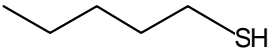
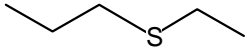


## Homework #9

1. You'd like to saturate 10,000 bpd benzene to cyclohexane (100% conversion).
  - How many bbl/day cyclohexane will result?
  - What is the change in boiling point between the benzene and the cyclohexane?
  - How much hydrogen will be needed (in both scf/bbl feed & scf/day)?
  
2. You'd like to hydrotreat 10,000 bpd of Medium Naphtha from Eocene (see attached assay) to essentially 0 wt%. Assume the sulfur is an equimolar mixture of 1-pentanethiol & ethyl propyl sulfide (see table for properties).
  - How much sulfur is associated with this feed (in terms of lb/hr and lb.mol/hr)?
  - How much of the sulfur-bearing compounds are in the feed (in terms of lb.mol/hr & bpd)?
  - How much of the feed is non-sulfur bearing (in bpd)?
  - The ethyl propyl sulfide will produce ethane & propane which is too light for the gasoline range. The 1-pentanethiol should produce pentane which will still be in the gasoline boiling range; how much pentane will be produced (in bpd)? How much liquid will remain in the gasoline range?
  - How much H<sub>2</sub>S will be produced (in terms of lb.mol/hr & scf/day)?
  - How much hydrogen will be needed (in terms of scf/day & scf/bbl feed)?

| Name                 | Structure   | Boiling Point [°F] | Specific Gravity |
|----------------------|---|--------------------|------------------|
| 1-Pentanethiol       |    | 258.9              | 0.8469           |
| Ethyl Propyl Sulfide |  | 245.4              | 0.8160           |

3. You'd like to hydrotreat 10,000 bpd of the total gas oil (Atm Gas Oil, Light VGO, & Heavy VGO) from Eocene (see attached assay) to essentially 0 wt%.
  - How much sulfur is associated with this gas oil feed rate (in terms of lb/hr and lb.mol/hr)?
  - How much H<sub>2</sub>S will be produced (in terms of lb.mol/hr & scf/day)?
  - How much hydrogen will be needed (in terms of scf/day & scf/bbl feed)?

