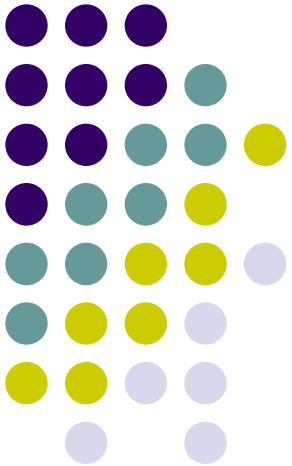
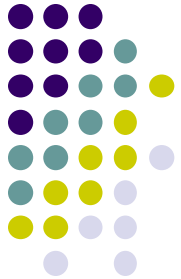
Chapter 6

Fuel and combustion



Fuel

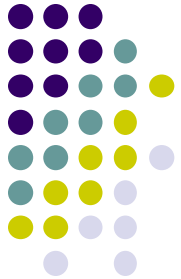


Any substance consists of carbon and hydrogen (hydrocarbons)and easily burning with air and give sufficient amount of energy.

Fuel composed mainly of

- *95% of fuel is carbon and hydrogen.*
- *5 of fuel is metals(Fe, Pb, …), sulfur, gases(O_2, CO_2…) and impurities.*

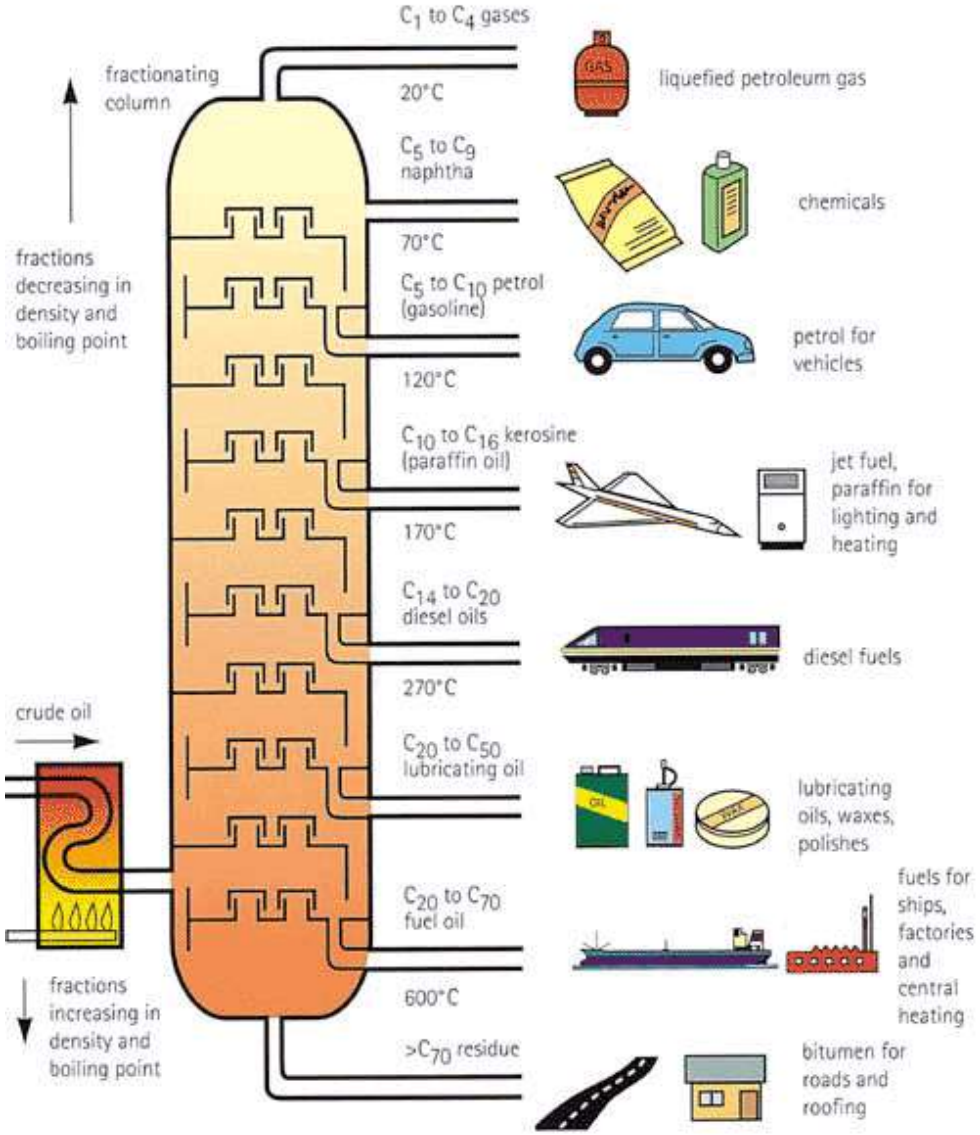
Classification of fuel



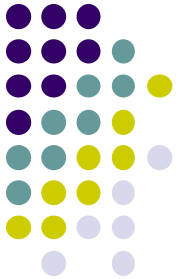
- Solid fuel such as coal, coke……

- *Liquid fuel such as gasoline, kerosene…..*
- *Gaseous liquid such as liquefied natural gas(LNG) and liquefied petroleum gas(LPG)*

LNG Tanker


C_1 to C_4 gases
20°C
liquefied petroleum gas
fractionating column
C_5 to C_9 naphtha
chemicals
70°C
fractions decreasing in density and boiling point
C_5 to C_{10} petrol (gasoline)
petrol for vehicles
120°C
C_{10} to C_{16} kerosine (paraffin oil)
jet fuel, paraffin for lighting and heating
170°C
C_{14} to C_{20} diesel oils
diesel fuels
270°C
crude oil
C_{20} to C_{50} lubricating oil
lubricating oils, waxes, polishes
C_{20} to C_{70} fuel oil
fuels for ships, factories and central heating
600°C
fractions increasing in density and boiling point
>C_{70} residue
bitumen for roads and roofing

Hydrocarbons in fuel



-Paraffin's :it is saturated compounds, having high heat value such as methane and ethane.

- Naphthenes : it is unsaturated compounds, having low heat value such as cyclohexane, ethylene.
- Aromatic : it is cyclic unsaturated compounds, having low heat value such as benzene.

Properties of fuel

- Specific gravity
- Viscosity
- Calorific value
- Surface tension
- Pour point
- Flash point
- Spentenous ignition tempreture
- Carbon to hydrogen ratio
- Sulfur content
- Ash content

Specific gravity = relative density

