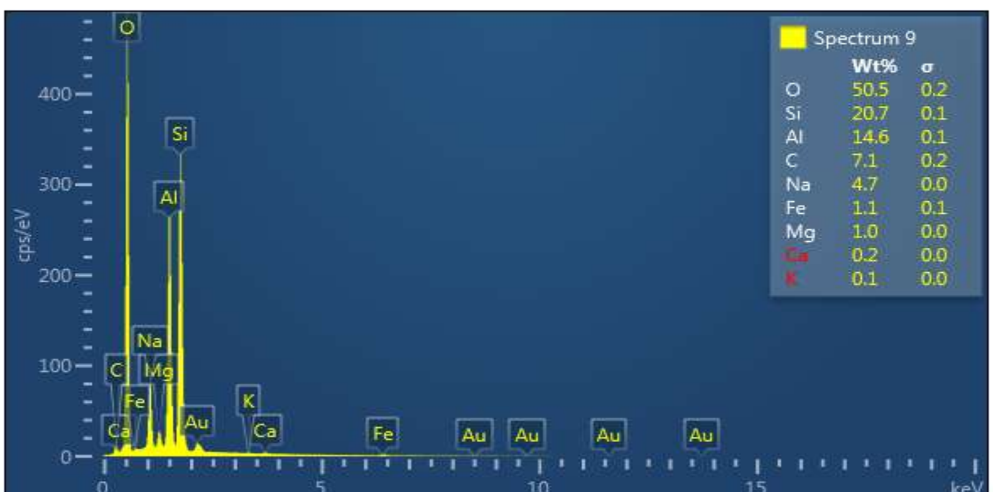


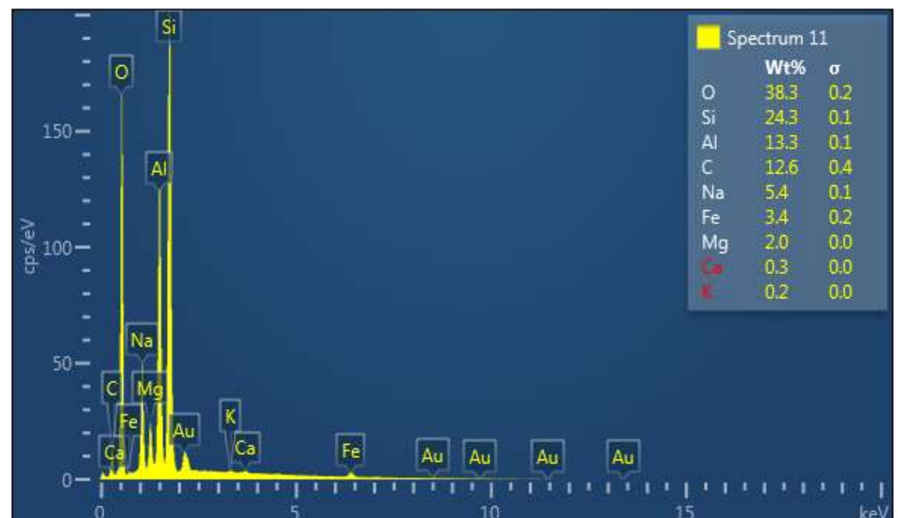
Aged Zeolite – SEM/EDX 3KX

Electron Image 1



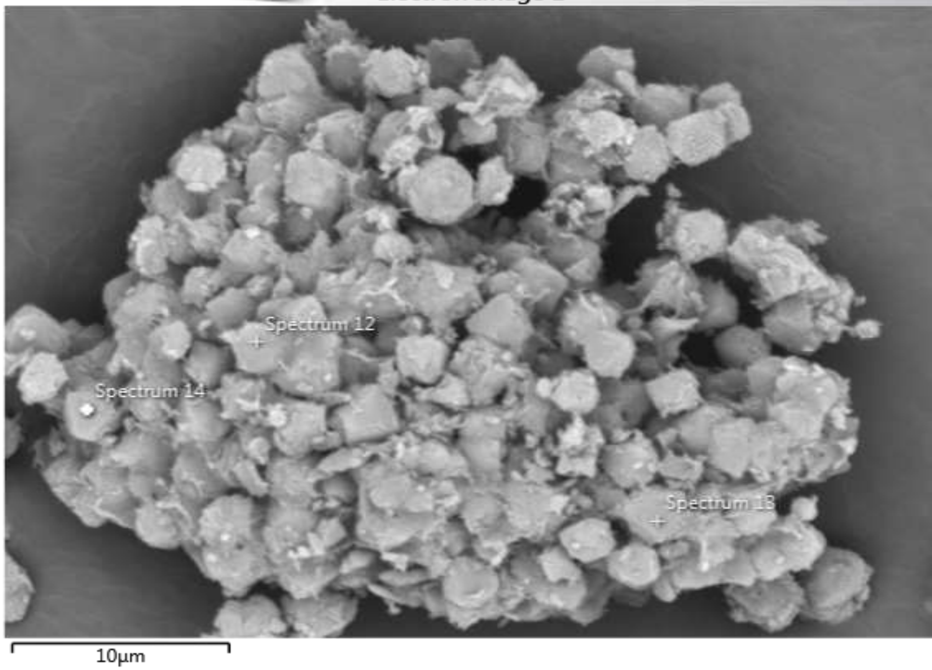


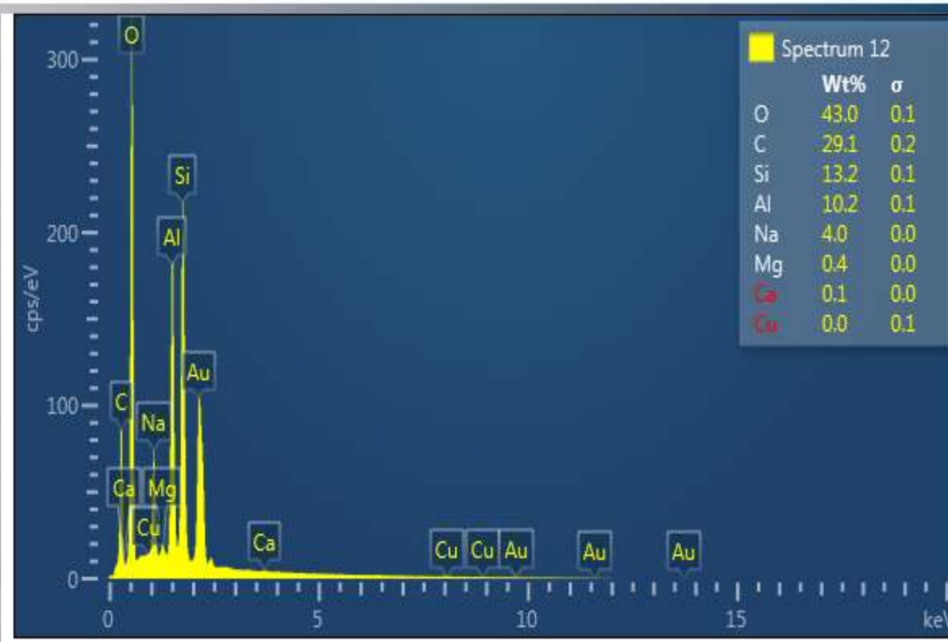


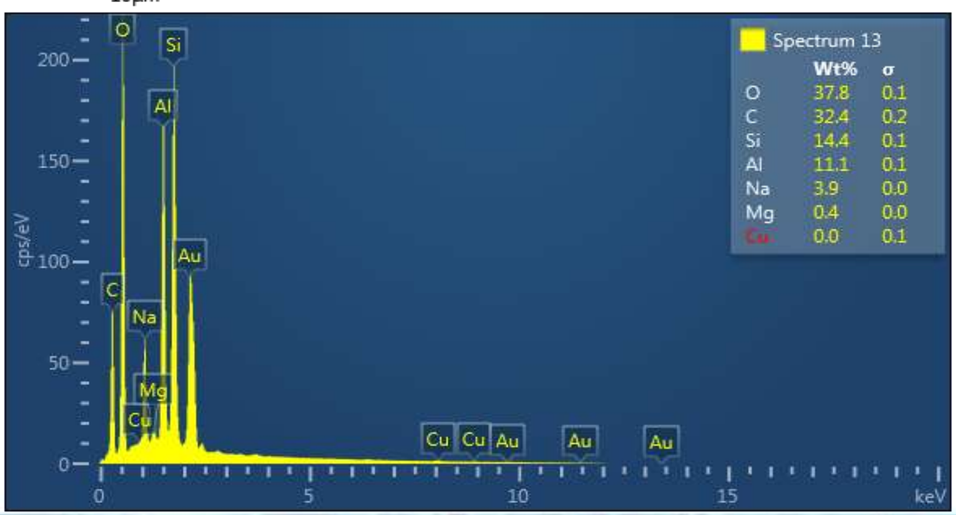


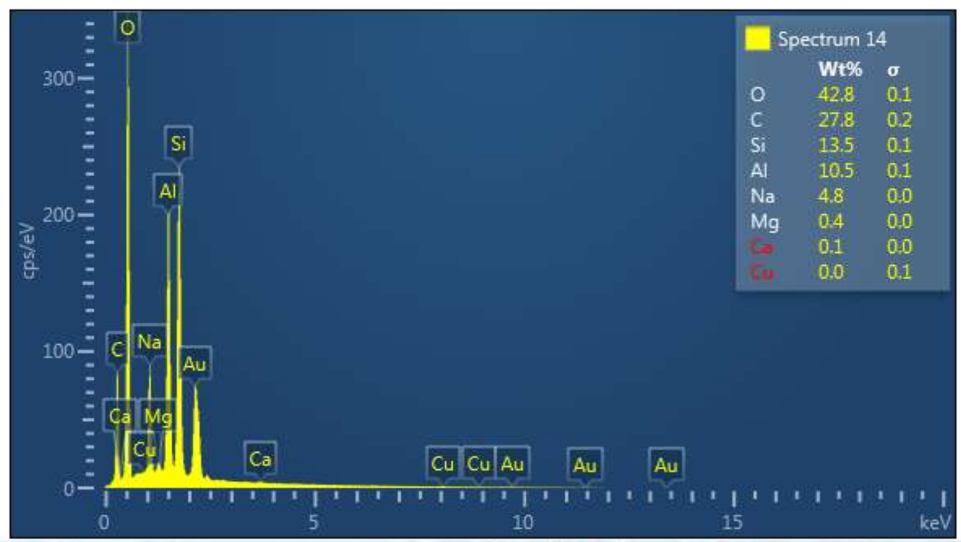