## Eocene Crude Oil – Summary of Major Cuts

|                                    | Whole<br>Crude | Light<br>Naphtha | Medium<br>Naphtha | Heavy<br>Naphtha | Kero    | Atm<br>Gas Oil | Light<br>VGO | Heavy<br>VGO | Vacuum<br>Resid | Atm<br>Resid |
|------------------------------------|----------------|------------------|-------------------|------------------|---------|----------------|--------------|--------------|-----------------|--------------|
| TBP Temp At Start, °C              | Start          | 10               | 80                | 150              | 200     | 260            | 340          | 450          | 570             | 340          |
| TBP Temp At End, °C                | End            | 80               | 150               | 200              | 260     | 340            | 450          | 570          | End             | End          |
| TBP Temp At Start, °F              | Start          | 55               | 175               | 300              | 400     | 500            | 650          | 850          | 1050            | 650          |
| TBP Temp At End, °F                | End            | 175              | 300               | 400              | 500     | 650            | 850          | 1050         | End             | End          |
| Yield at Start, vol%               |                | 0.4              | 2.7               | 7.1              | 12.5    | 19.1           | 31.2         | 50.0         | 69.4            | 31.2         |
| Yield at End, vol%                 |                | 2.7              | 7.1               | 12.5             | 19.1    | 31.2           | 50.0         | 69.4         | 100.0           | 100.0        |
| Yield of Cut (wt% of Crude)        |                | 1.6              | 3.5               | 4.6              | 5.8     | 11.3           | 18.4         | 19.8         | 34.7            | 73.0         |
| Yield of Cut (vol% of Crude)       |                | 2.3              | 4.4               | 5.4              | 6.6     | 12.1           | 18.8         | 19.4         | 30.6            | 68.8         |
| Gravity, °API                      | 18.7           | 82.7             | 56.9              | 45.5             | 39.0    | 29.5           | 21.5         | 15.5         | 1.0             | 10.1         |
| Specific Gravity                   | 0.9422         | 0.6607           | 0.7512            | 0.7993           | 0.8299  | 0.8789         | 0.9245       | 0.9626       | 1.0682          | 0.9992       |
| Sulfur, wt%                        | 3.97           | 0.14             | 0.20              | 0.24             | 0.70    | 2.00           | 3.33         | 4.15         | 6.47            | 5.05         |
| Mercaptan Sulfur, ppm              |                | 509              | 1633              | 1890             | 536     | 118            | 46           | 24           |                 |              |
| Nitrogen, ppm                      | 2149           |                  |                   | 0                | 0       | 35             | 543          | 1466         | 5057            | 2940         |
| Hydrogen, wt%                      | 11.4           | 16.2             | 14.9              | 14.1             | 13.6    | 12.9           | 12.2         | 11.3         | 9.3             | 10.6         |
| Viscosity @ 40 °C (104 °F), cSt    | 132            | 0.813            | 0.940             | 1.20             | 1.92    | 4.56           | 31.2         | 245          | 5.01E+14        | 9181         |
| Viscosity @ 50 °C (122 °F), cSt    | 78.6           | 0.718            | 0.835             | 1.07             | 1.64    | 3.62           | 20.4         | 140          | 2.02E+11        | 3900         |
| Viscosity @ 100 °C (212 °F), cSt   | 13.5           | 0.445            | 0.530             | 0.686            | 0.916   | 1.55           | 4.76         | 21.1         | 84100           | 242          |
| Viscosity @ 135 °C (275 °F), cSt   | 6.31           | 0.351            | 0.423             | 0.548            | 0.689   | 1.04           | 2.52         | 9.38         | 2850            | 49.9         |
| Freeze Point, °C                   |                | -114.000         | -98.000           | -84.000          | -66.000 | -34.000        |              |              |                 |              |
| Freeze Point, °F                   |                | -173             | -145              | -120             | -86     | -29            |              |              |                 |              |
| Pour Point, °C                     | -37            | -135             | -104              | -90              | -71     | -39            | -2           | 19           | 100             | 19           |
| Pour Point, °F                     | -35            | -211             | -155              | -130             | -96     | -39            | 28           | 66           | 212             | 66           |
| Smoke Point, mm (ASTM)             |                |                  | 29                | 24               | 20      | 16             | 13           |              |                 |              |
| Aniline Point, °C                  |                | 48               | 49                | 52               | 57      | 62             | 68           | 76           |                 |              |
| Aniline Point, °F                  |                | 118              | 120               | 126              | 134     | 143            | 155          | 168          |                 |              |
| Total Acid Number, mg KOH/g        | 0.20           | 0.1              | 0.1               | 0.1              | 0.2     | 0.2            | 0.2          | 0.3          |                 |              |
| Cetane Index, ASTM D976            |                |                  |                   | 32               | 44      | 43             |              |              |                 |              |
| Diesel Index                       |                | 97               | 68                | 57               | 52      | 42             | 33           | 26           |                 |              |
| Characterization Factor (K Factor) | 11.7           | 12.7             | 11.8              | 11.7             | 11.7    | 11.5           | 11.5         | 11.6         | 11.4            | 11.6         |
| Research Octane Number, Clear      |                | 84.1             | 60.0              | 45.4             |         |                |              |              |                 |              |
| Motor Octane Number, Clear         |                | 80.7             | 59.0              |                  |         |                |              |              |                 |              |
| Paraffins, vol%                    |                | 87.6             | 50.6              | 43.4             | 39.5    | 32.0           | 23.7         |              |                 |              |
| Naphthenes, vol%                   |                | 12.4             | 46.6              | 34.4             | 33.9    | 30.8           | 28.6         |              |                 |              |
| Aromatics, vol%                    |                | 0.0              | 2.8               | 22.2             | 23.9    | 23.2           | 28.1         |              |                 |              |
| Thiophenes, vol%                   |                | 0.1              | 0.0               | 0.0              | 2.7     | 14.0           | 19.6         |              |                 |              |
| Molecular Weight                   | 377            | 98               | 117               | 142              | 175     | 220            | 312          | 453          | 821             | 492          |
| Gross Heating Value, MM BTU/bbl    | 6.15           | 4.82             | 5.32              | 5.57             | 5.72    | 5.92           | 6.09         | 6.23         | 6.51            | 6.34         |
| Gross Heating Value, kcal/kg       | 10350          | 11580            | 11230             | 11040            | 10950   | 10710          | 10470        | 10260        | 9660            | 10060        |
| Gross Heating Value, MJ/kg         | 43.3           | 48.5             | 47.0              | 46.2             | 45.8    | 44.8           | 43.8         | 42.9         | 40.4            | 42.1         |
| Heptane Asphaltenes, wt%           | 6.4            |                  |                   |                  |         |                |              |              | 18.5            | 8.8          |
| Micro Carbon Residue, wt%          | 10.2           |                  |                   |                  |         |                |              |              | 29.3            | 13.9         |
| Ramsbottom Carbon, wt%             | 9.7            |                  |                   |                  |         |                |              |              | 27.8            | 13.2         |
| Vanadium, ppm                      | 56             |                  |                   |                  |         |                |              |              | 160             | 76           |
| Nickel, ppm                        | 21             |                  |                   |                  |         |                |              |              | 60              | 28           |
| Iron, ppm                          |                |                  |                   |                  |         |                |              |              |                 |              |