

Enabling Biomass Utilization

Cornell University

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Biomedical and Chemical Engineering

Syracuse University

Research Overview

- **Core Discipline: Heterogeneous Catalysis**
 - Inorganic Materials
 - Catalytic Kinetics
 - Physical Chemistry
- **Applied Focus: Resource Sustainability**
 - **Large scale** industrial alternatives to petroleum
 - Abundant biomass
 - [**Large Scale**] Bio-based **fuels** and chemicals
 - How do we utilize biomass economically?
 - How do we process sugar and lignin?

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Find materials to facilitate difficult chemistry!

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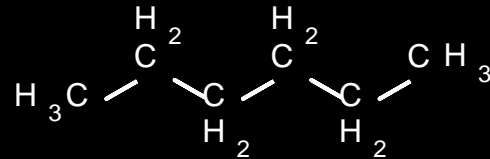
Understanding the Challenge...

- **Biomass Processing (Lignocellulose)**
 - Making industrial commodities from sugars and/or lignin
 - **Hydrocarbon Fuels** are difficult to source biologically

Hydrocarbons



Hexane (C₆H₁₄)

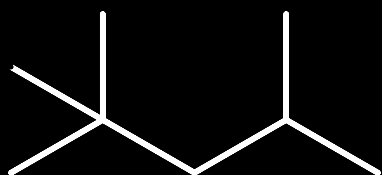


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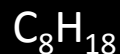
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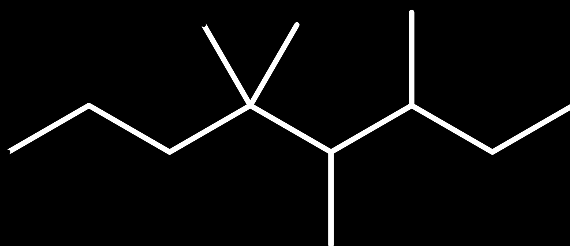
Gasoline



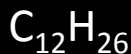
2,2,4-trimethylpentane
(Isooctane; RON = 100)



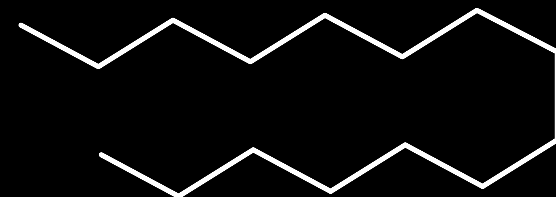
Jet Fuel



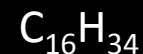
4,4,5,6-tetramethyloctane
(Isododecane)



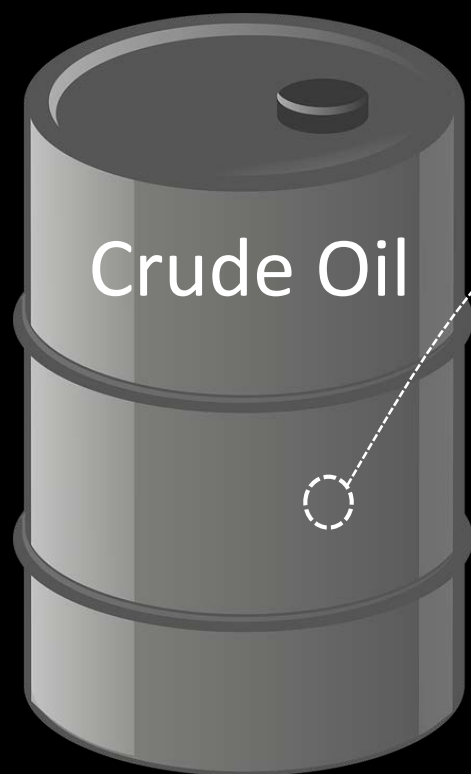
Diesel Fuel



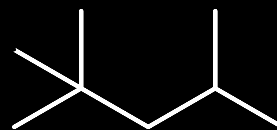
n-hexadecane
(Cetane; CN = 100)



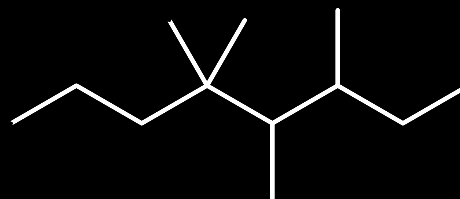
Understanding the Challenge...



