

Novel process for shale oil upgrading without using hydrogen

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Ceramatec Overview

- Founded 1976 – Advanced R&D Company
- Customers
 - 60% Fortune 100/500 Companies
 - 40% US Government
- Concept to commercialization
- Subsidiary of  since 2008
 - Privately held
 - World's largest advanced ceramics manufacturer

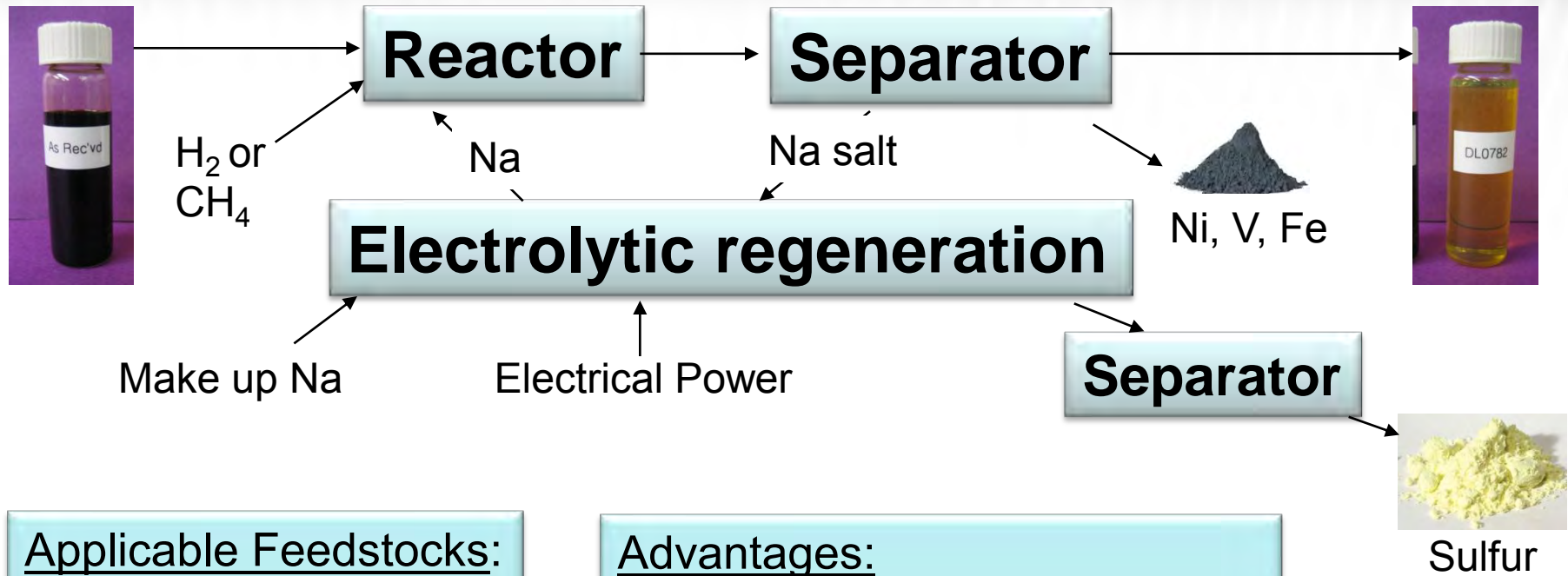


New process impact

- Upgrading without H₂
 - Reduces CO₂ from steam methane reforming
 - Reduces cost
 - Uses methane directly



The Upgrading Process



Applicable Feedstocks:

- Shale Oil
- Heavy Oil
- Resids
- Bitumen
- FCC Pretreatment

Advantages:

- Increases value of oil
- Yields valuable byproducts
- Enables utilization of standard refining processes
- Eliminates metals which foul hydro-treaters

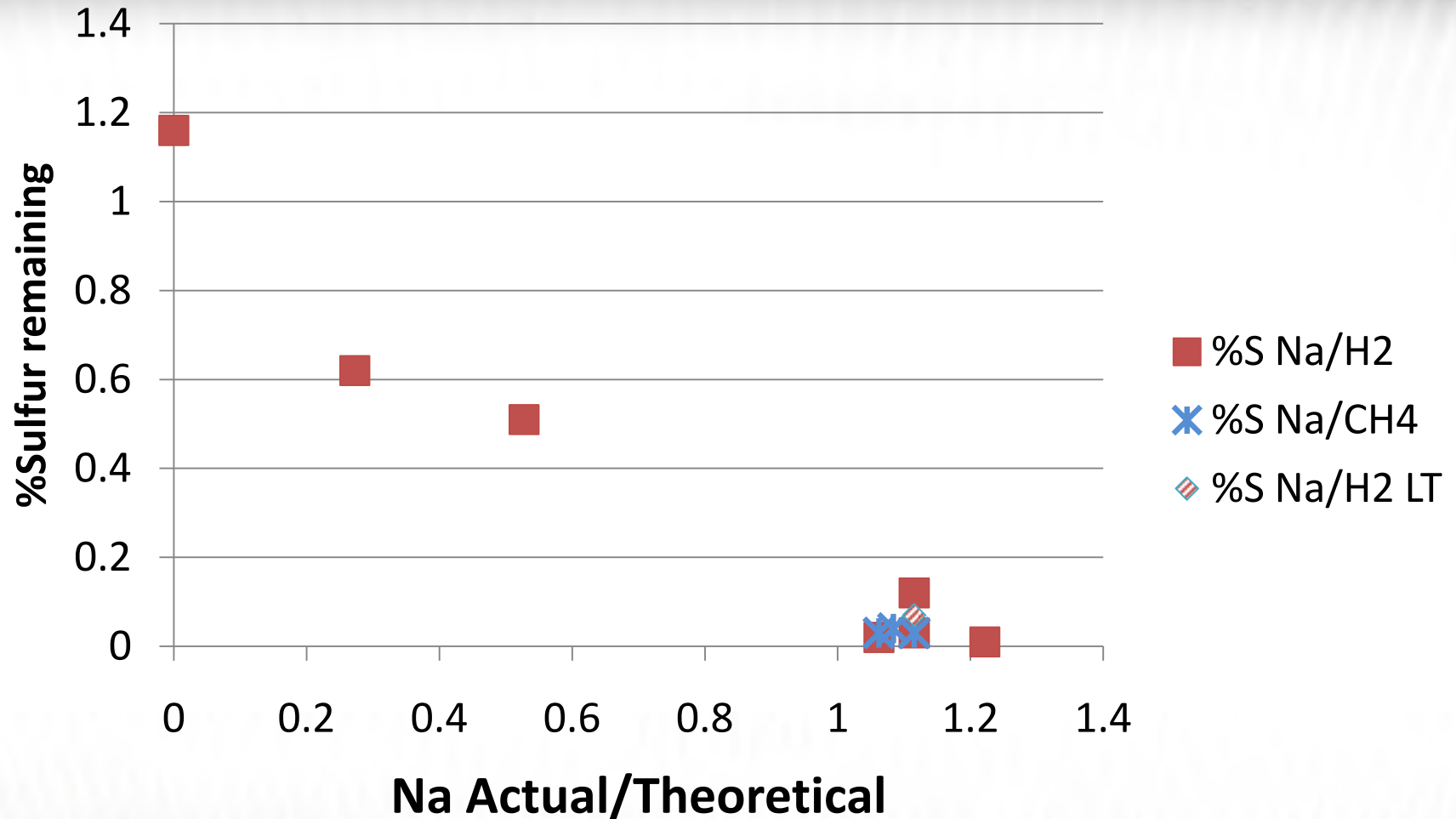


Feedstock Compositions Tested

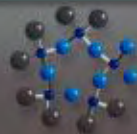
Feedstock	Bitumen Alberta Cold Lake	Heavy Oil California	Oil Shale Uintah Surface Retort
Initial API	8.8	13.4	45.1
%S	4.96	1.54	1.16
%N	0.39	0.76	0.65
Ni ppm	79	331	undetec
V ppm	200	197	undetec
Fe ppm	16	218	1.43



