Liquid fuel

Petroleum, Shale oil, Coal Tar, Bitumen, synthetic liquid fuel from gaseous fuel and Biofuels

Liquid Fuels

- **Include … Oils, tars, pitches**
- **Sources … Petroleum, Coal, Oil Shale, tar sand.**
- **Types of liquid fuels**
  1. **Light oils or spirits (suitable for internal combustion and jet engines).**
  2. **Heavy oils (used for burning in furnaces).**

Petroleum

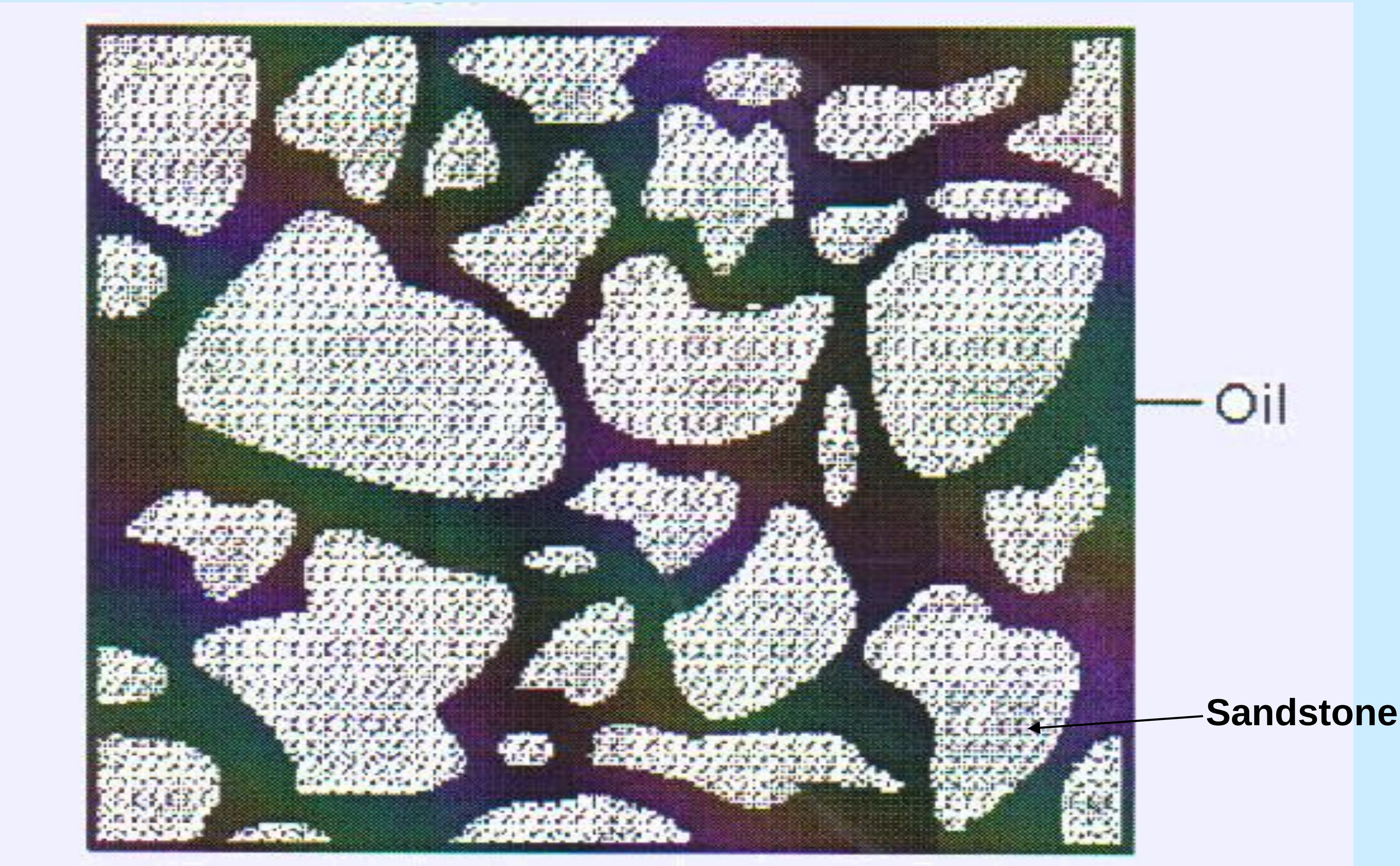
1. Origin

Coal	Petroleum
Formed mainly from land plants	Formed from sea plants & animals
Plants decomposed under mild reducing conditions	Deposits decomposed under sever reducing conditions
Coal seams remained where deposited	Oil can migrate from one location to another