Fresh Zeolite – SEM/EDX 3KX

Electron Image 1







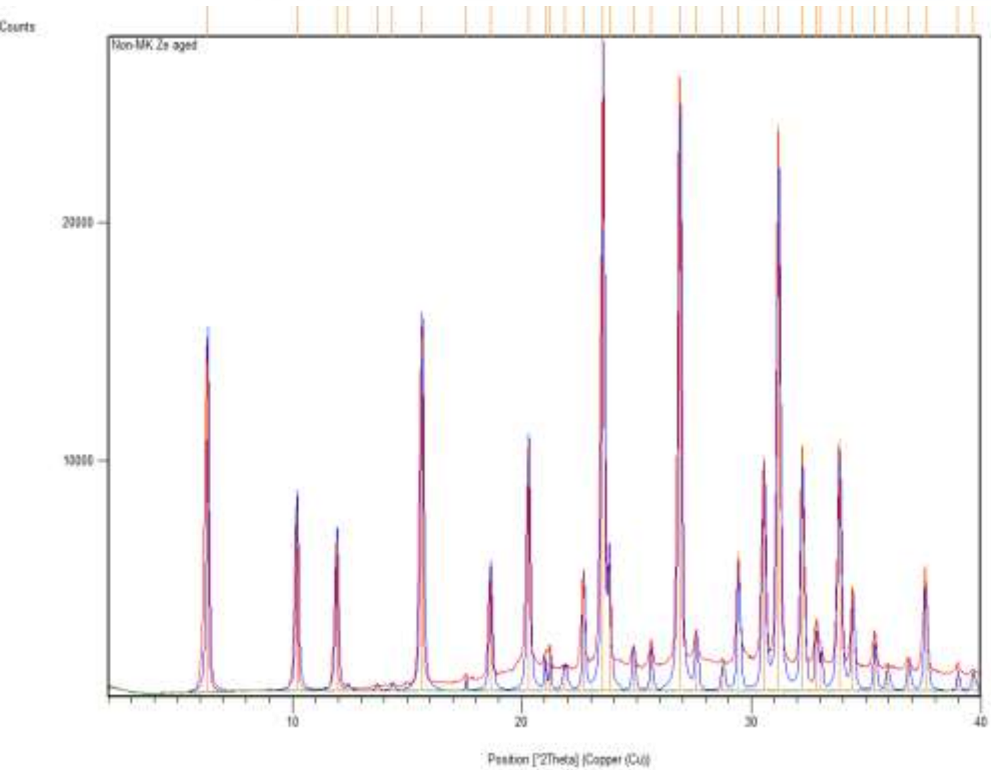


SEM – EDX Comparative Contaminant Summary - X13 Zeolite

	Zeolite – Fresh			
				average
O	43	37.8	42.8	41.20
C	29.1	32.4	27.8	29.77
Si	13.2	14.4	13.5	13.70
Al	10.2	11.1	10.5	10.60
Na	4	3.9	4.8	4.23
Mg	0.4	0.4	0.4	0.40
Ca	0.1	0	0.1	0.07
Cu	0	0	0	0.00
Fe	0	0	0	0.00
K	0	0	0	0.00

Zeolite - Aged			
			average
40.4	45.3	44.2	43.30
32.7	18.1	17.6	22.80
11.5	17	18	15.50
7.9	12.5	12.8	11.07
5.7	5.5	5.6	5.60
1	1	2	1.33
0.3	0.2	0.3	0.27
0	0	0	0.00
0.8	1.1	0.95	0.95
0.1	0.2	0.1	0.13

XRD – Aged Zeolite – X13 (time in service – unknown)



