Lecturer information:

Assist Prof. Dr. Omar Yasin Thayee

BSc, MSc, PhD (**Petroleum, Polymer & Petrochemical Engineering**)

Tikrit University Iraq, Kingston University, Materials Research Centre Kingston upon Thames London UK.

Email: omaroilgas@tu.edu.iq

Faculty of Petroleum Process Engineering

Petroleum & Gas Refining Engineering

Teacher note

Please feel free to contact me on email or visit my office during office hours. I am always here to help. I am encouraging you to express any questions or any difficulties experienced during the course directly to me. I also welcome and value your feedback so that we can make any changes as we learn together.

Course name

Properties of Petroleum & Gases, 2nd Year

Course code: PPG 203 **Credits: 6** mandatory

Teaching scheme: 2 hours lecture and 2 hours laboratory per week

Percentage of allowable change in syllabus: 20 %

Course Description

- This course is for the students of petroleum & Gas Refining engineering and the student of Industrial chemistry. The course provides more information about the origin, evaluation, composition and classification of crude oil. A brief overview to crude oil refining, crude oil products, quality control on petroleum products gases.

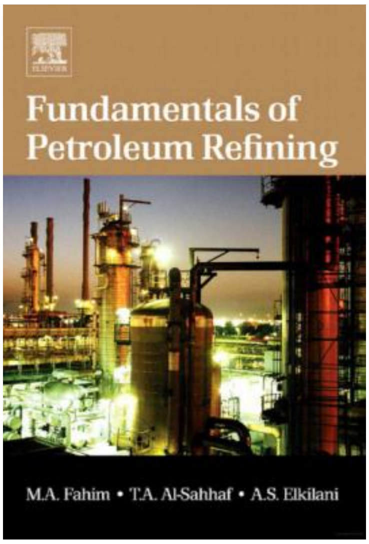
Course Goals and Objectives

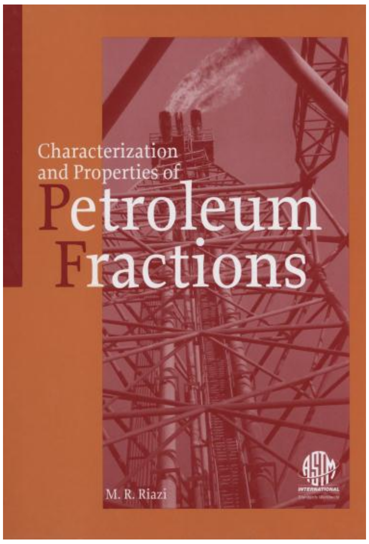
- The purpose of this course is to provide the students with an opportunity to acquire a basic scientific and technological understanding of the evaluation techniques of crude oil and its products. This course is an excellent introduction for those working or interested in the Oil & Gas industry.

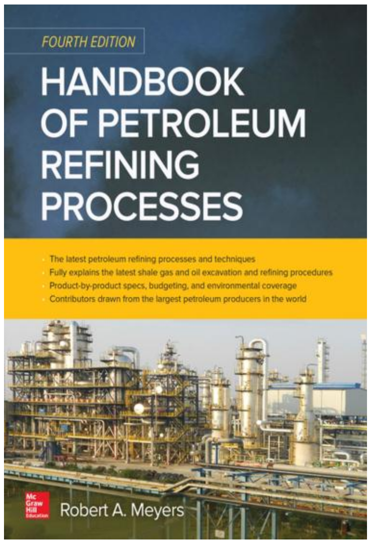
Reference book:

1- Characterization of petroleum products by Riazi
2- Handbook of Petroleum Refining Processes by Meyers
3- Fundamentals of Petroleum Refining by Fahim

Reading Materials:







Distribution of grades:

- **Monthly examinations: 30%**
- **Quizzes, assignment, homework, and class activities: 5%**
- **Laboratory reports and examinations: 15%**
- **Final exam: 50%**