It’s the ratio between the density of fuel at specific temperature to density of water at the same temperature.

OR

It’s the ratio between the weight of given volume of fuel at specific temperature to weight of the same volume of water at the same temperature.

Effect of sp.gr

- An increase of sp.gr associated with decrease the percent of paraffin's which tends to bad ignition(incomplete combustion).

- An decrease of sp.gr associated with increase the percent of paraffin's which tends to good ignition(complete combustion).

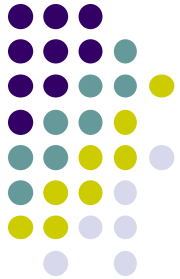
viscosity

-it’s the resistance of fluid to flow

-its measure of the internal friction

- Liquids which flows freely is said to have low viscosity.
- Liquids which have sluggish flowing is said to have high viscosity.

Different types of viscosity



Dynamic viscosity

Defined as the force which exist when a layer of fluid of unit area is moving at unit velocity relative to similar layer unit distance from and parallel to the original layer.

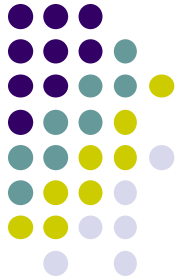
If force measured by dyne, viscosity will be in poise.

Its related to dynamic force

μ = (force/area) (distance/velocity)

unit= (Dyne.sec/Cm2) or poise

Different types of viscosity



Kinematic viscosity

Defined as the dynamic viscosity divided by density of fluid.

Kinematic viscosity(ɣ)= μ / ρ

P is the density of fluid

Unit : Cm2/sec or stoke

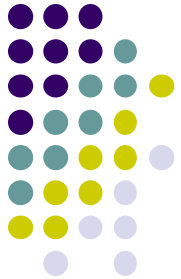
Effect of viscosity

an increase of viscosity associated with increasing the sp.gr, decrees the percent of paraffin's which tends to bad ignition(incomplete combustion)

(large particle size)

an decrease of viscosity associated with decrease the sp.gr, increase the percent of paraffin's which tends to good ignition(complete combustion) (small particle size)

Calorific value



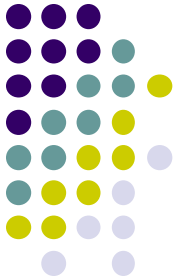
It’s the amount of heat evolved by burning the unit mass of fuel with oxygen.

