NavApp: Fuels and Lubricating Oils

Learning Objectives

- Recognize that heavier hydrocarbons generally have stronger intermolecular forces
- Recognize that heavier hydrocarbons generally have higher boiling points
- Recognize that heavier hydrocarbons generally have lower vapor pressures

1. Introduction

In this module, we are going to begin introducing fuels and lubricating oils used in the military. To begin this introduction, we must recognize a few terms associated with fuels. These terms include:

I. Hydrocarbon: an organic compound whose molecules contain only carbon and hydrogen atoms.
II. Boiling point: the temperature at which the vapor pressure of a liquid is equal to the external atmospheric pressure.
III. Vapor pressure: the pressure exerted by a gas in equilibrium with its liquid phase at a given temperature.

A *fuel*, such as petroleum, is any substance that is burned or reacted to provide heat and other forms of energy. The refining of petroleum begins with the separation of the crude oil into groups of compounds with distinct boiling point ranges. Since crude petroleum contains literally thousands of hydrocarbon compounds, separation of the crude into pure compounds is neither feasible nor necessary. Rather, the petroleum fractions that are obtained are often mixtures of hundreds of hydrocarbons with boiling points within certain ranges. The physical properties of petroleum fractions determine their eventual end use. The table below lists common fractions obtained from crude oil with their approximate boiling ranges.

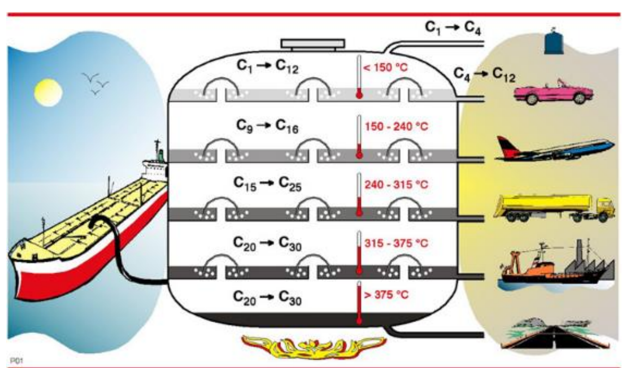
Table I: Petroleum Fractions

Fraction	Carbon Atoms in chain	Boiling Pt. Range (°C)	Uses
Natural gas	C_1-C_4	-161 to 20	Fuel and cooking gas
Petroleum ether	C_5-C_6	30-60	Solvent for organic compounds
Ligroin	C_7	20-135	Solvent for organic compounds
Gasoline	C_6-C_{12}	30-180	Automobile fuels
Kerosene	C_{11}-C_{16}	170-290	Rocket and jet engine fuels, domestic heating
Heating Fuel Oil	C_{14}-C_{18}	260-350	Domestic heating and fuel for electricity production
Lubricating Oil	C_{15}-C_{24}	300-370	Lubricants for automobiles and machines
Paraffins	C_{20} and up	Low-melting solids	Candles, matches
Asphalt	C_{30} and up	Gummy residues	Surfacing roads, fuel

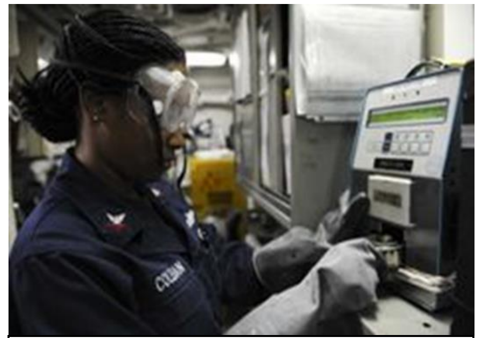
2. Chemistry in the Operating Forces

The source of Naval Distillate Fuel and other petroleum-derived products is crude oil. The main fractions separated during crude distillation, in order of increasing boiling point are:

I. Fuel gas (essentially methane and ethane)
II. Liquid Petroleum Gas (LPG) (propane and butane)
III. Naphtha (gasoline blends)
IV. Gas oils (jet and diesel fuel stock)
V. Residuum (heavy fuels, lube-oil stock, or asphaltic compounds)



The Navy has standardized one preferred fuel for all shipboard power plants: NATO Code Number F-76. This fuel type is used for propulsion, is a middle distillate fuel, and is blended from higher-boiling stocks than jet fuels. F-76 consists primarily of C_9-C_{20} hydrocarbons (MW~198-202 g/mol) with a typical boiling point between 220-400°C.