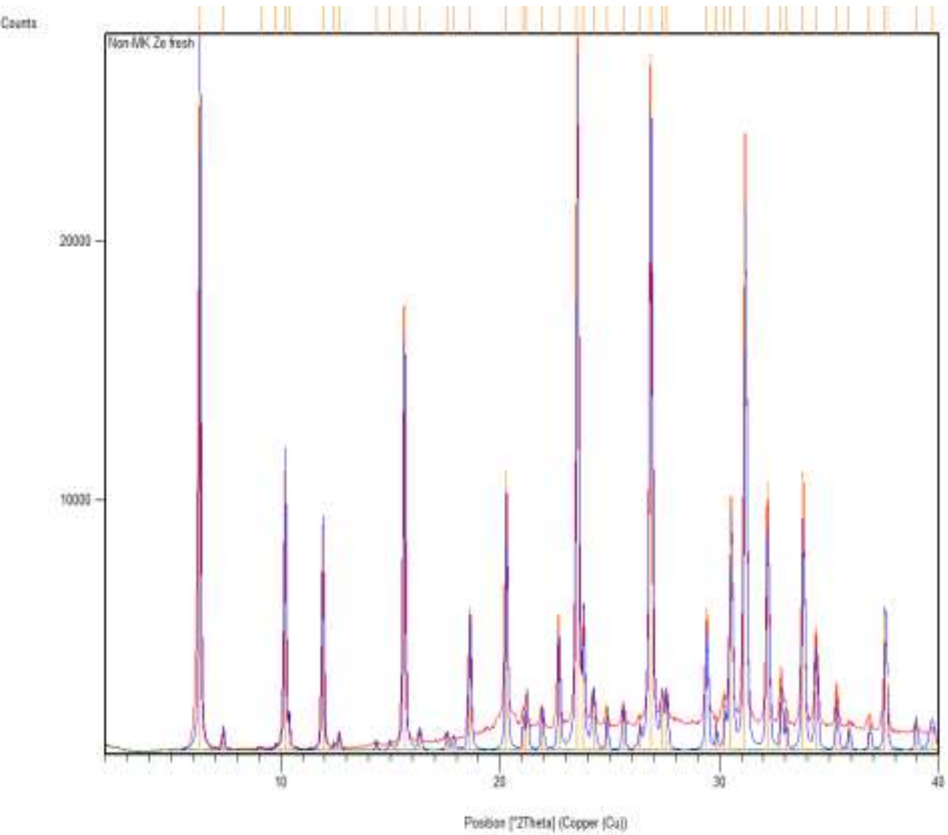
Selected Candidate: 00-005-0586

No.	Ref. Code	Score	Compound Name	Chemical Formula
1	00-005-0586	28	Calcite, syn	Ca C O3
2	00-033-1161	17	silica	Si O2
3	00-046-1045	17	Quartz, syn	Si O2
4	00-010-0173	16	alumina	Al2 O3
5	00-024-0072	13	Hematite	Fe2 O3
6	00-024-1977	13	Sucrose	C12 H22 O11
7	01-073-1667	7	Bornite	Cu5 Fe S4
8	00-033-0664	7	burnt ochre	Fe2 O3
9	00-006-0329	4	Praseodymium Oxide	01.83
10	01-075-0134	4	Uranium Oxide	U O2
11	01-077-2041	1	Sodium Erbium Flu...	Na Er F4
12	00-005-0628	1	Halite, syn	Na Cl

Sucrose, a disaccharide, (C12H22O11), from monomers glucose and fructose like originated in a condensation reaction between the flux and thixotropic agents. Aged Zeolite ~ 6.0mmD originally 4.0mm, absorbed CO2 and water.