Syllabus for the course code PPG203 for the academic year 2018-2109

Topics covered

1- **Crude oil composition**
2- **Crude oil classification**
3- **Petroleum product specifications**
4- **Physical and chemical properties of petroleum products**
5- **Quality control of crude oil and its products (crude oil evaluation)**
6- **Evaluation of sulphur and wax content**
7- **Distillation curves (ASTM, TBP, SD, and EFV) at atmospheric pressure**
8- **Thermo-physical properties calculations**
9- Prediction and conversion of distillation data
10- Interconversion of various distillation data at atmospheric pressure
11- Interconversion of various distillation data at reduced pressure
12- Predication of Molecular Weight (*Riazi-Daubert Methods)*
13- **Prediction of Normal Boiling Point *Riazi-Daubert Correlations***
14- **Prediction of Specific Gravity/API Gravity**

15- **Prediction of Critical Properties**

16- Prediction of Density, Refractive Index, CH Weight Ratio, And Freezing Point

17- Prediction Of Kinematic Viscosity At 38 And 99°C

18- **Prediction of the Composition of Petroleum Fractions**

19- **Prediction Of PNA Composition**

20- **Prediction of Elemental Composition**

21- **Properties Related to Volatility**

22- **Pour Point**

23- **Cloud Point**

24- **Aniline Point**

25- **Cetane Number and Diesel Index**

26- **Octane Number**

27- **Carbon Residue**

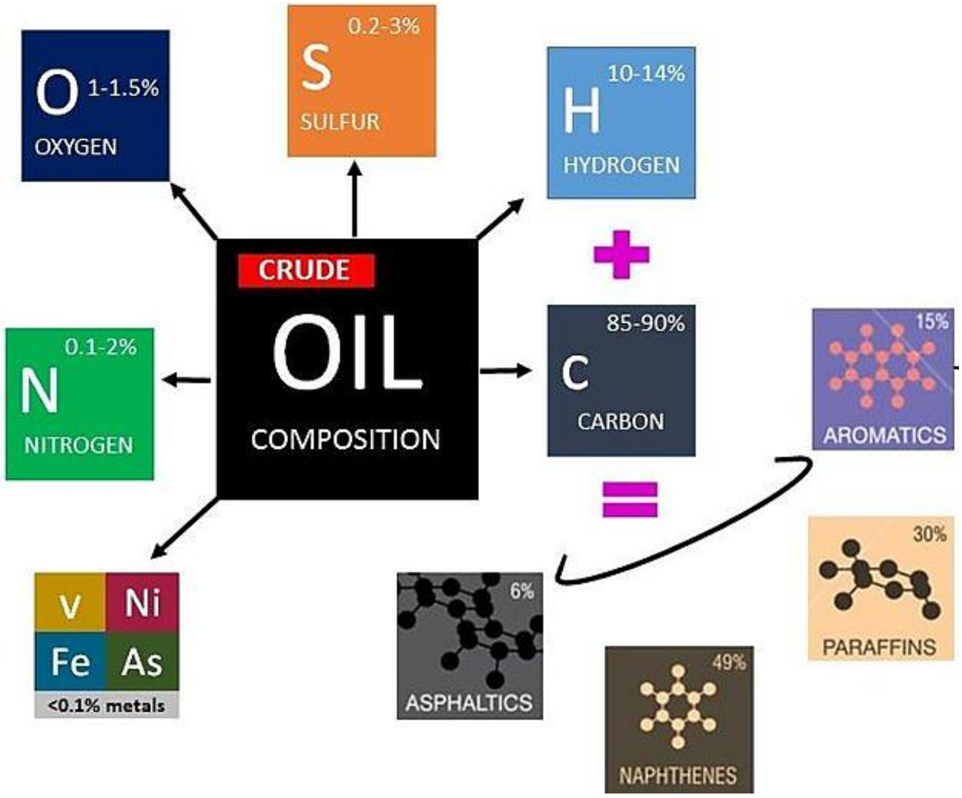
28- **Smoke Point**

29- **Natural Gas Properties**

30- **Natural Gas Composition (Liquefied Petroleum Gases Properties& Refinery Gases Properties)**