Unit: (MJ/kg) or (J/g) or (Cal/gm) or (B.t.u/lb)

H.C.V = Higher calorific value = gross .C.V

L.C.V = Lower calorific value = actual or net .C.V

Higher calorific value



-Its calculated value with high accuracy

Calculated from the empirical formula

-Its theoretical value

Heat content reduced due to formation of moisture during combustion which tends to heat loss.

Lower calorific value

Its measured value

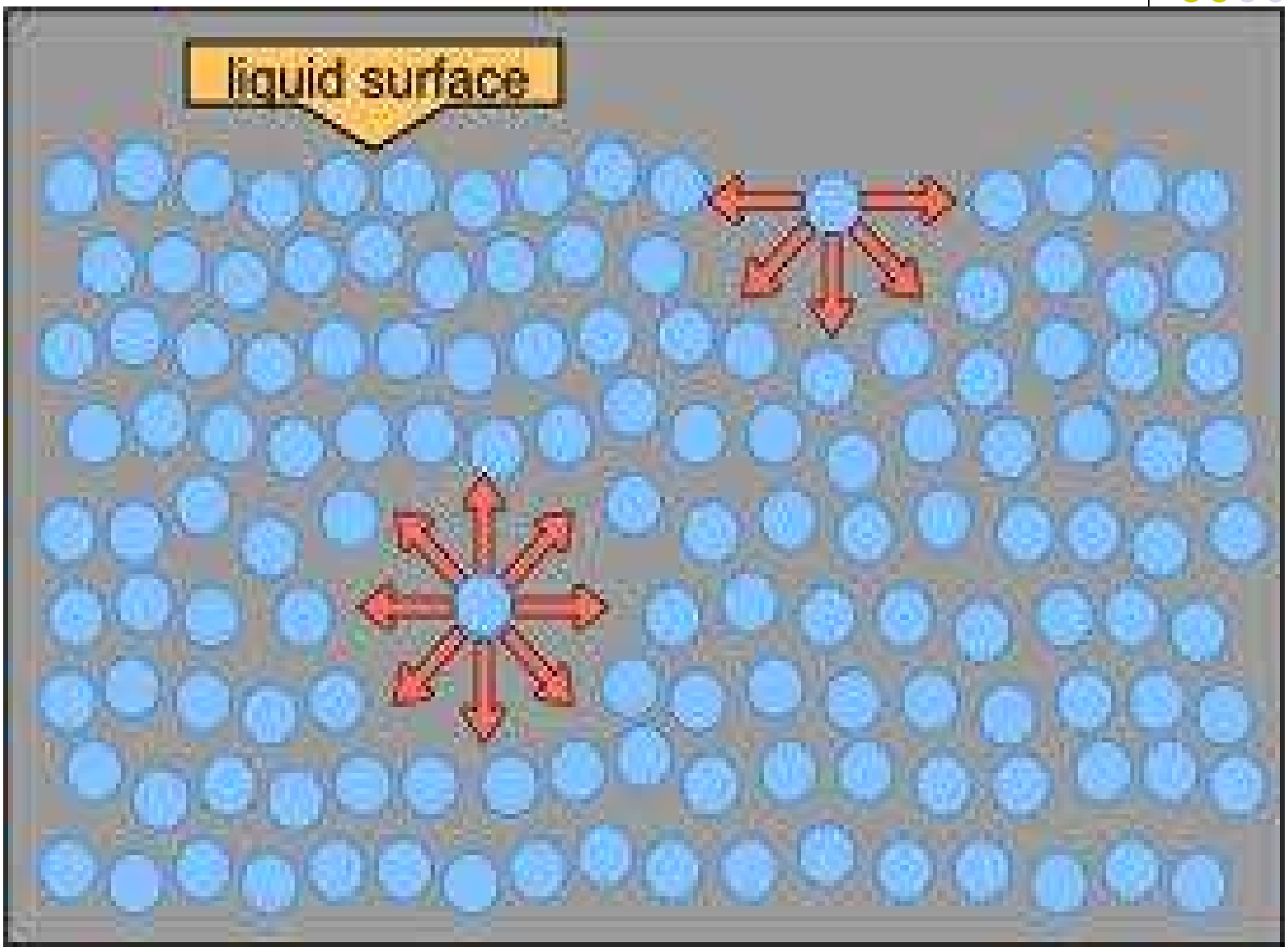
Its actual value

Due to presence of hydrogen in fuel its associated with water vapor formation and decreasing the heat content