Burnt Ochre = Fe2O3. FeO.(OH).nH20, is a hydrated iron hydroxide, also referred to a gold ochre

XRD – Fresh Zeolite – X13



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5	00-024-0072	7	Hematite	Fe2 O3
6	01-073-1667	6	Bornite	Cu5 Fe S4
7	00-006-0329	4	Praseodymium Oxi...	Pr O1.83
8	01-075-0134	3	Uranium Oxide	U O2
9	00-005-0628	1	Halite, syn	Na Cl
10	01-077-2041	1	Sodium Erbium Flu...	Na Er F4

Zeolites are microporous, aluminosilicate minerals commonly used as commercial adsorbents and catalysts.

- Presence of Calcite is considered significant

- Zeolite extrudate size ~4mm

- Si –Al ratio ~3 to 1

- Pore size unknown (TEM being considered)

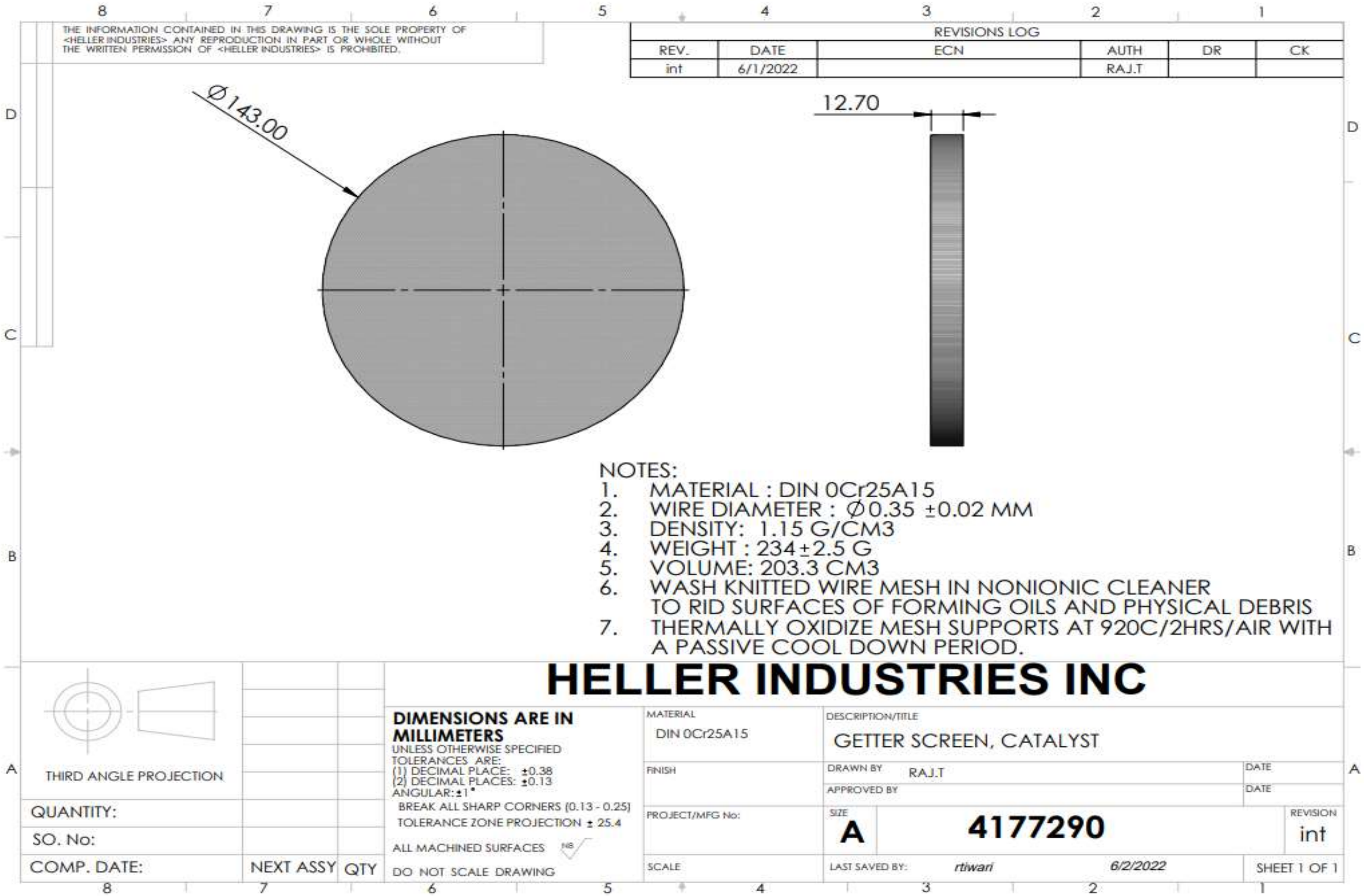
LPA (TH-100) w/ 10% Cu Applied to Wire Mesh Trap