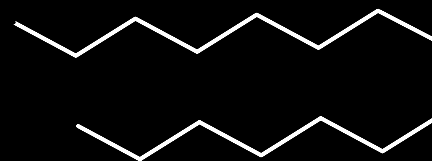
Gasoline

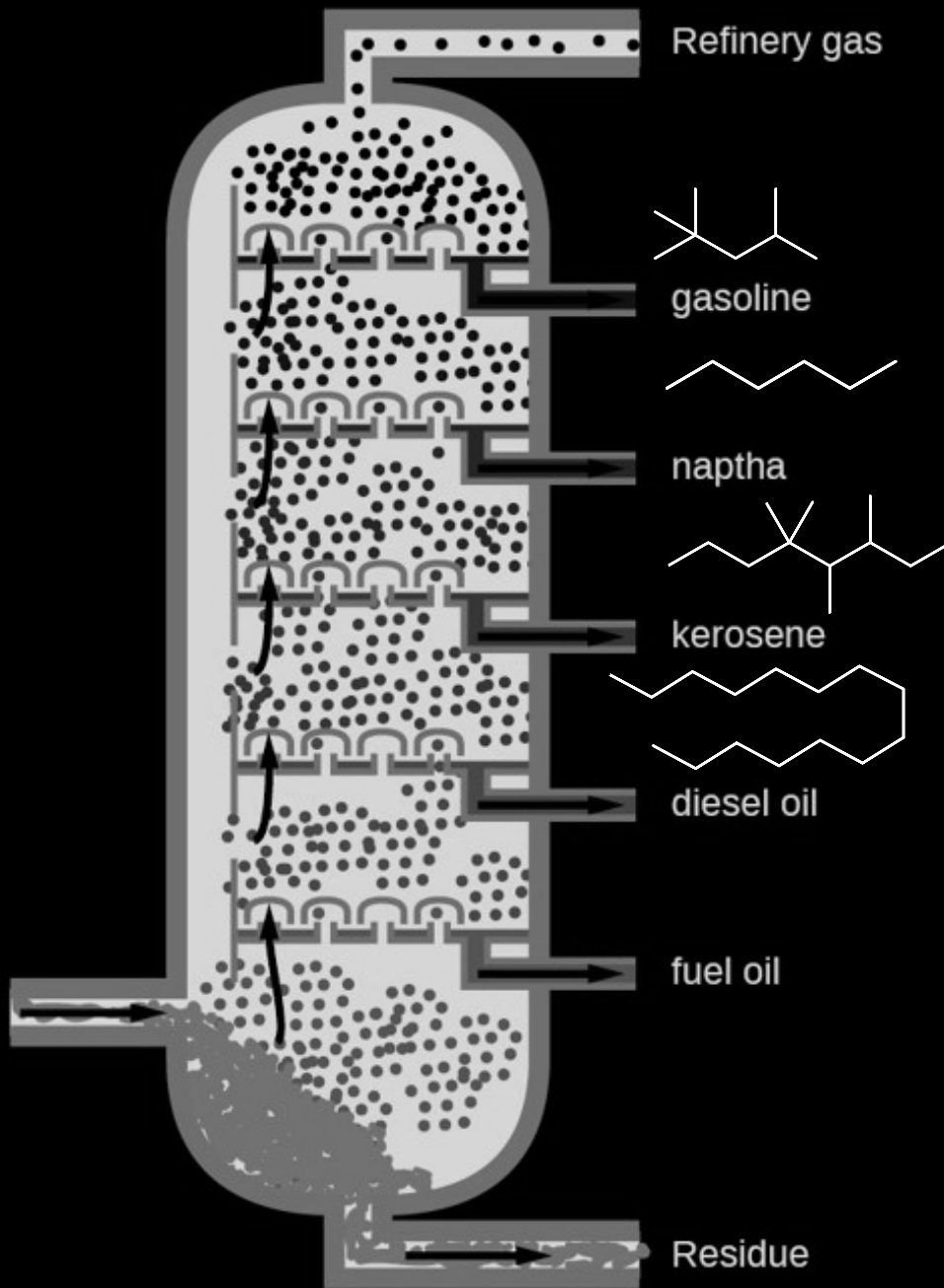
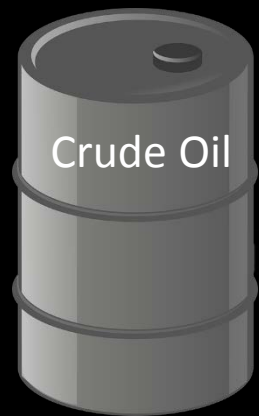