Composition & Classifications of Crude Oil

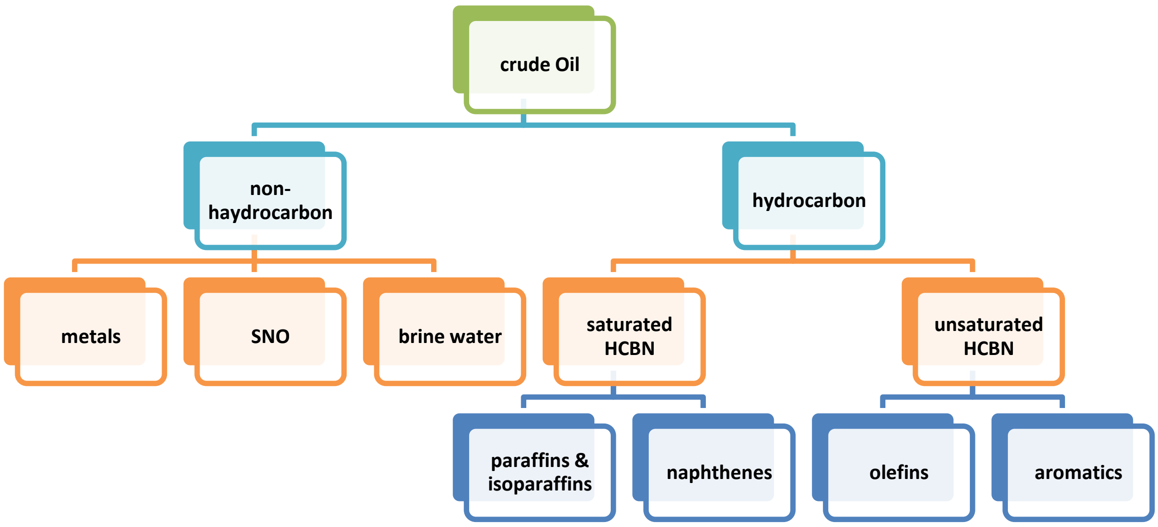
- Crude oil is a **complex liquid mixture** of hydrocarbon compounds that consist mainly of **carbon and hydrogen.**
- In addition, small amounts of organic compounds containing **sulphur**, **oxygen**, **nitrogen** **and metals such as vanadium, nickel, iron and copper**.



Hydrogen to carbon H/C ratios affects the physical properties of crude oil.

- As the hydrogen to carbon ratio **decreases**, the gravity and **boiling point** of the hydrocarbon compounds **increases**.
- The **higher H/C ratio** of the feedstock, the **higher its value** to a refinery because less hydrogen is required.