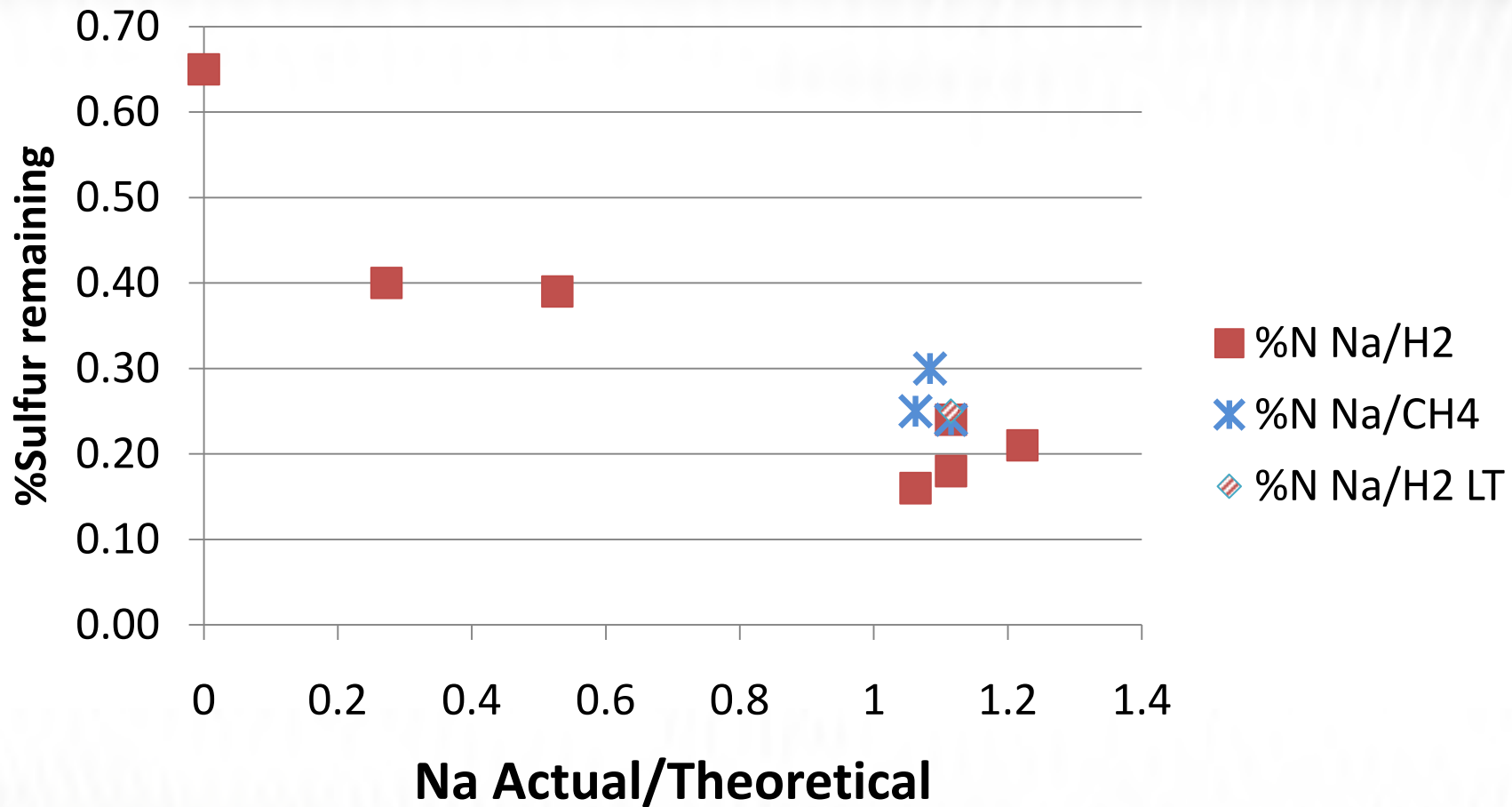
Sulfur removal from Shale Oil



96% sulfur removed using alkali metal upgrading



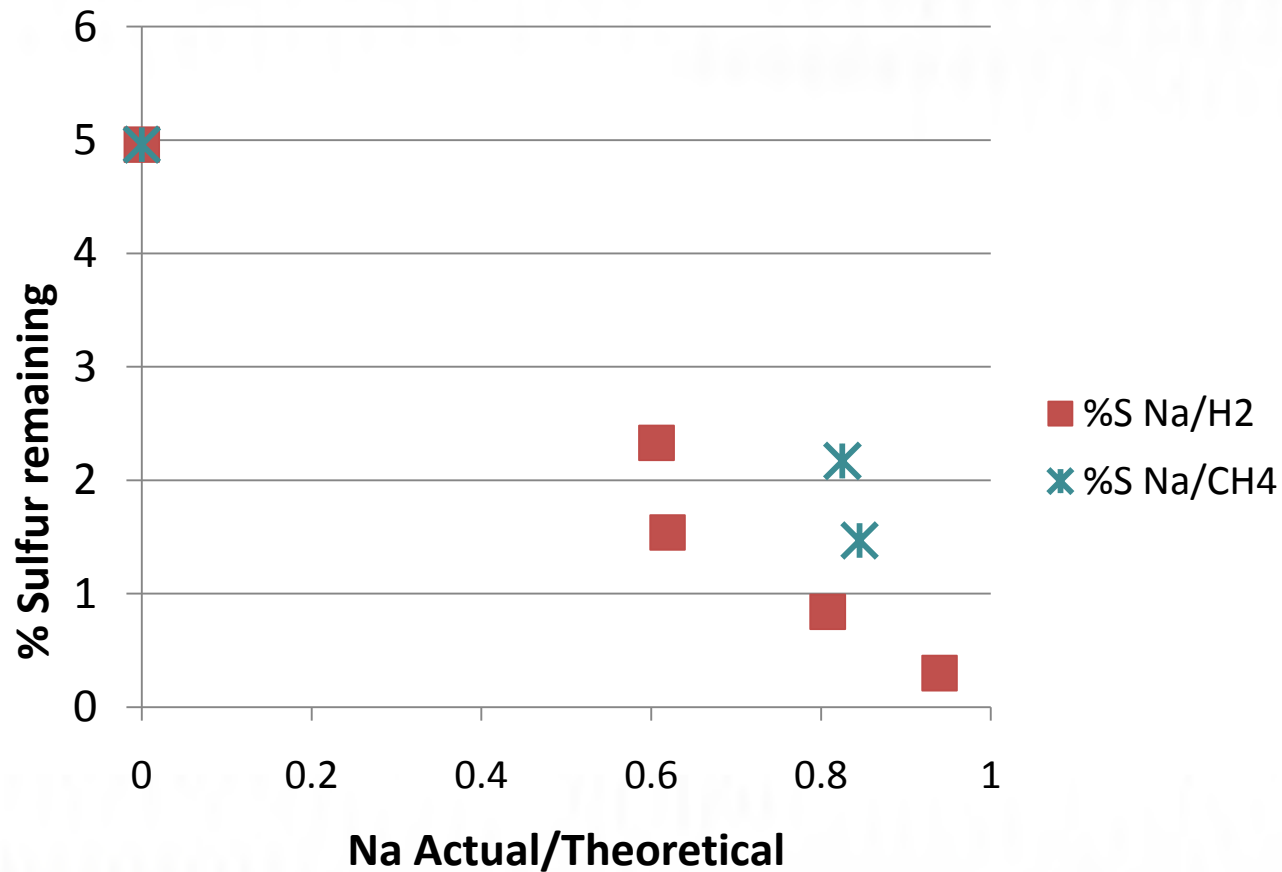
Nitrogen removal from Shale Oil



70% nitrogen removal typical



