Physical and Chemical Properties of Crude Oil and Oil Products

1- Density, Specific Gravity, and API Gravity

Density is defined as mass per unit volume of a fluid. Density is a state function and for a pure compound depends on both temperature and pressure and is shown by ρ. Liquid densities decrease as temperature increases but the effect of pressure on liquid densities at moderate pressures is usually negligible.Liquid density for hydrocarbons is usually reported in terms of specific gravity (SG) or relative density defined as Since

$$SG = \frac{\text{density of liquid at temperature } T}{\text{density of water at temperature } T}$$

Since the standard conditions adopted by the petroleum industry are 60°F (15.5° C) and 1 atm, specific gravities of liquid hydrocarbons are normally reported at these conditions. Water density at 60°F is 0.999 or almost 1 g/cm3, thus

$$SG\ (60°F/60°F) = \frac{\text{density of liquid at } 60°F \text{ in g/cm}^3}{0.999 \text{ g/cm}^3}$$

The American Petroleum Institute (API) defined the API gravity (degrees API) to quantify the quality of petroleum products and crude oils. The API gravity is defined as

$$\text{API gravity} = \frac{141.5}{SG\ (\text{at } 60°F)} - 131.5$$

Crude Oils API = 10 – 50, crude oils can generally be classified according to API as shown

Crude Category	Gravity
Light crudes	API > 38
Medium crudes	38 > API > 29
Heavy crudes	29 > API > 8.5
Very heavy crudes	API < 8.5

The definition of specific gravity for gases is somewhat different. The specific gravity of a gas is proportional to the ratio of molecular weight of gas (Mg) to the molecular weight of air (28.97)

$$SG_g = \frac{M_g}{28.97}$$

2- Viscosity

The viscosity of oil is a measure of its resistance to internal flow and an indication of its oiliness in the lubrication of surfaces. There are two types of viscosity: dynamic and kinematics viscosity.

Kinematic viscosity (υ) = dynamic viscosity (μ) / density (ρ)

The unit of dynamic viscosity is poise (0.1 Pa·s). It is more commonly expressed, particularly in ASTM standards, as centipoises (cP). While the kinematics viscosity as centiStokes –cSt (10^{-6} $m^2.s^{-1}$). The following equations can be used to calculate the liquid viscosities of petroleum fractions at atmospheric pressure and at temperatures of 37.8 °C(100 °F) and 98.9°C (210 °F)

$$\begin{aligned}\log \nu_{210} = &-0.463634 - 0.166532(\mathrm{API}) + 5.13447\times10^{-4}(\mathrm{API})^2 \\ &- 8.48995\times10^{-3}K(\mathrm{API}) \\ &+ \frac{8.0325\times10^{-2}K + 1.24899(\mathrm{API}) + 0.197680(\mathrm{API})^2}{\mathrm{API} + 26.786 - 2.6296K}\end{aligned}$$

$$\begin{aligned}\log \nu_{100} = &\ 4.39371 - 1.94733K + 0.127690K^2 + 3.2629\times10^{-4}(\mathrm{API})^2 \\ &- 1.18246\times10^{-2}K(\mathrm{API}) \\ &+ \frac{0.17161K^2 + 10.9943(\mathrm{API}) + 9.50663\times10^{-2}(\mathrm{API})^2 - 0.860218K(\mathrm{API})}{\mathrm{API} + 50.3642 - 4.78231K}\end{aligned}$$

where ν_{100} and ν_{210} are the kinematic viscosities at 100 and 210 °F, in centistokes. The viscosity can be measured by several instruments (U-tube Viscometer, Saybolt Universal Viscosity (SSU), thermo-viscosity, Red wood viscometer and Englar)

Thermo. = 15 + 148.5 kinematic Vis. = 46 SSU – 1183

The comparison of viscosity by different instruments is shown in Figure 1>

Ex) Calculate the kinematic viscosities for oil which has a Me ABP of 320 °C and API gravity of 34.

Sol.:

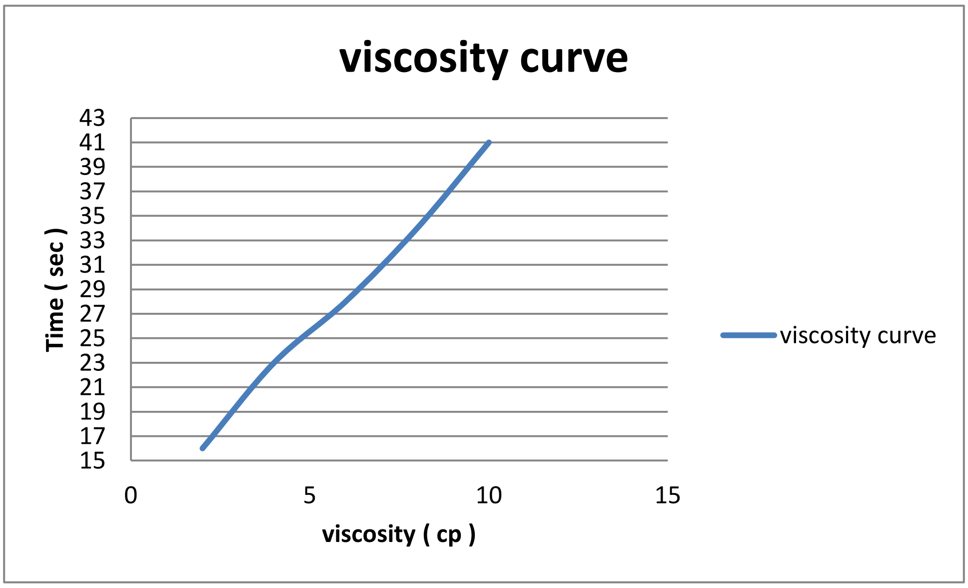
The boiling point is 593.15 K or 1067.7 R. the specific gravity is 0.855 and the Watson K factor is 11.95.

ν_{100}= 5.777 cSt and ν_{210} = 1.906 cSt

Practically measure the viscosity of Oil :

The following table shows Standard liquid - Known viscosity

Viscosity (CP)	Time (Sec)
2	16
4	23
6	28
8	34
10	41



It is possible to compare these measurements with the measurements we obtain practically to find the value of viscosity at a specific time .