Jet Fuel



Diesel Fuel





Small molecules:
- Low boiling point
- Very volatile
- Flows easily
- Ignites easily



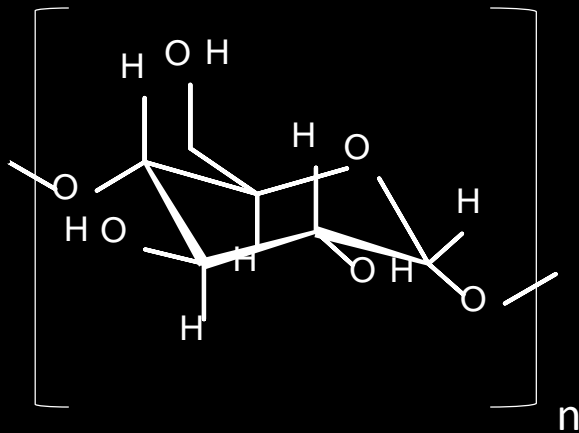
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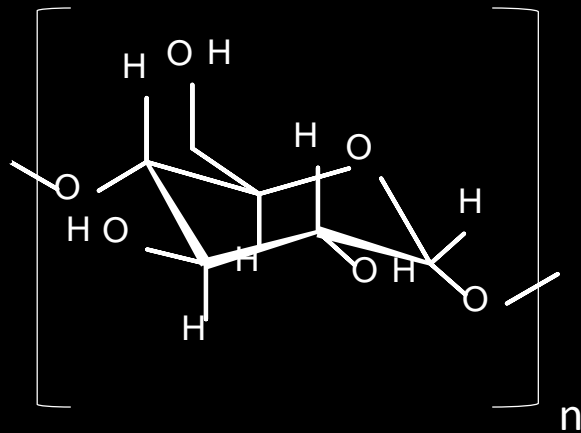


Cellulose ($C_6H_{12}O_6$)_n

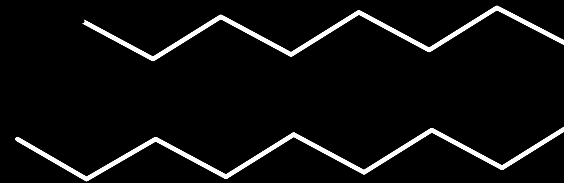
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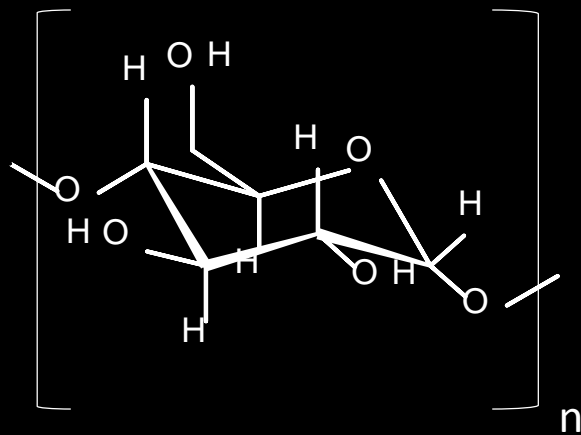


Octadecane ($C_{18}H_{38}$)

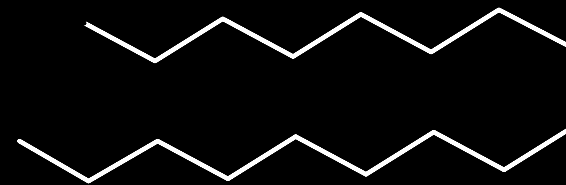
Understanding the Challenge...

- **Biomass Processing (Lignocellulose)**

- Making industrial commodities from sugars and/or lignin
- **Hydrocarbon Fuels** are difficult to source biologically
- Solids handling and depolymerization?