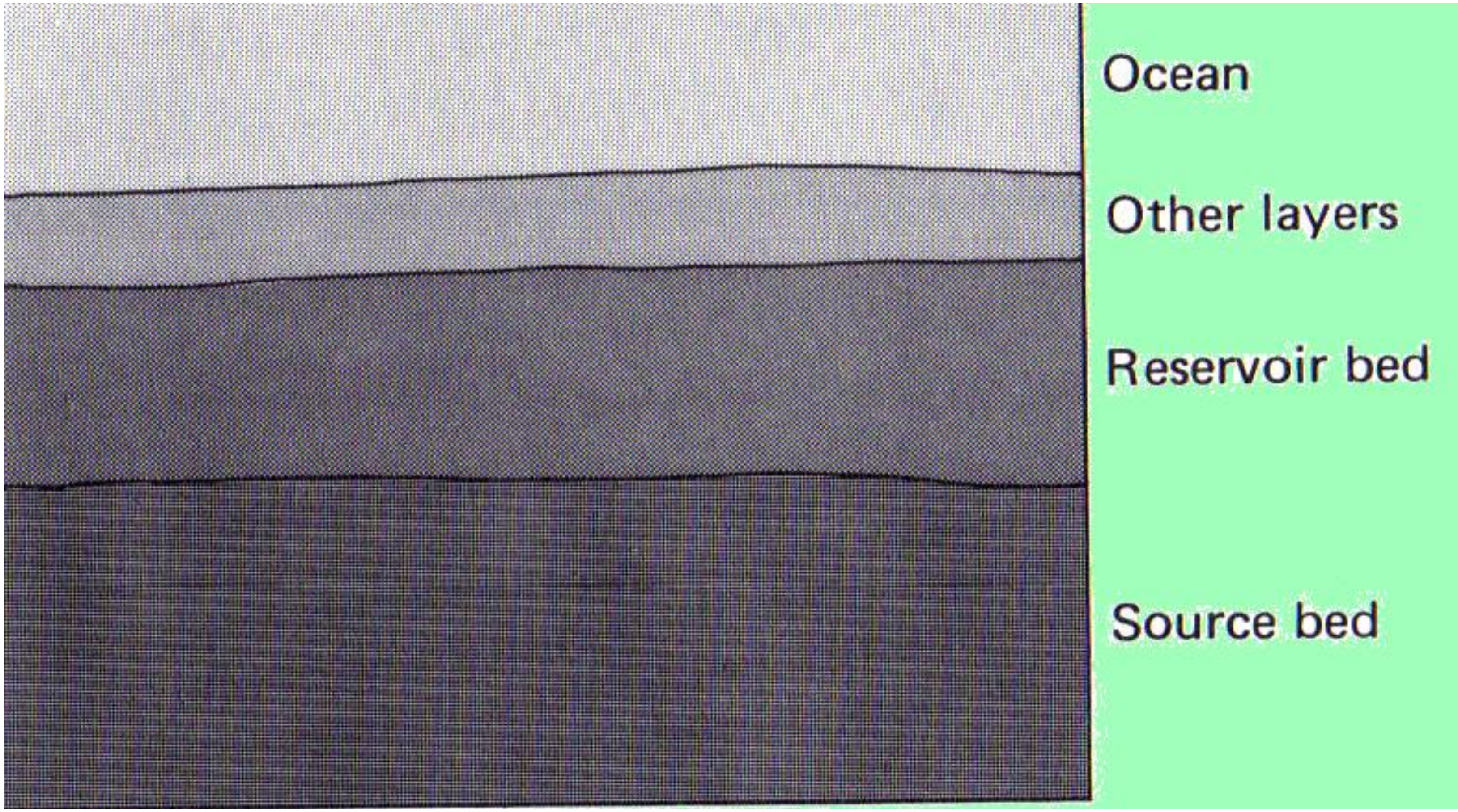
2. Formation of existing deposits

- The suitable geological structure for oil trapping is the porous sedimentary rock called "Reservoir Rock".
- The upper and lower layers of the reservoir rock should be impermeable to cease oil leakage.