Crude Oil Composition Chart

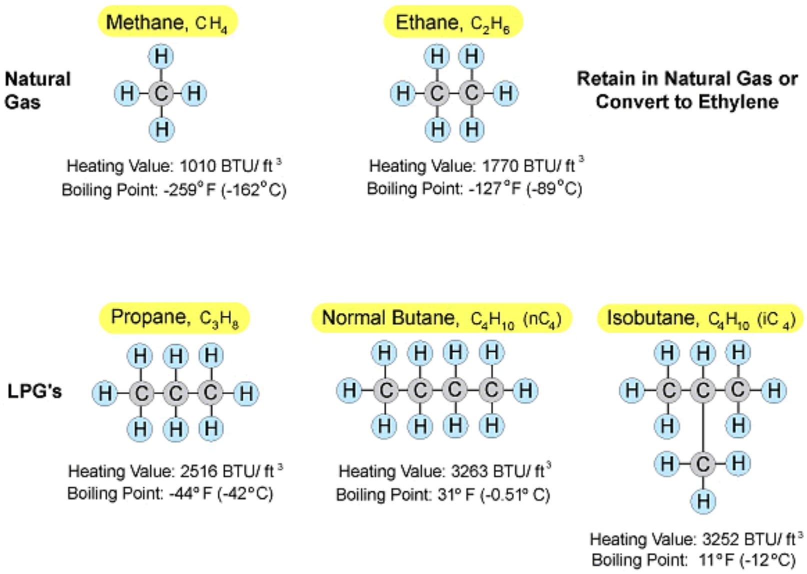


Hydrocarbon Components

✓ Saturated hydrocarbons

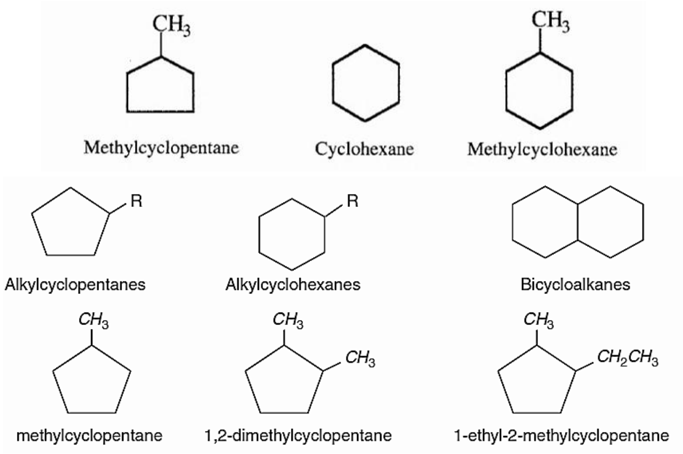
- **Paraffins & Isoparaffins** (alkanes) **(C_nH_{2n+2}):** **C1 to C3 alkanes** are usually found associated with crude oils in a dissolved state.

- The presence of isoparaffins in gasoline is **essential for increasing the octane number** of gasoline fuels.



- **Paraffins are** high molecular weight, high boiling point **and Low** octane number.
- **Isoparaffins are low boiling points and high octane number.**

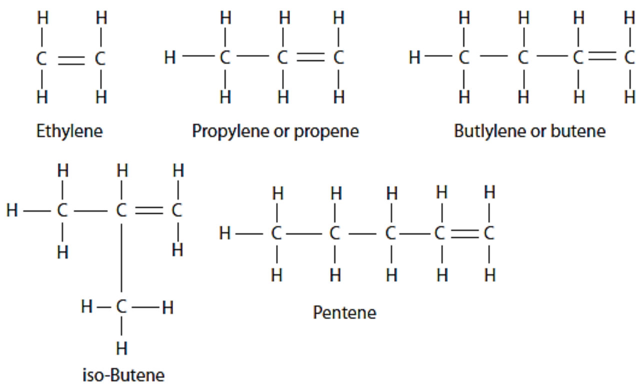
- **Naphthenes** (cycloalkanes) C_nH_{2n}



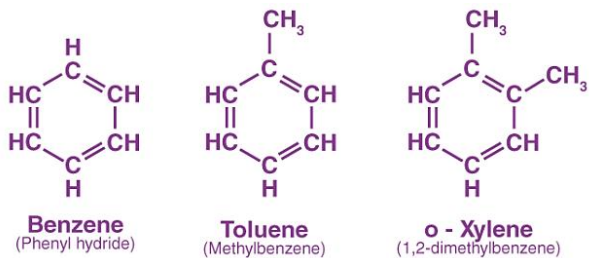
- **The boiling point and densities of naphthenes are higher than those of alkanes having the same number of carbon atoms?**
- **Mutli-ring naphthenes** are present in the heavier parts of the crude oil.