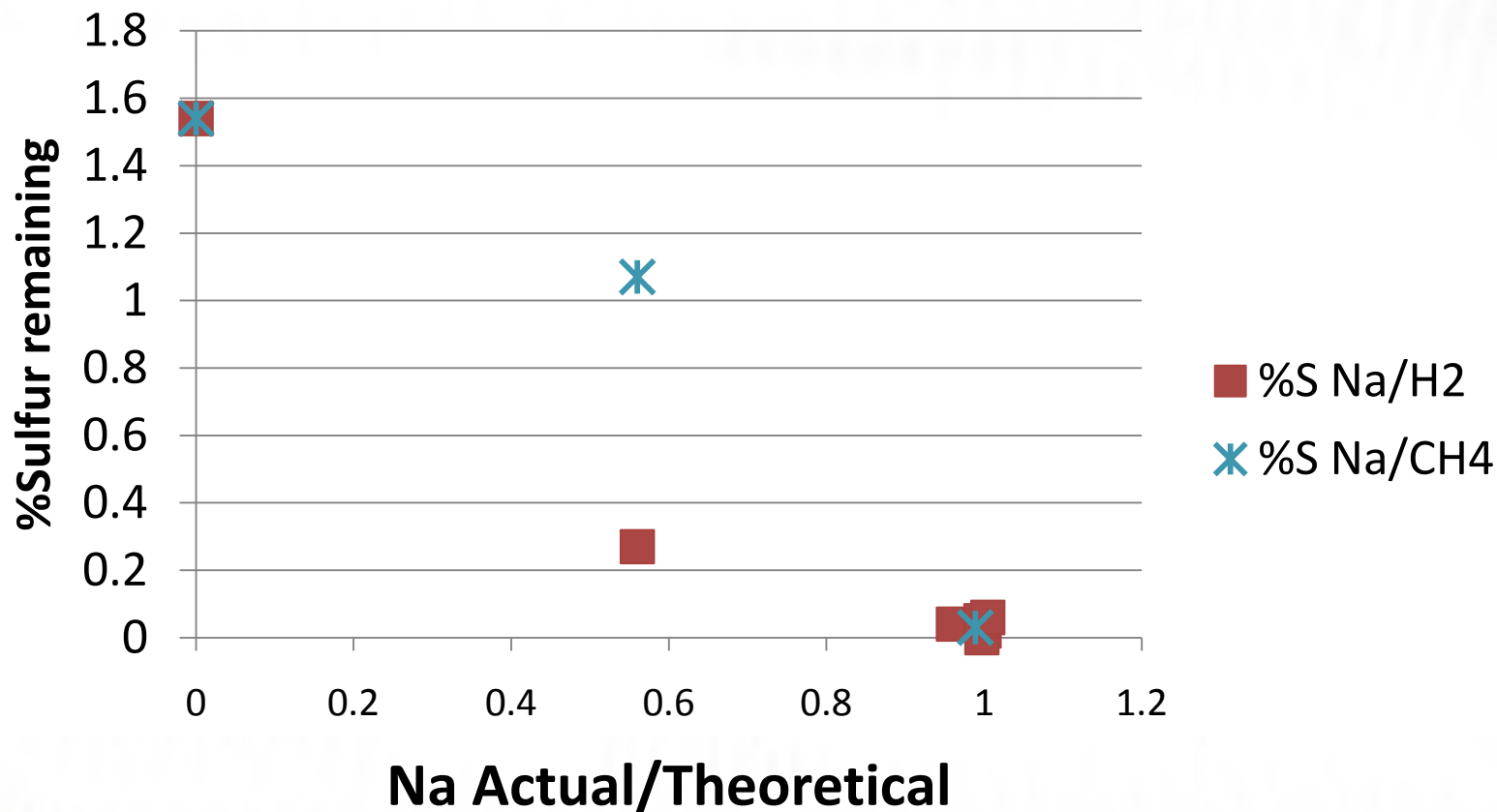
Sulfur removal from Bitumen



94% sulfur removed using alkali metal upgrading



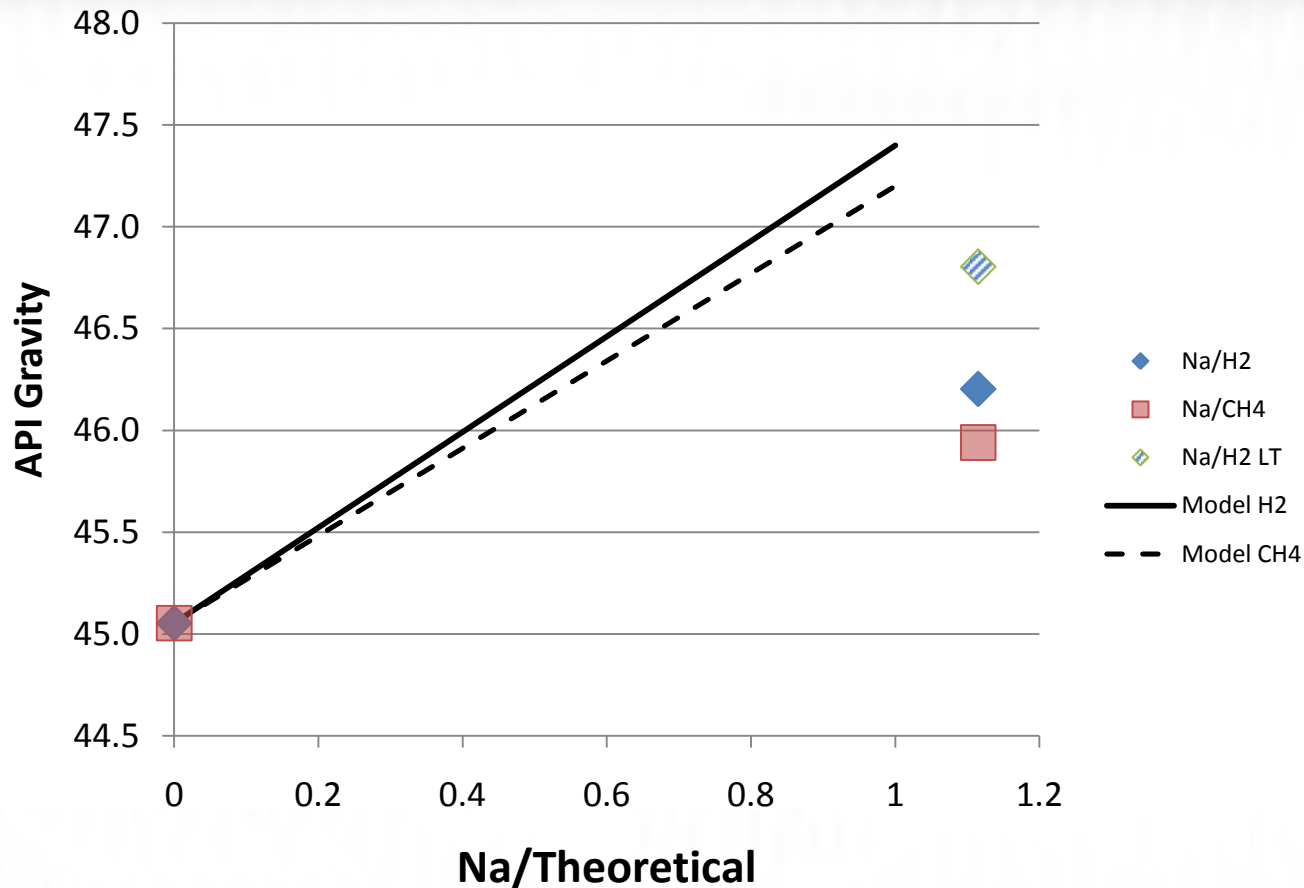
Sulfur removal from Heavy Oil



>97% sulfur removed using alkali metal upgrading