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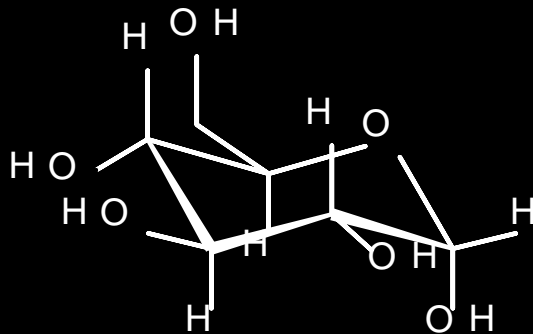


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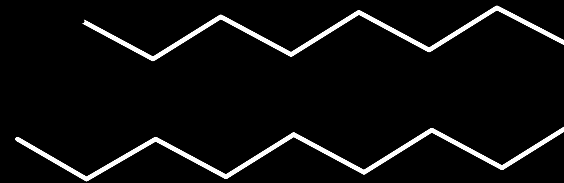
Understanding the Challenge...

- **Biomass Processing (Lignocellulose)**

- Making industrial commodities from sugars and/or lignin
- **Hydrocarbon Fuels** are difficult to source biologically
- Need to find new catalysts so that we can...



Glucose ($C_6H_{12}O_6$)

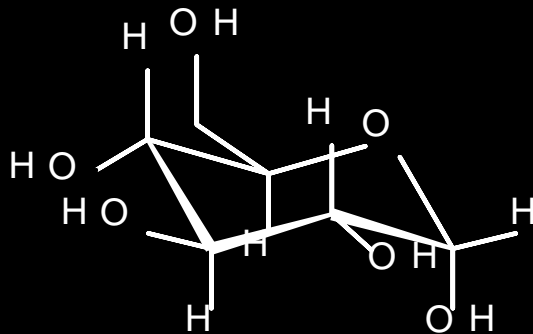


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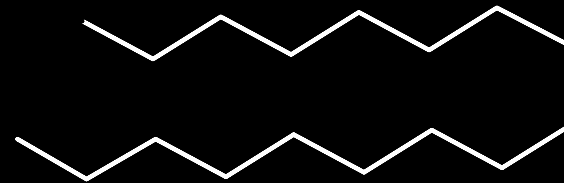
Understanding the Challenge...

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- **Hydrocarbon Fuels** are difficult to source biologically
- Form new C-C bonds (build larger molecules)



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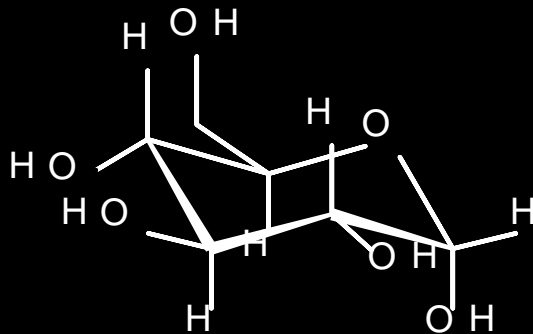


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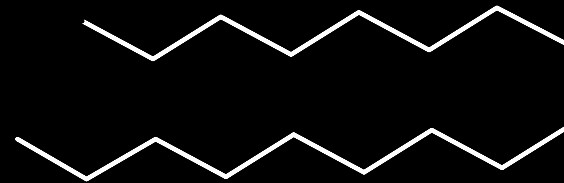
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- Remove oxygen (improve stability and energy density).



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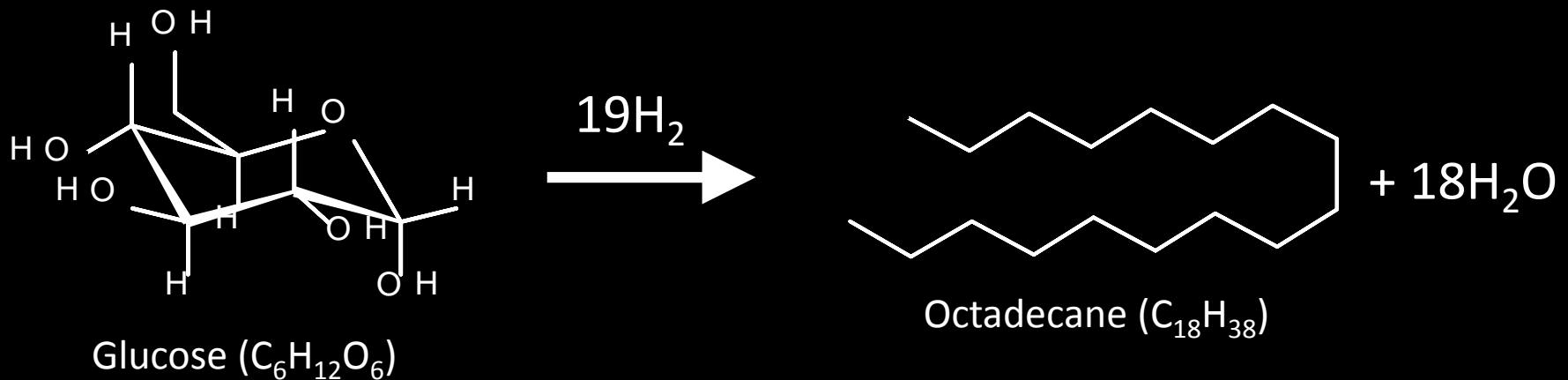