✓ **Unsaturated hydrocarbons**

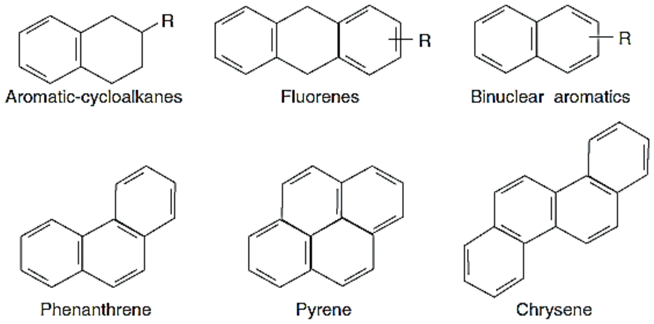
- **Olefins** are rarely formed in the crude oil?
- Contain carbone-carbone multiple bonds (double, triple or both)
- They are produced during cracking and conversion processes.
- This may indicate that crude oil originated under a high pressure.



- **Aromatic hydrocarbons**



- **Light petroleum fractions contain mono-aromatics rings such as benzene, Toluene and Xylene.**
- **BTX is important petrochemical feed stocks, and their presence in gasoline increases the octane number.**
- **Poly-aromatic** compounds are found in the heavy crude oil, and their presence is undesirable because they cause **catalyst deactivation and coke deposition** during processing, and **environmental problems** when they are present in diesel and fuel oils.

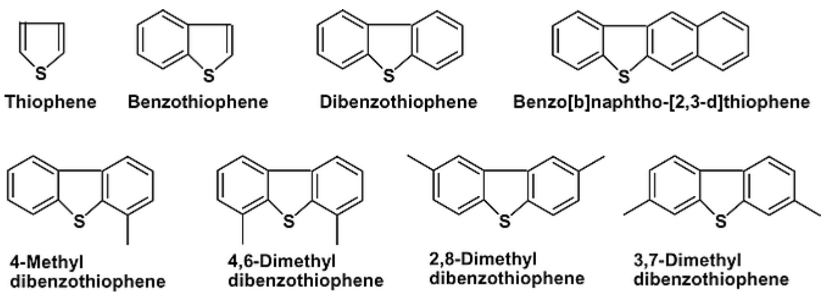


The amount of aromatics in different crude oils varies from **15 to 50%.** The highest amounts of aromatics are typically found in naphthenic oils?.

Non-hydrocarbon Components

✓ **Sulphur Compounds**

- Crude oil contain sulphur heteroatoms in the form of elemental sulphur S, dissolved hydrogen sulphide H_2S, carbonyl sulphide COS, inorganic sulphur and **most importantly organic sulphur.**
- The presence of sulphur compounds could be explained by **thermal reaction** between elemental sulphur, or H_2S and the other organic components of the sediments including HCBN.



Disadvantages of Sulphur components:

1- Corrosion of the metallic parts of the internal combustion engine.

2- Reduce octane number.

3- Reduce oxidation resistance.

4- Causes solid depositions.

The Sulphur content of crude oils varies from less than **0.05 to more than 10 wt%**.

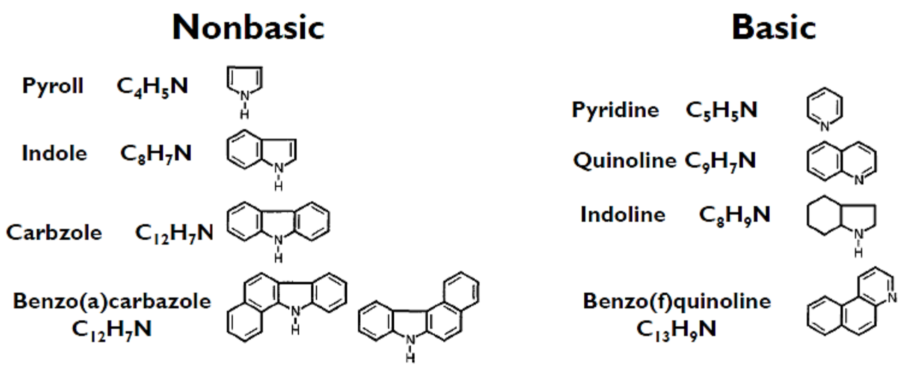
✓ **Oxygen Compounds**

- **The oxygen content of crude oil is usually less than 2 wt%.**
- The presence of such compounds causes the crude to be acidic with consequent processing problems such as corrosion.