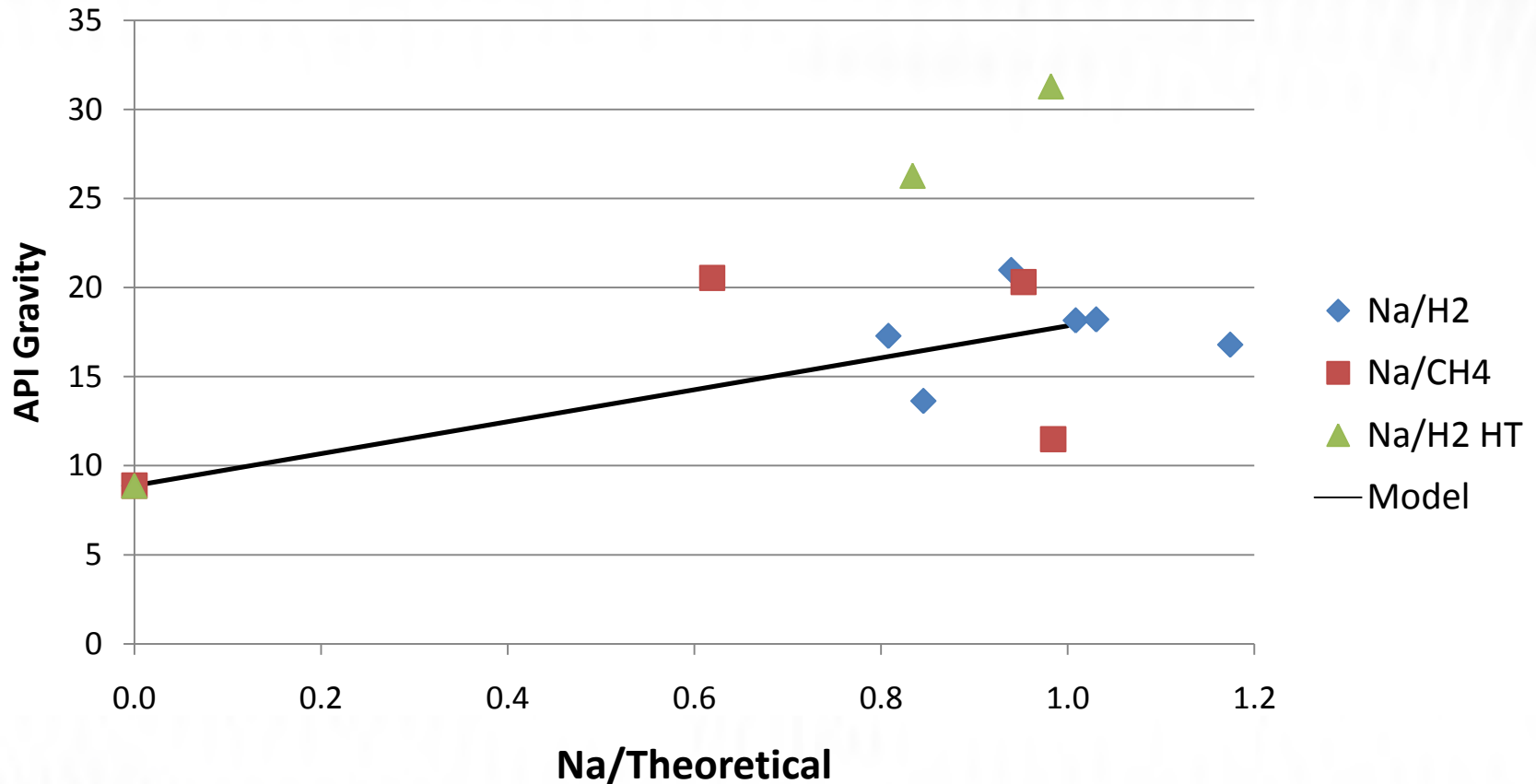


API changes with Shale Oil



- Ceramatec Process enhances the API gravity Model prediction matched experimental more closely when process operated at lower temperature