Un-coated wire mesh trap

Coated trap

DOC/DPF	143.8*152/300 5g/2:1:0
DOC/GPF	118.4*127/300 5g/2:1:0
CuSCR/GPF	118.4*127/300

Wire Mesh Trap Support



Atomic Size, Coking, Deactivation, Active Sites

Average zeolite is 1-10A Pore Diam.
10000A = 1 micron-U
C = 1.5A
O = 1.3A
H = 0.5A
H bond = 1.09A

- Silica/Alumina Ratio (SAR) will influence the acidity, thus activity
- Low SAR = more acidity with lower hydrophobicity, undesirable
- Higher Al results in greater coking and deactivation
- Too much acidity can lead to quicker coking and deactivation
- Many reactions require a tradeoff, (FAU and MFI)

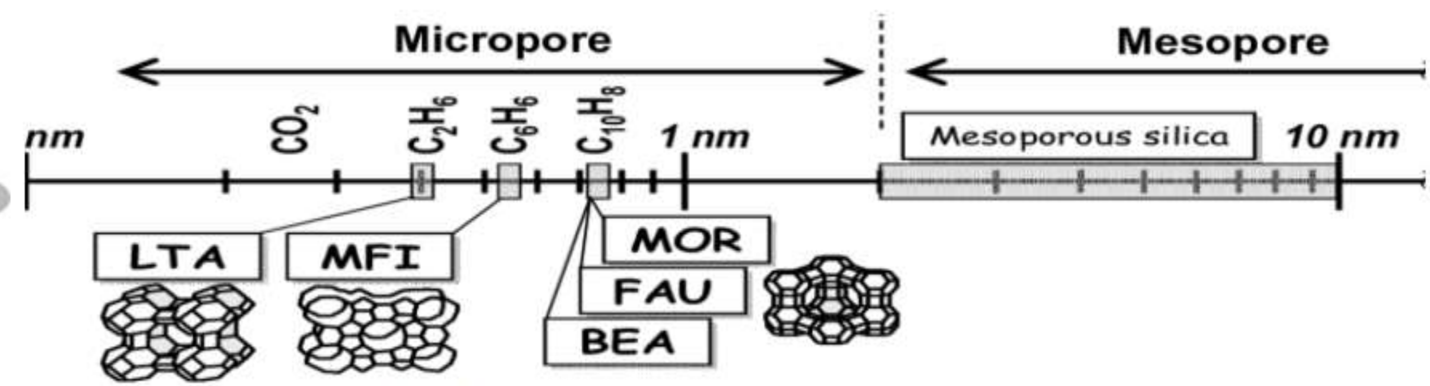
Zeolyst: "some reactions can occur on the outer surface/pore mouth of a zeolite. so, molecules don't always need to fit in the pore".