Alcohols	
Methyl alcohol	CH_3OH
Phenol	C_6H_5OH
Ethers	
Dimethyl ether	CH_3OCH_3
Diphenyl ether	$C_6H_5OC_6H_5$
Carboxylic acids	
Acetic acid	CH_3CO_2H
Benzoic acid	$C_6H_5CO_2H$
Esters	
Ethyl acetate	$CH_3CO_2CH_2CH_3$
Ketones	
Acetone	CH_3COCH_3
Furans	
Furan	$CH{=}CHOCH{=}CH$

✓ **Nitrogen Compounds**

- Crude oils contain very low amounts of nitrogen compounds **(0.1-0.9 wt%)**
- **In general, the more asphaltic the oil, the higher its nitrogen content.**
- **Nitrogen compounds are more stable than sulphur compounds and therefore are harder to remove.**
- Nitrogen compounds can be responsible for the poisoning of a cracking catalyst, increases carbon residue, decreases API and they also contribute to gum formation in finished products.



✓ Metallic components:

1- Metals (Iron Fe, Nickel Ni, Vanadium V, Cadmium Cd, Magnesium Mg, and Calcium Ca).

3- Salt metallic (Na^{+} and Ba^{2+}).

Disadvantages:

Decrease catalyst activity, coke formation, reduce the yield of the gasoline, ash deposits, and Corrosion.

✓ Brine water :

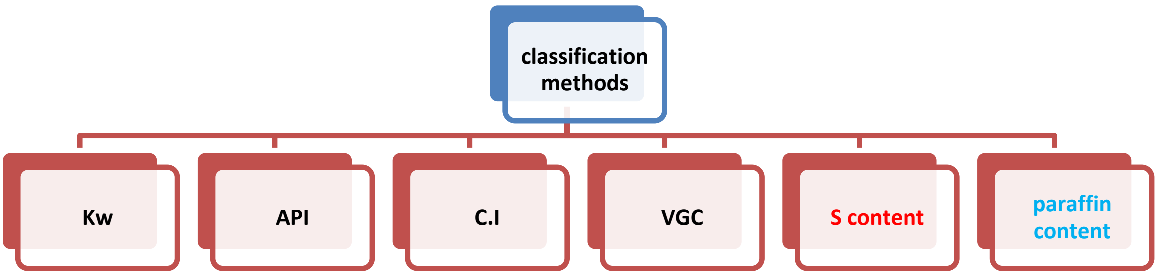
Water molecules are dispersed in crude oil with extremely high concentrations of dissolved salt ions nearly **300-300.000** ppm. The ions are divided into two types:

1- Positive ions (Na^{+}, Ba^{2+}, Mg^{2+}, Al^{3+}…etc.)

2- Negative ions (Cl^{-} , Br^{-} , SO_4^{-2}, I^{-}…etc.)

note: *These ions are removed in desalting operations. More important are metals which are present in form of oil-soluble organometallic compounds.*

Crude Oil Classification



A- Watson or UOP characterization factor (Kw):

Watson characterization factor (Kw) can be calculated from the following equation:

$$K_w = \frac{\sqrt[3]{MeABP}}{Sp.Gr\ @\ 60°F} \quad \ldots.1$$

1- **K_w = 12.15 – 13 paraffinic base crude oil**

2- **K_w = 11.1 – 12.0 mixed (paraffinic and naphthenic) base crude oil**

3- **K_w = 10 – 11.0 naphthenic (asphaltic) base crude oil**

Kw = Watson characterization factor

MeABP = mean average boiling point temperature in Rankin = **VABP - Δ**

VABP = volume average boiling point temperatures in °F.