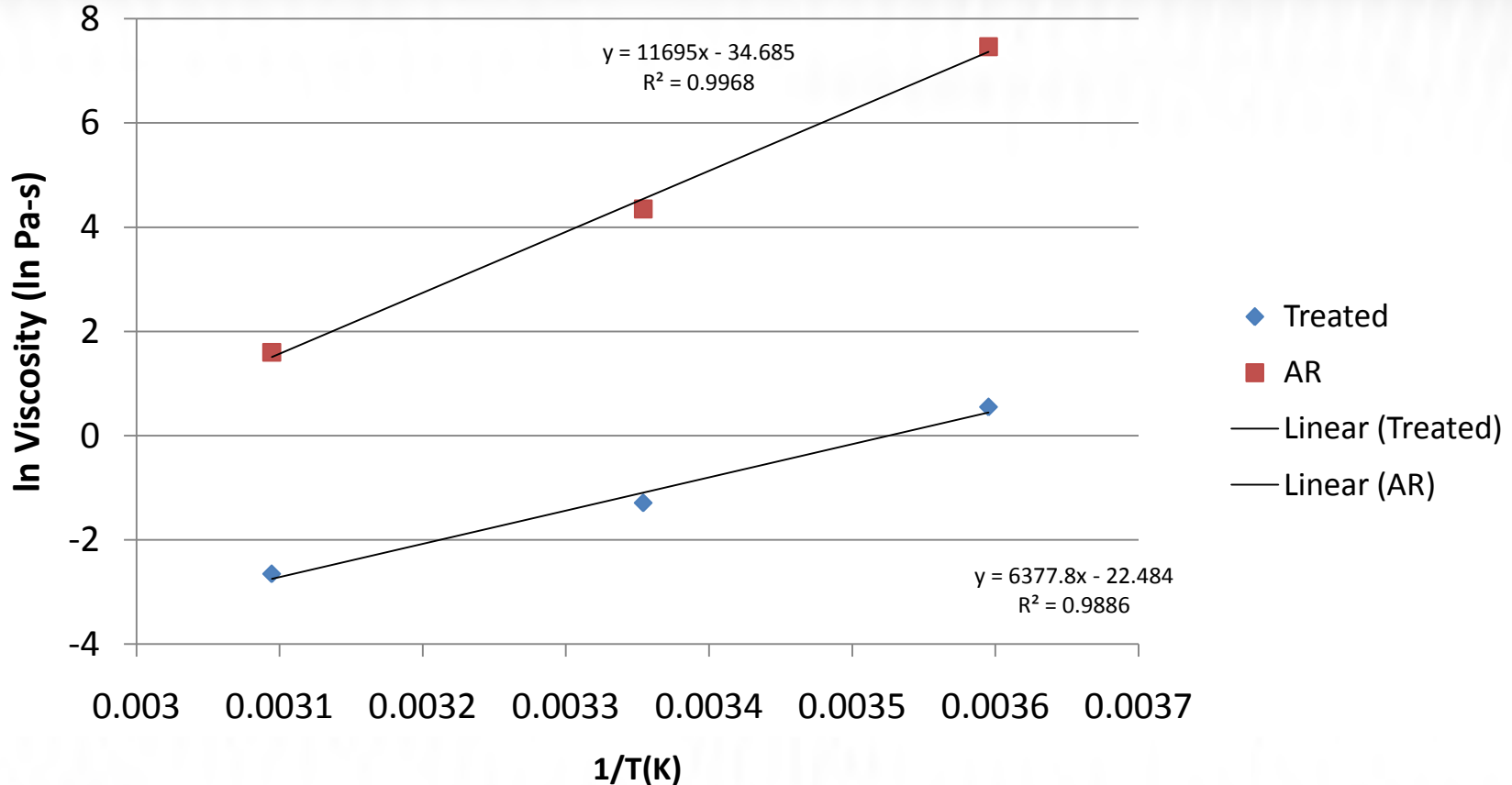
API changes with Bitumen



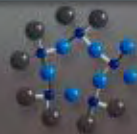
Ceramatec Process enhances the API gravity from 8.8 to about 18 following model, or higher with higher reactor temperatures



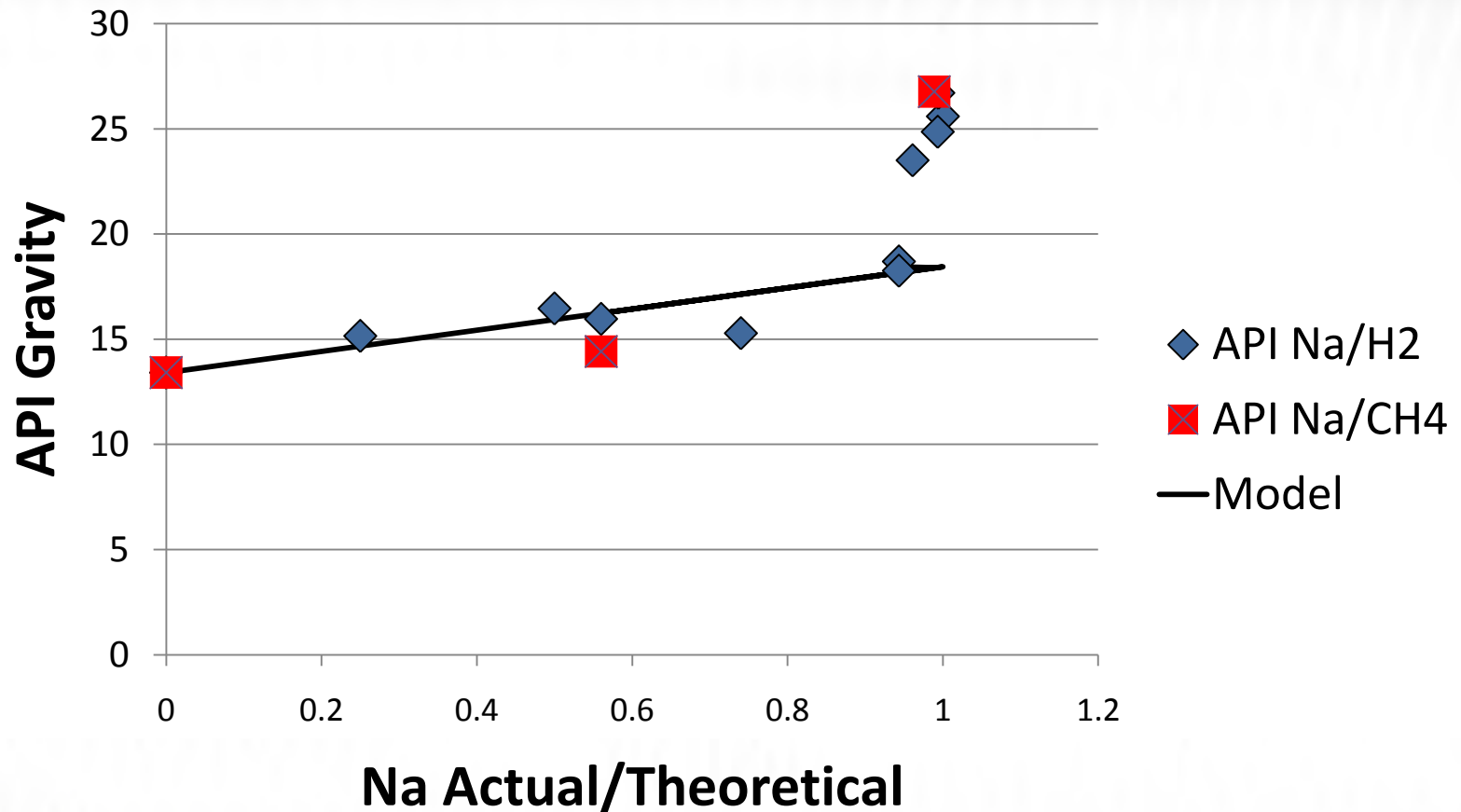
Viscosity changes with Bitumen



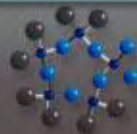
Treated viscosity is shifted lower and rises more slowly with declining temperature Follows Arrhenius behavior



