**What is Petroleum?**

- **Petroleum**
- **Hydrocarbons** (mostly H, C, bits of S, N, O)
- **Gas**
  - Natural Gas
- **Condensate**
- **Liquids**
  - Oil, Crude oil
- **Plastic**
  - Asphalt, Tar
- **Solids**
  - Kerogen- Insoluble in organic solvents
  - Bitumen-Soluble
  - Coal

**Units**

- **Liquid Volume**:
  - 1 oil barrel = 42 gallons
  - ≈158.9 m³ (in Europe)
  - Giant Oil field > 500 Million barrels (75 million m³)

- **Gas Volume**:
  - Thousand cubic feet of gas (Mcf)
  - Million cubic feet of gas (MMcf)
  - Billion cubic feet of gas (Bcf)
  - Trillion cubic feet of gas (Tcf)

- **Flow rates**:
  - Barrels of oil per day (BOD)
  - Thousand cubic feet of gas per day (McfD)

**Natural Gas**

- Chains of 1 to 4 Carbons
  - CH₄ - Methane
  - C₂H₆ - Ethane
  - C₃H₈ - Propane
  - C₄H₁₀ – Butane
  - Plus sometimes non-hydrocarbon gases:
    - He, Ar, Kr, Radon, N₂, O₂, CO₂, H₂, H₂S

**Good Gas and Bad Gas**

- **Good**
  - He
  - Ar
  - CO₂ (?)

- **Bad**
  - Radon- radioactive
  - H₂S - poison, corrosive

**Sources**:

- He, Radon, Ar - radioactive decay of U, K
- CO₂ – thermal maturation of bitumen, Limestone breakdown, bacterial metabolism
- H₂S – bacterial metabolism, breakdown of evaporates (salt)
**Natural Gas**
- Paraffins (Alkanes)
- Saturated Chains

**Energy Equivalence**
1 Barrel of Oil = 6000 Cubic Feet of Gas (approx)
- Liquefied Natural Gas (LNG)
  - Methane
  - Cool to -160°C, compress it
- Liquefied Petroleum Gas (LPG)
  - Propane (60%)+ Butane (40%)
  - Compressed 250:1

**Economics of Natural Gas**
- Abundant
- Cleanest of fossil fuels
- Hard to transport: need a pipeline or LNG facility
- Economics of natural gas are local, not global

**Crude Oil**
- Mix of hydrocarbons of different types
  - 30% Paraffins- Chains
  - 50 % Naphthenes- Single bond rings
  - 15 % Aromatics – Double bond rings
  - 5 % Asphaltics- Include impurities (N, S, O)
**Paraffins (Alkanes)**
- C1 to C80 chains
- Millions of possible branched chains
- C1-C4 Gases
- C5-C14 Liquids
- >C15 Solid
- Waxy
- C5-C8 in gasoline
- Octane rating: equivalent iso-octane/heptane ratio

**Naphthenes (Cycloparaffins)**
- Rings with single bonds
- Most common HC in crude oil (~40%)
- Usually liquids
- C5 - Cyclopentane
- C6 - Cyclohexane

**Aromatics**
- Unsaturated rings
- Based on benzene
- High octane rating
- Concentrate in heavy oil
- Carcinogenic

**Heavy Hydrocarbons**
- Medium length chains (C11-C18)
- Thicker liquids
- Kerosene
- Diesel
- Long chains (C19- >40)
- Viscous to solid
- Motor oil
- Tar
- Asphaltics
  - Impurities- O, N, S
  - S 0.1 - 4% (sour oil)
  - Pollution and Acid rain

**Average Crude 35 API**
- Weight %
  - Paraffin 25%
  - Naphtene 50%
  - Aromatic 17%
  - Asphaltic 8%
Cracking of Hydrocarbon Chains

[Diagram]

Shell Ethane Cracker Plant in PA

- Ethane to ethylene, polyethylene, etc
- Fibers, plastic food containers, engine coolants, anti-freeze

API Gravity

API Gravity = \(141.5\left(\frac{\rho_{\text{oil}}}{\rho_{\text{water}}}\right) - 131.5\)

\(\rho_{\text{water}}\) - \(\rho_{\text{oil}}\) = density at 60°F

10°API = Specific gravity of water

Low API = High Density, high viscosity
High API = Low Density, low viscosity

Typical Crude 35° API Crude

<table>
<thead>
<tr>
<th></th>
<th>Vol, %</th>
<th>API</th>
<th>Density g/cm³</th>
<th>Viscosity millipoise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline (C₅-C₁₀)</td>
<td>27%</td>
<td>60</td>
<td>0.74</td>
<td>6</td>
</tr>
<tr>
<td>Kerosene (C₁₁-C₁₃)</td>
<td>13%</td>
<td>50</td>
<td>0.78</td>
<td>20</td>
</tr>
<tr>
<td>Diesel (C₁₄-C₁₈)</td>
<td>12%</td>
<td>45</td>
<td>0.79</td>
<td>100</td>
</tr>
<tr>
<td>Heavy Gas Oil (C₁₉-C₂₅)</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lubricating Oil (C₂₆-C₄₀)</td>
<td>20%</td>
<td>30</td>
<td>0.85</td>
<td>500</td>
</tr>
<tr>
<td>Residuum (&gt;C₄₀)</td>
<td>18%</td>
<td>10</td>
<td>1</td>
<td>&gt;10⁵</td>
</tr>
</tbody>
</table>

Reading for next time

- Subsurface Environment
- Ch. 4 Selley
- Ecampus Quiz closes on Sunday at 9 PM