Sp.gr. 60/60°F = Specific Gravity at 15°C (60 °F)

$$Sp.Gr\ @\ 60°F = \frac{141.5}{API + 131.5} \quad \ldots.2$$

B- (API gravity)

API: American Petroleum Institute

$$API = \frac{141.5}{Sp.Gr.@\ 60°F} - 131.5 \ldots.3$$

At atmospheric (1 atm), the crude oil classification will be as follows:

1- **API gravity > 38 light crude oil**

2- API gravity = 33 - 38 intermediate crude oil

3- API gravity < 33 heavy crude oil

C- Correlation Index (C.I)

This method based on the percentages of various hydrocarbons types in the crude oil which are classified into paraffinic or aromatic according to following

$$C.I = 473.7\ SG\ at\ 60F - 456.8 + \frac{48680}{ABP\ °K} \ldots.4$$

ABP: average boiling point in Kelvin

The crude oil can be classified as follow as:

1. **C.I. = 0 (paraffinic (n-Pf & iso-Pf) base crude oil**
2. **C.I = 0-15** (predominance of n-paraffinic crude oil)
3. **C.I = 15 – 50** (paraffinic and aromatic mixture)
4. **C.I > 50** (aromatic crude oil)
5. C.I = **100 (benzene)**

D- Classification by Viscosity-Gravity Constant

Indicator of the hydrocarbon composition of a crude oil.

VGC is calculated from one of the following equations, depending on the temperature at which viscosity is determined

$$VGC = \frac{10\ Sp.Gr - 1.0752\ \log(v_{38} - 38)}{10 - \log(v_{38} - 38)} \ldots.5$$

For heavy oils where low-temperature viscosity is difficult to measure, an alternative formula are used in which the **99°C (210°F) saybolt viscosity is used**.

$$VGC = \frac{Sp.Gr - 0.24 - 0.022\ \log(v_{99} - 35.5)}{0.755} \ldots.6$$

The Saybolt universal second (SUS) is the time in seconds required for the flow of 60 ml of petroleum from a container, at a constant temperature, through a calibrated orifice.

VGC:

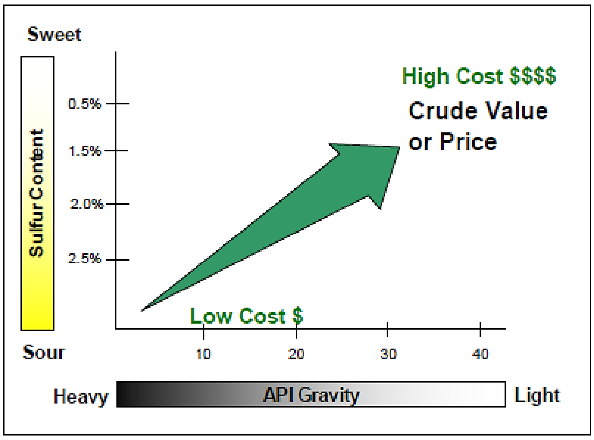
0.70-0.79 paraffinic hydrocarbon.

0.80-0.90 naphthenic base.

0.91-1.31 aromatic base.

E - Sulfur Content

- Sweet crude oil: If crude has **less than 0.5%** (**5000 ppm**) sulphur content.
- Sour crude oil: If crude has **greater than 2.5%** (**25000 ppm**) sulphur.



F- Technological Classification (paraffin content)

- **Low paraffinic oil** containing less than 1.5% of paraffins. This type of oil can be used for production of jet and winter diesel fuels without deparaffinization.
- **Medium paraffinic oil** containing over 1.5% and fewer than 6% of paraffins. This type of oil can be used for production of jet and summer diesel fuels without deparaffinization.
- **High paraffinic oil** containing over 6% of paraffins. This type of oil can be used for production of diesel and jet fuels only after deparaffinization.