Sailor conducting a Flashpoint test on F-76.

JP-5 is a jet fuel (NATO F-44). JP-5 is the only jet fuel authorized on fleet oilers and for use on Navy ships; however, aircraft fueled on land can use JP-5/JP-8. In fact, under no circumstance shall JP-4 or JP-8 turbine fuel be taken on board Naval ships. JP-5 consists of C_9-C_{16} hydrocarbons (MW~185 g/mol) with a typical boiling point between 156°C to 293°C.

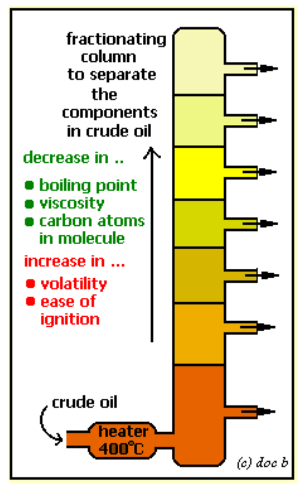
The primary lube oil used in the Navy is 2190 mineral oil and has several different uses including lubrication of main reduction gear.

The Navy has several standards for their fuels. F-76 and JP-5 must have a Flash point no less than 140°F. Additionally, a Bottom Sediment and Water Test (BS&W) is conducted periodically on fuel. Testing is done to establish any level of fuel contamination and to establish the density of the fuel for weight distribution and heating value.

3. Scientific Practices

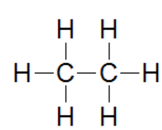
Remember, a general trend is the bigger the molecule, the stronger the intermolecular forces. If the molecule has the same molar mass, the longer the carbon chain will allow more intermolecular forces to occur. These factors will increase viscosity, melting point and boiling point.

In fractional distillation, the crude oil passes through a heater. The larger molecules will remain at the bottom of the column, as they are less volatile and have a higher boiling point. This larger molecules will remain at the bottom of the column because they generally have stronger intermolecular forces, keeping the vapor pressure relatively low compared to smaller molecules. For a liquid to boil, the vapor pressure must becomes equal to the pressure of the gas above it.



4. Questions

a. Review previous chapter: Ethane is a fuel gas, C_2H_6, as shown to the right. What is the electron pair geometry of the carbon (both carbons have the same geometry)?


ethane

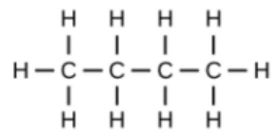
b. Review previous chapter: What is the hybridization of the carbon atom (both carbons have the same hybridization)?

c. Normal butane (C_4H_{10}) and octane (C_8H_{18}) are components of liquid petroleum gas. Which is likely to have a higher boiling point? Why?

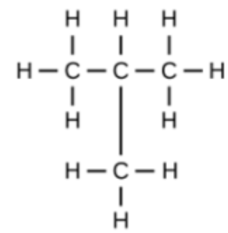
d. Kerosene is the fraction of crude oil composed of $C_{12}H_{26}$–$C_{15}H_{32}$ hydrocarbons. Is $C_{12}H_{26}$ or $C_{15}H_{32}$ expected to have a higher vapor pressure? Why?

e. Butane and isobutene are shown on the right. Which is expected to have a higher boiling point? Why?

Butane



Isobutane



References and Additional Readings

References are given in the figure captions, where available/applicable. Additional readings can be found on the Chemistry Department's website: https://intranet.usna.edu/ChemDept/plebeChem/navapps.php

https://www.ncbi.nlm.nih.gov/books/NBK231234/#:~:text=The%20hydrocarbons%20in%20jet%20and,%2C%20and%20olefins%20(0.5%25).

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