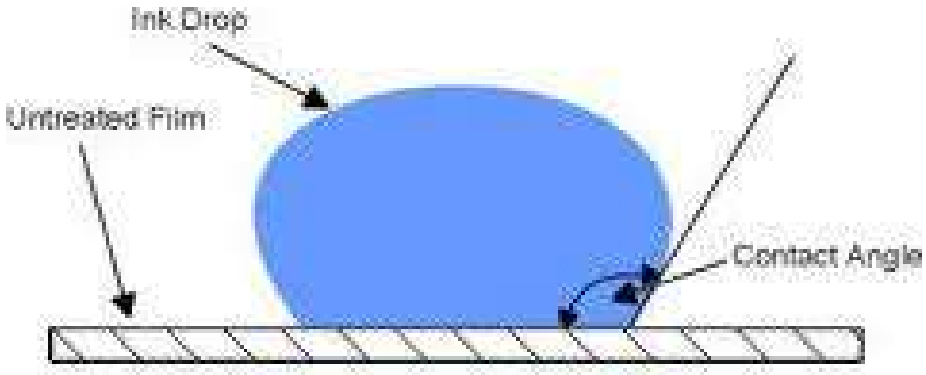
H.C.V = L.C.V + Latent heat

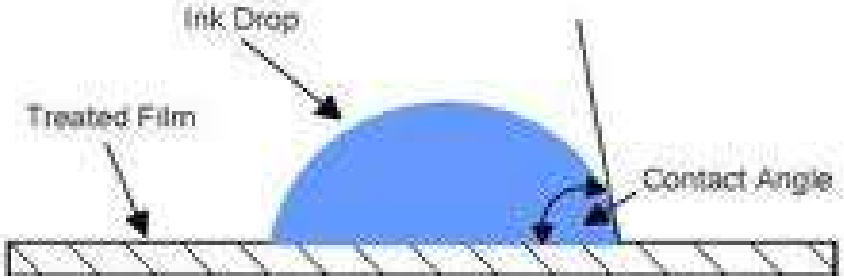
Surface tension

- Due to the attraction force between surface molecules.
- Higher surface tension (cohesive force higher than adhesive force) lead to bad ignition
- lower surface tension (cohesive force lower than adhesive force) lead to good ignition.


liquid surface

Surface Tension





Pour point

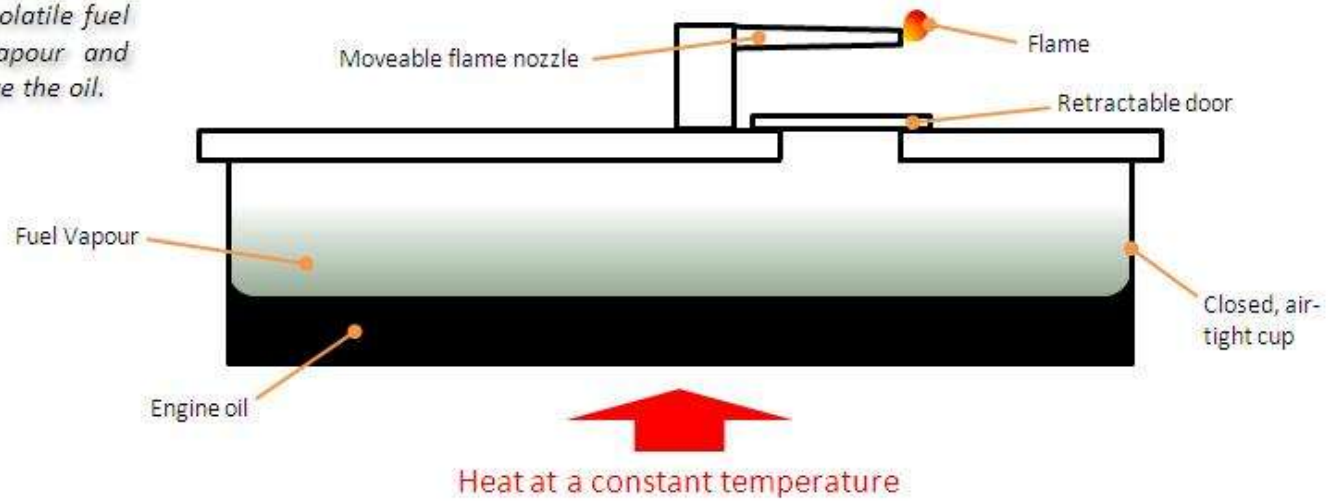
- Temperature at which the fuel oil will just flow under slandered test