API changes with Heavy Oil



API follows model ... Rises with Na addition

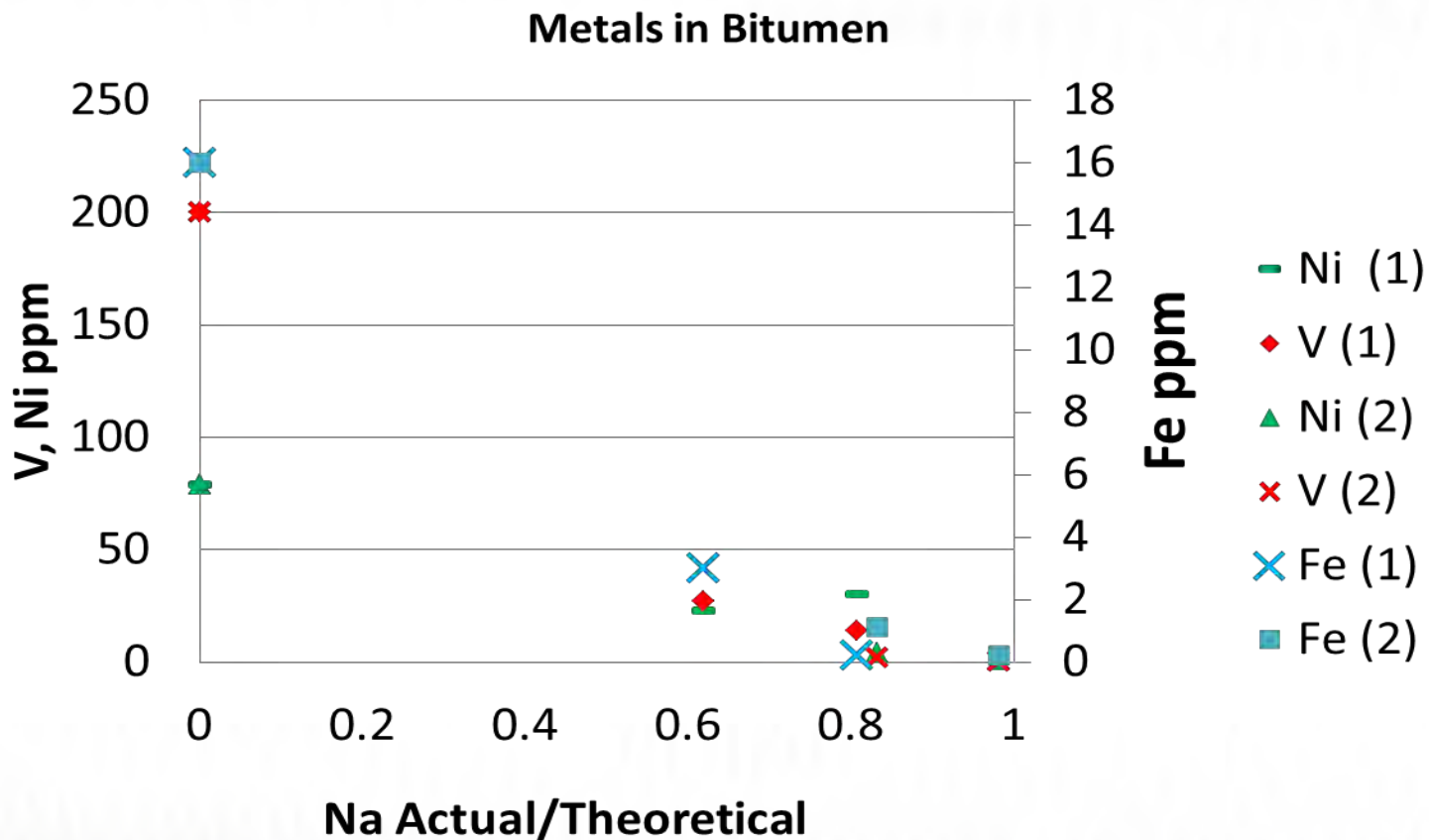


Metals removal from shale oil

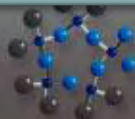
Metals start out low and often are undetectable after process



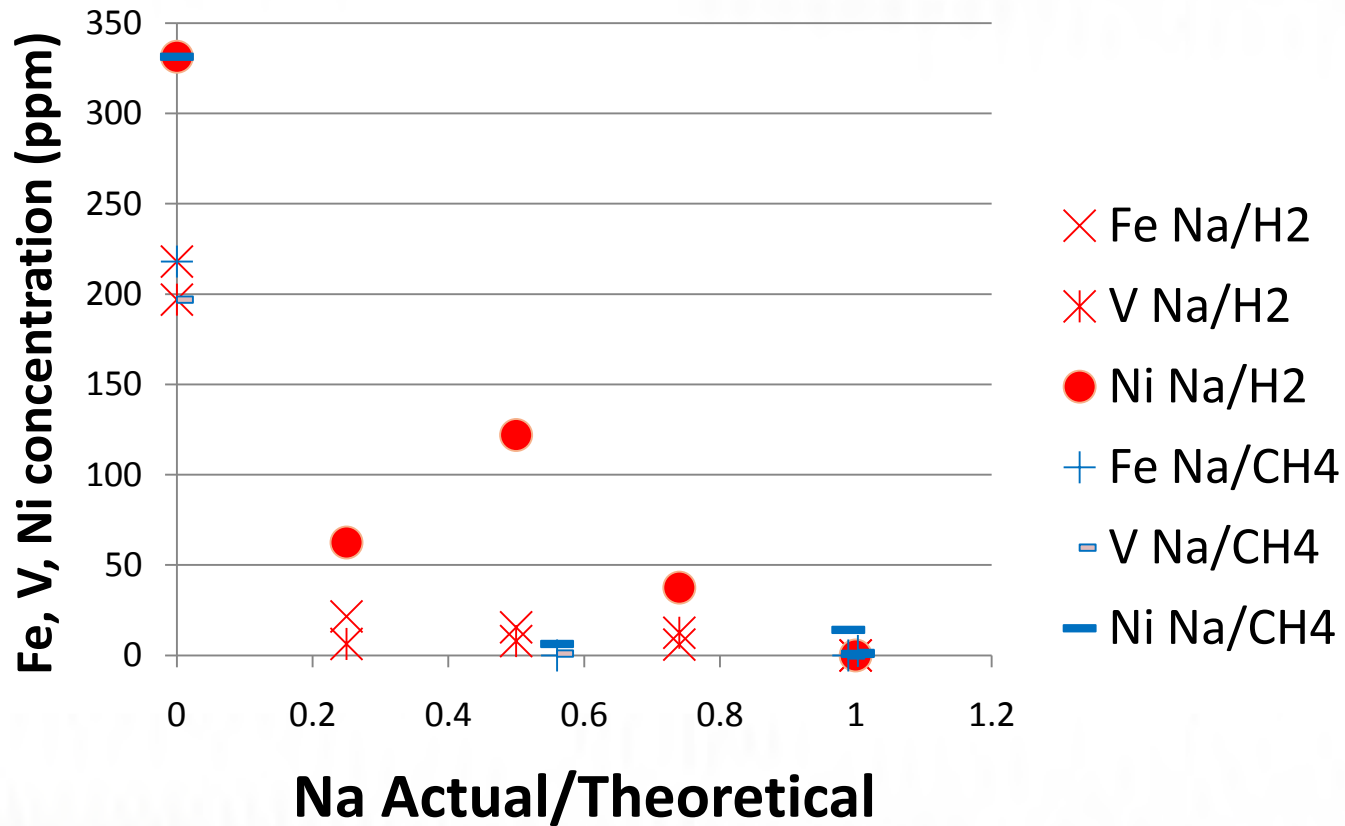
Metals removed from bitumen



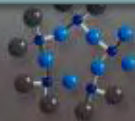
Metals drop down to nearly undetectable levels