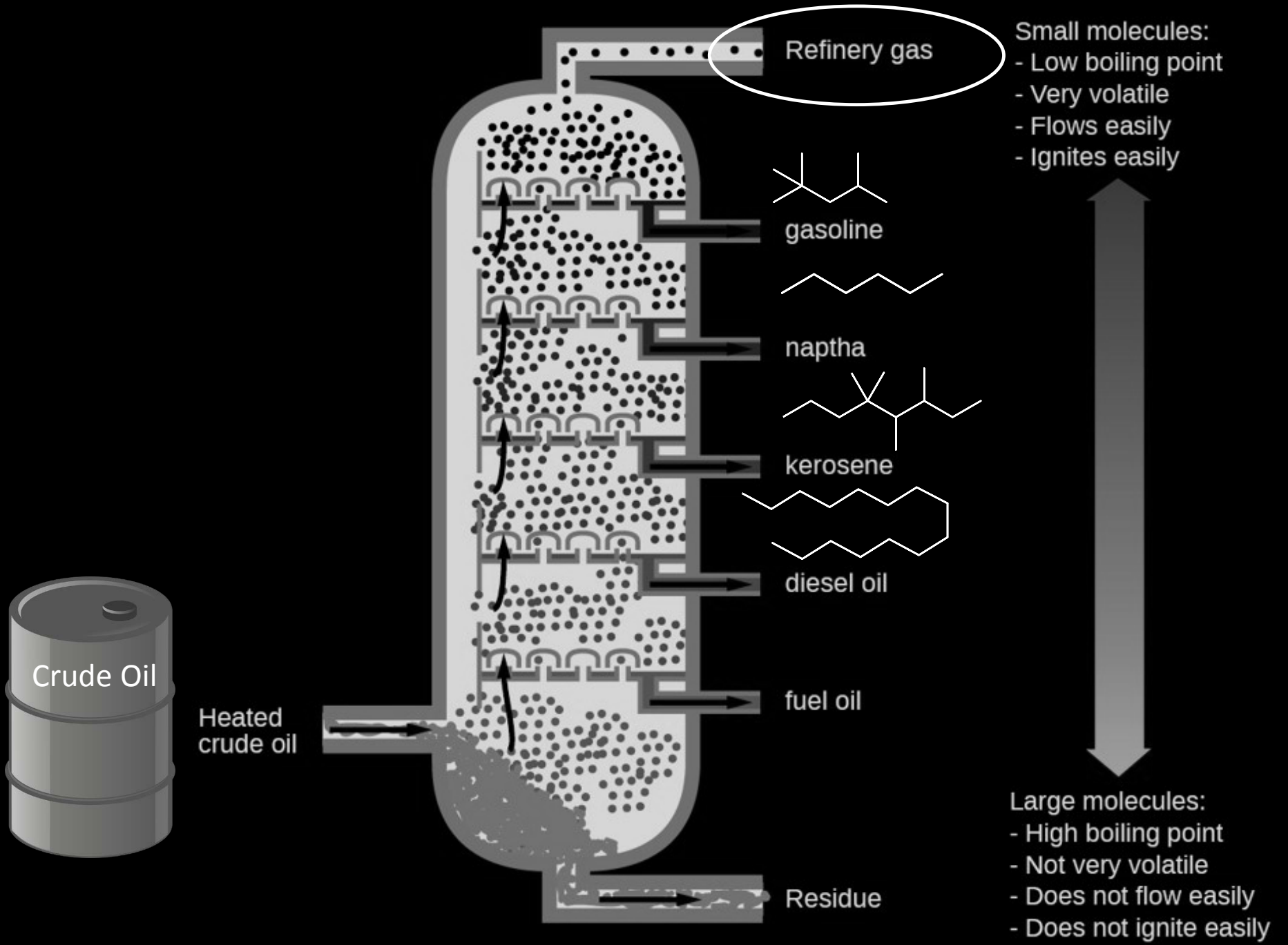
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- But chemistries are nontrivial and.....