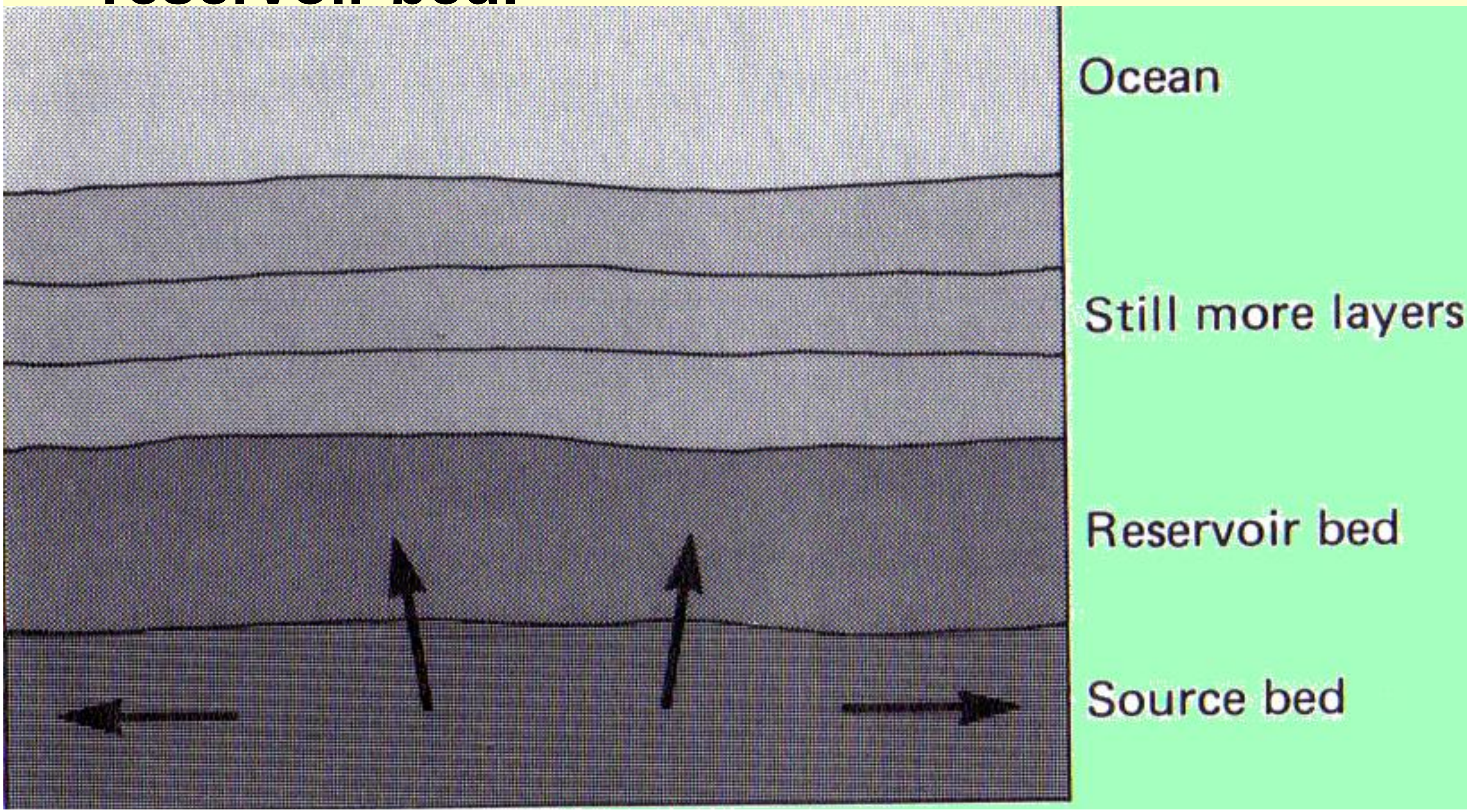
Petroleum Accumulation in Reservoir Rock