Flash point

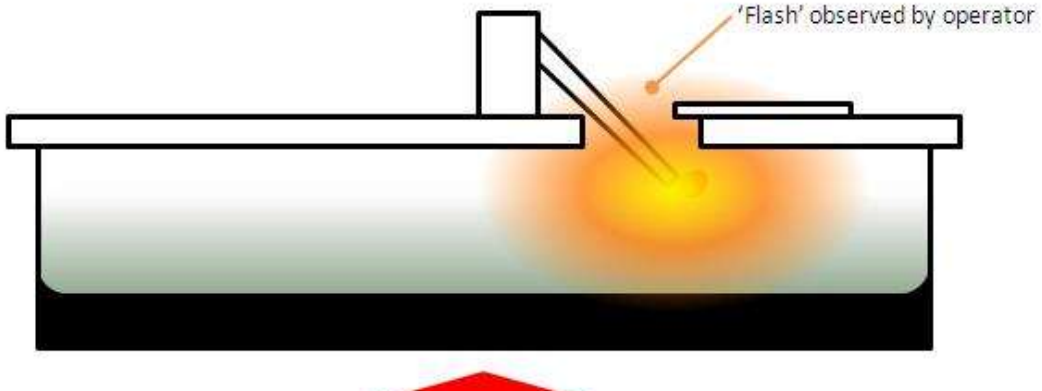
- The temperature at which the fuel oil will form enough amount of flammable mixture to ignite with air in presence of flame.
- Flash point give good indication for volatility of fuel, storage condition, safety
- Flash point is inversely proportional with the fuel volatility.
- Gasoline(F.P)= 22 C°
- Diesel oil(F.P)= 65 C°

Flash Point Test

The oil is heated at a constant temperature for a set time.
During this time, any volatile fuel will evaporate into vapour and collect in the space above the oil.



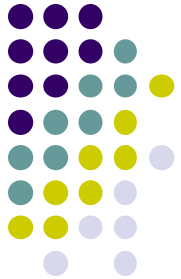
After this time, the flame is introduced into the closed cup and a flash will be seen if enough fuel vapour has collected.
The test will be reported as 'negative' if no flash is seen.



Effect of flash point

- Lower flash point associated with increase the volatile compound and may be tend to good ignition and higher calorific value.

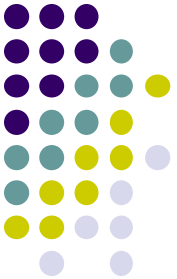
Spontaneous ignition temperature



- The temperature at which the fuel starts to ignite with air without flame or spark.
- S.I.T is much greater than F.P.
- Gasoline(S.I.T) = 260 C°