Zeolites – Pore Size

Pore Size	Number of Tetrahedra (MR [1])	Pore Diameter (Å)	Example
Small	8	4	PST-1 (NAT)
Medium	10	5.5	ZSM-5 (MFI)
Large	12	7.5	ZSM-12 (MTW)
Extra-large	>12	>7.5	CIT-5 (CFI)

[1] MR: Members of the ring.

Classification of zeolites according to their pore size.



Zeolite structure, pore size and molecular diameter of hydrocarbons.

Zeolyst: "some reactions can occur on the outer surface/pore mouth of a zeolite. so, molecules don't always need to fit in the pore"

Framework Type **CHA**

Framework

Cell Parameters:	trigonal	R -3 m (# 166)	
	a = 13.6750 Å	*b* = 13.6750 Å	*c* = 14.7670 Å
	α = 90.000°	β = 90.000°	γ = 120.000°
	Volume =	2391.6 $Å^3$	
	R_{DLS} =	0.0015	
Framework density (FD_{Si}):	15.1 T/1000 $Å^3$		
Topological density:	TD_{10} = 677	TD = 0.566667	
Ring sizes (# T-atoms):	8 6 4		
Channel dimensionality:	Topological (pore opening > 6-ring): 3-dimensional		
Maximum diameter of a sphere:			
that can be included	7.37 Å		
that can diffuse along	a: 3.72 Å	b: 3.72 Å	c: 3.72 Å
Accessible volume:	17.27 %		
ABC sequence	AABBCC sequence of 6-rings		
Secondary Building Units:	6-6 or 6 or 4-2 or 4		
Composite Building Units:			

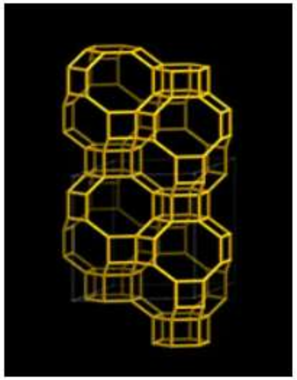
d6r (t-hpr)

cha (t-cha)

Natural Tiling *t-cha* *t-hpr*

Framework images

(click on icon for larger image)



Viewed normal to [001]

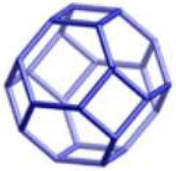
projection along [001]

Framework Type **FAU**

Framework

Cell Parameters:	cubic	F d -3 m (# 227)	
	a = 24.3450 Å	b = 24.3450 Å	c = 24.3450 Å
	α = 90.000°	β = 90.000°	γ = 90.000°
	Volume =	14428.8 $Å^3$	
	R_{DLS} =	0.0009	
Framework density (FD_{Si}):	13.3 T/1000 $Å^3$		
Topological density:	TD_{10} = 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 Å		
that can diffuse along	a: 7.35 Å	b: 7.35 Å	c: 7.35 Å
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:			

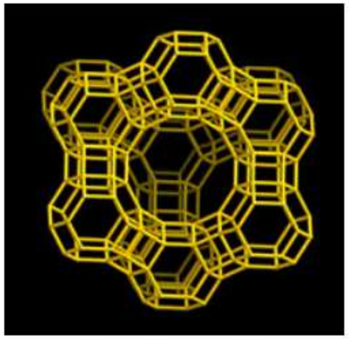
d6r (t-hpr)



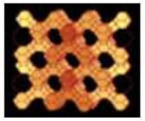
sod (t-toc)

Natural Tiling *t-fau* *t-hpr* *t-toc*

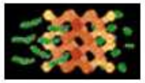
Framework images
(click on icon for larger image)



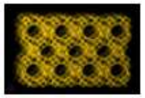
Viewed along [111]



Polyhedral model viewed along [110]



an 'artist impression' of a catalytic reaction



viewed along [110]