Metals removal from heavy oil

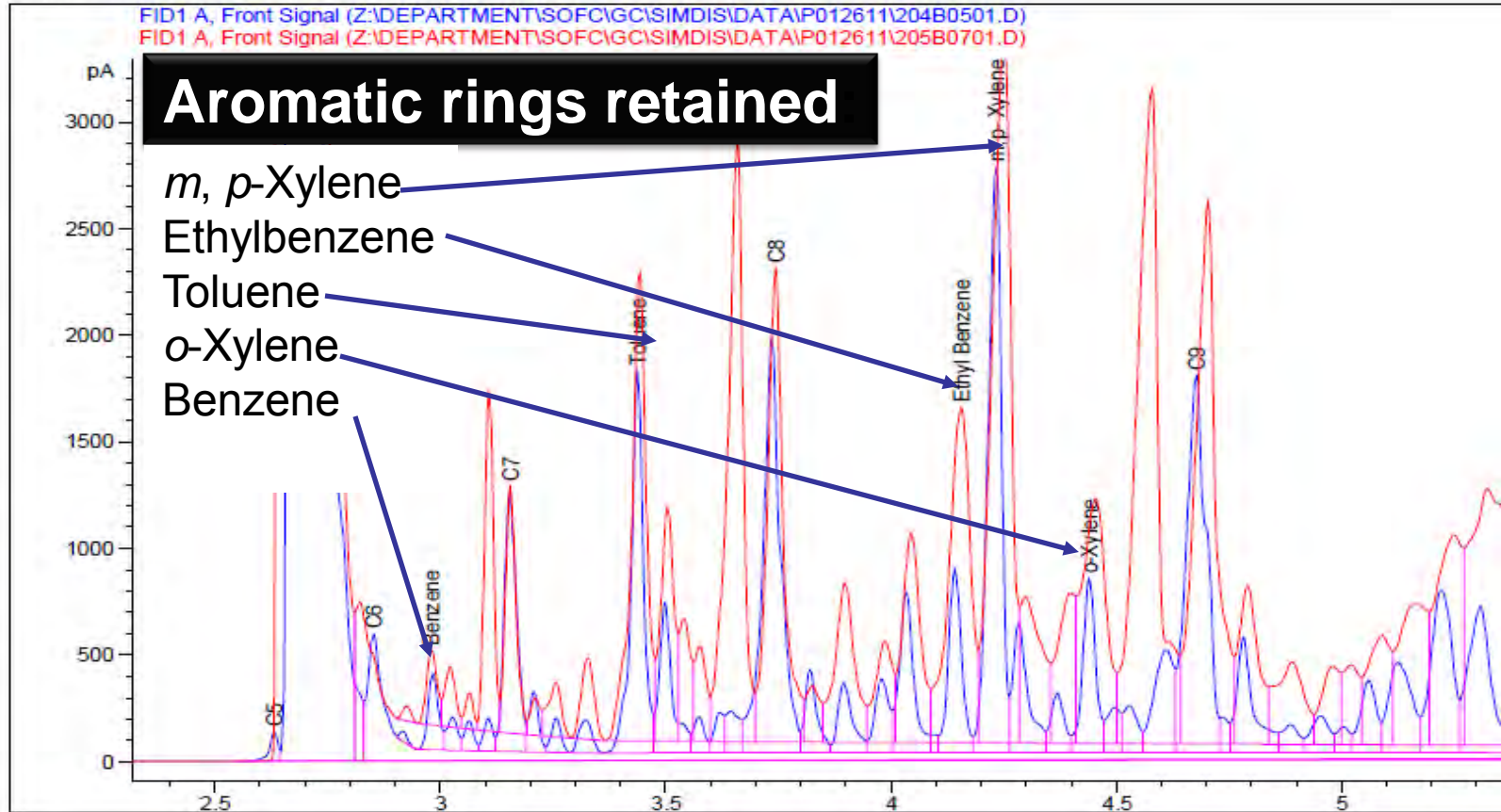


Metals drop down to nearly undetectable levels



Aromaticity Retention (Shale Oil)

Current Chromatogram (s)

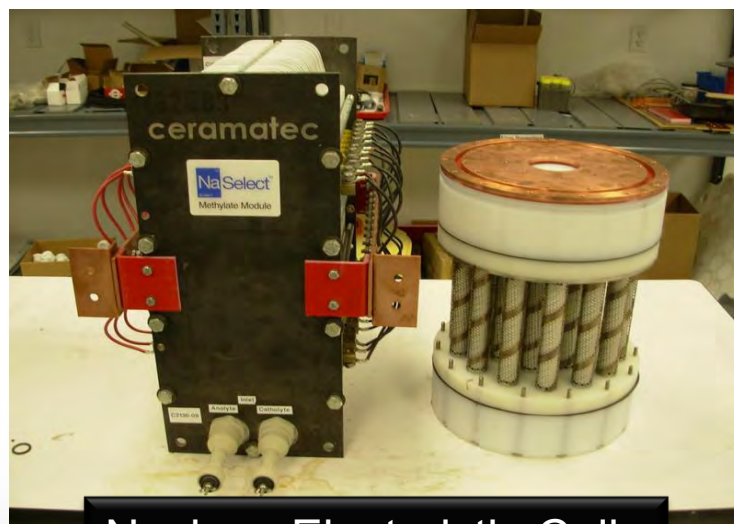


Partial chromatogram of shale oil before and after treatment with alkali metal upgrading, blue plot: before treatment, red plot: after treatment.



Electrolytic Recovery of Sodium

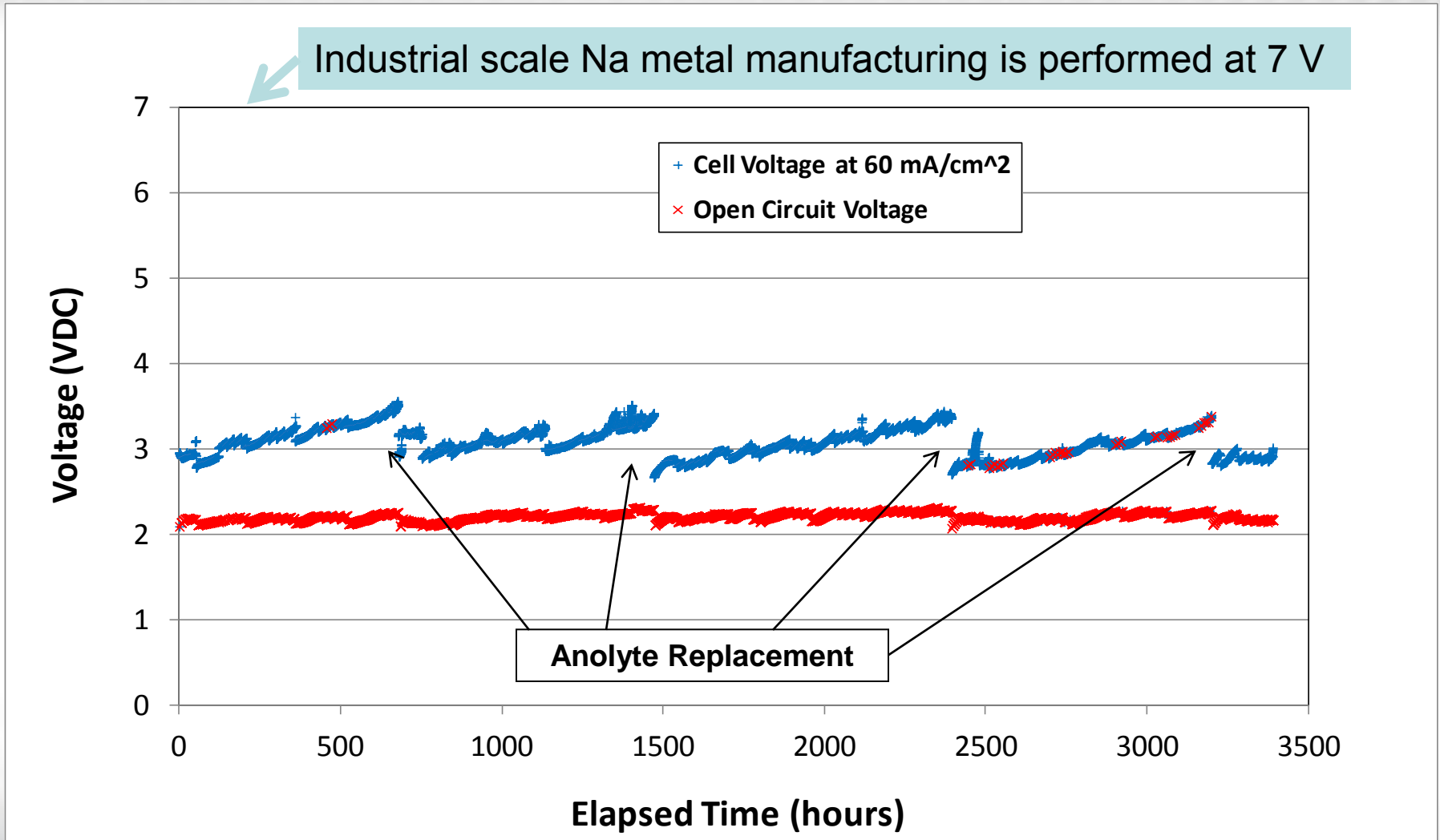
- Electrolytic recovery of sodium demonstrated with Bitumen salts
- NaSICON ceramic membrane
 - *Conductive at low temperature*
 - Tubes or planar membranes