Spontaneous ignition test

Carbon hydrogen ratio

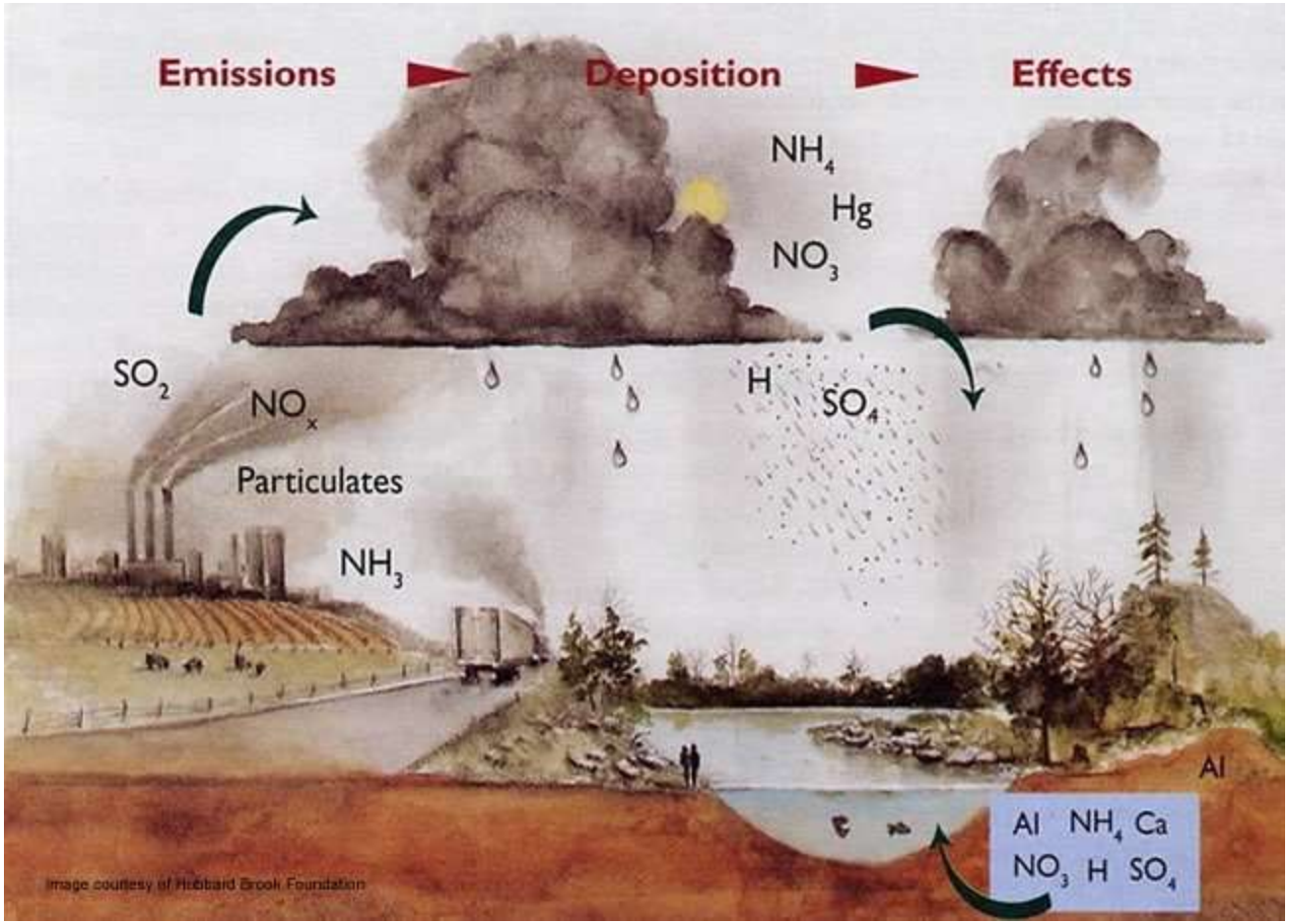


- An increase of the carbon than hydrogen associated with decrease the percent of parafins and increase Sp.gr, viscosity and decreasing the C.V which tends to bad ignition.
- Higher percent of carbon give luminous flame(black smoke) during ignition.

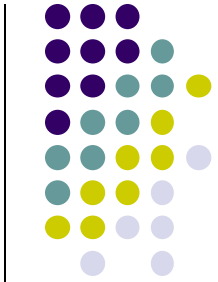
Sulfur content

- Sulfur in fuel refers to free sulfur and its compounds such as thioether, mercaptens, hydrogen sulfide.
- Presence of sulfur in fuel associated with formation of sulfur oxide gases(which react with water or dew forming sulfuric acid and tends to air pollution and formation of strong corrosive environment.

Air Pollution


Emissions
Deposition
Effects
NH_4
Hg
NO_3
SO_2
NO_x
Particulates
NH_3
H
SO_4
Al
Al NH_4 Ca
NO_3 H SO_4
Image courtesy of Hubbard Brook Foundation

Ash content



- Refers to non combustible material present in fuel.
- Ash in fuel present as all inorganic compound such as metals(Al, Ca, Fe, Mg, Ni, V, Na, …) , metal oxides and inorganic salts.
- Percent of ash in normal liquid fuel is about 0.1%.
- Separation of ash is uneconomically process