Refinery gas

- Small molecules:
- Low boiling point
 - Very volatile
 - Flows easily
 - Ignites easily

gasoline

naptha

kerosene

diesel oil

fuel oil

Residue

Crude Oil

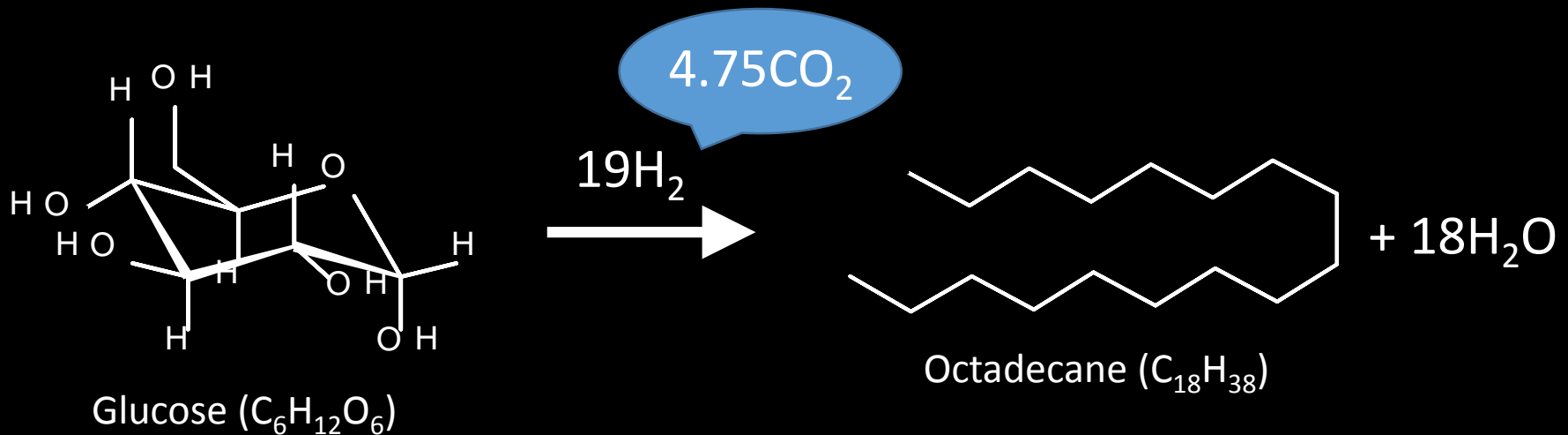
Heated crude oil

- Large molecules:
- High boiling point
 - Not very volatile
 - Does not flow easily
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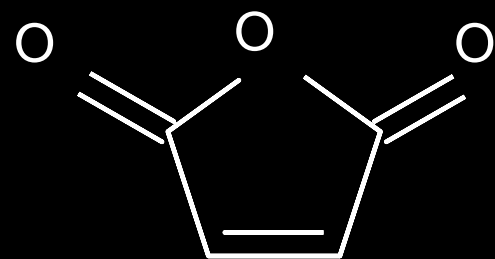
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 - **[Large Scale]** Bio-based **fuels** and **chemicals**
- How do we utilize biomass economically?
 - How do we process sugar and lignin?
- How can we resolve these challenging economics?
 - Especially to allow near-term development?

Viabile opportunities!

- Find products that do not need H₂ input
 - Bio-char is a good example; high value, low cost to manufacture!

Viability opportunities!

- Find products that do not need H_2 input
 - Bio-char is a good example; high value, low cost to manufacture!
- Find products that are difficult to source from oil
 - Oxygenated chemicals
 - Alkanes are hard to activate...



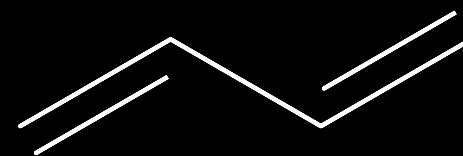
Maleic Anhydride

Viable opportunities!

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- Hydraulic Fracturing has disrupted supply chain
 - New opportunities for biomass!

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 - The Butadiene dilemma
 - Supply is becoming constrained...



Butadiene