Nasicon Electrolytic Cells



Sodium from Na_2S_4 with NaSICON



Regeneration of Na requires <50% of energy compared to commercial



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Technology Commercially Deployed for Other Applications

- ✓ NaSelect Ceramic Membrane Technology Deployed
- ✓ Producing Sodium Methoxide for Archer Daniels Midland
- ✓ ***Technology is Scalable***



Installed in ADM BioDiesel Facility



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Sodium Handling Safety

- DuPont Services Offered to Customers
 - Design assistance
 - PHA participation
 - Safety training
 - Employees
 - Local Fire Department
 - Field assistance during initial delivery and transfer



The miracles of science™



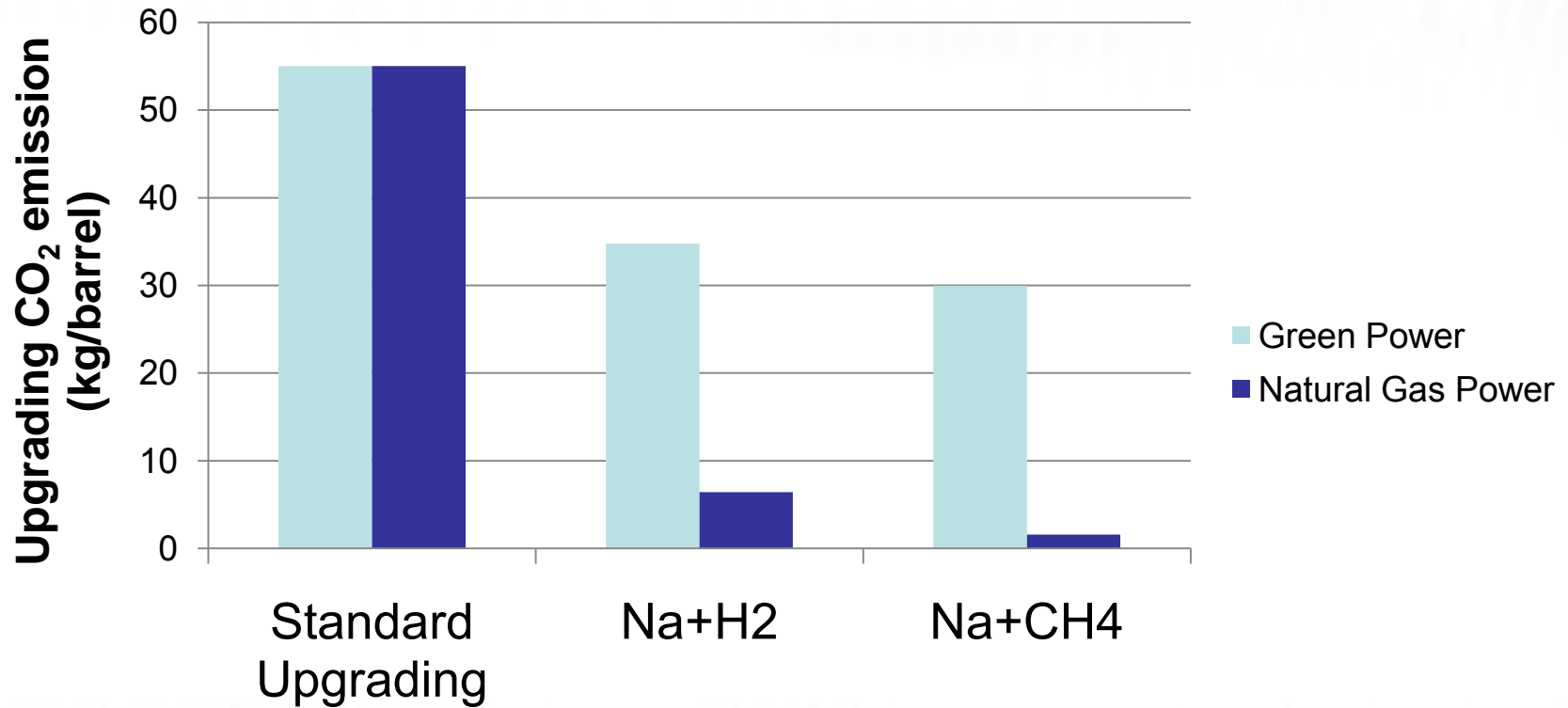
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Strong Intellectual Property Position

- Issued US Patents:
 - 7,897,028, Gordon et al., Process for the recovery of materials from a desulfurization reaction
 - 5,580,430, Balagopal et al., Selective metal cation-conducting ceramics
- US Patent Applications
 - 20090134040, Gordon et al., Process For Recovering Alkali Metals and Sulfur From Alkali Metal Sulfides and Polysulfide
 - 20100089762, Gordon, Apparatus and Method For Reducing an Alkali Metal Electrochemically at a Temperature Below the Metal's Melting Temperature
 - 20110100874, Gordon, Upgrading of Petroleum Oil Feedstocks Using Alkali Metals and Hydrocarbons
 - 20100331170, Balagopal et al., Alkali Metal Super Ionic Conducting Ceramic



CO₂ Impact for Bitumen



Based upon LCA numbers from: Spath P., Mann M., Lifecycle assessment of hydrogen production via natural gas reforming, Doc ID NREL/TP-570-27637, 2001

**Standard upgrading number takes as average of 50 and 60 Kg/Bbl, as stated in Flint Lin, BITUMEN & VERY HEAVY CRUDE UPGRADING TECHNOLOGY – Long Term R&D Opportunities, March 2004



Path Forward

- Continue Development
 - Continuous operation of the system
 - Separation of the upgraded oil and sodium salts
 - Process integration
 - Time on stream for integrated process
 - Economics at Scale
- Seek strategic partners



Key points

- Upgrading with sodium permits removal of heteroatoms without saturation
 - Requires less or no hydrogen (Use methane directly)
 - CO₂ emissions dramatically reduced
 - Aromaticity and olefins retained
 - Need for cracking to produce aromatics downstream eliminated
 - No heterogeneous catalyst
- Add carbon to fuel rather than atmosphere
 - Product mass increases
- TAN reduced



**Come see us in the hallway or contact us
for more information**



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