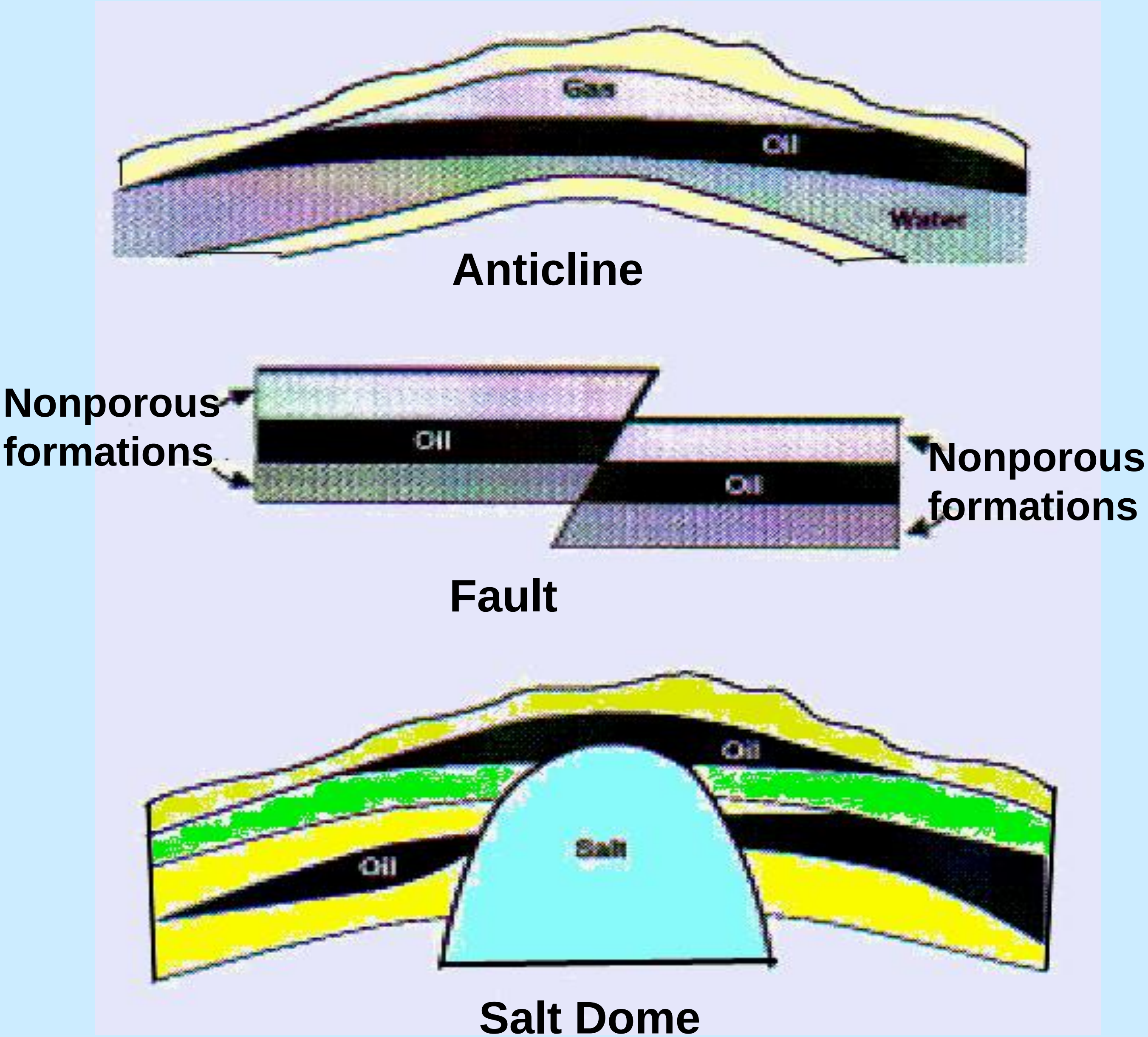
- Marine creatures accumulate in a source bed consisting of silt and mud.
- A reservoir bed of porous material such as sandstone forms over the source bed



- **Pressure from the weight of material over the source bed squeezes petroleum into the reservoir bed.**



OIL TRAPS


Gas
Oil
Water
Anticline
Nonporous formations
Oil
Oil
Nonporous formations
Fault
Oil
Salt
Oil
Salt Dome

3.Detection of oil deposits

- Visual methods
- Geological methods
- Geophysical methods

  include: a. Gravimetric

  b. Seismic [موجات زلزالية]

  c. Magnetic

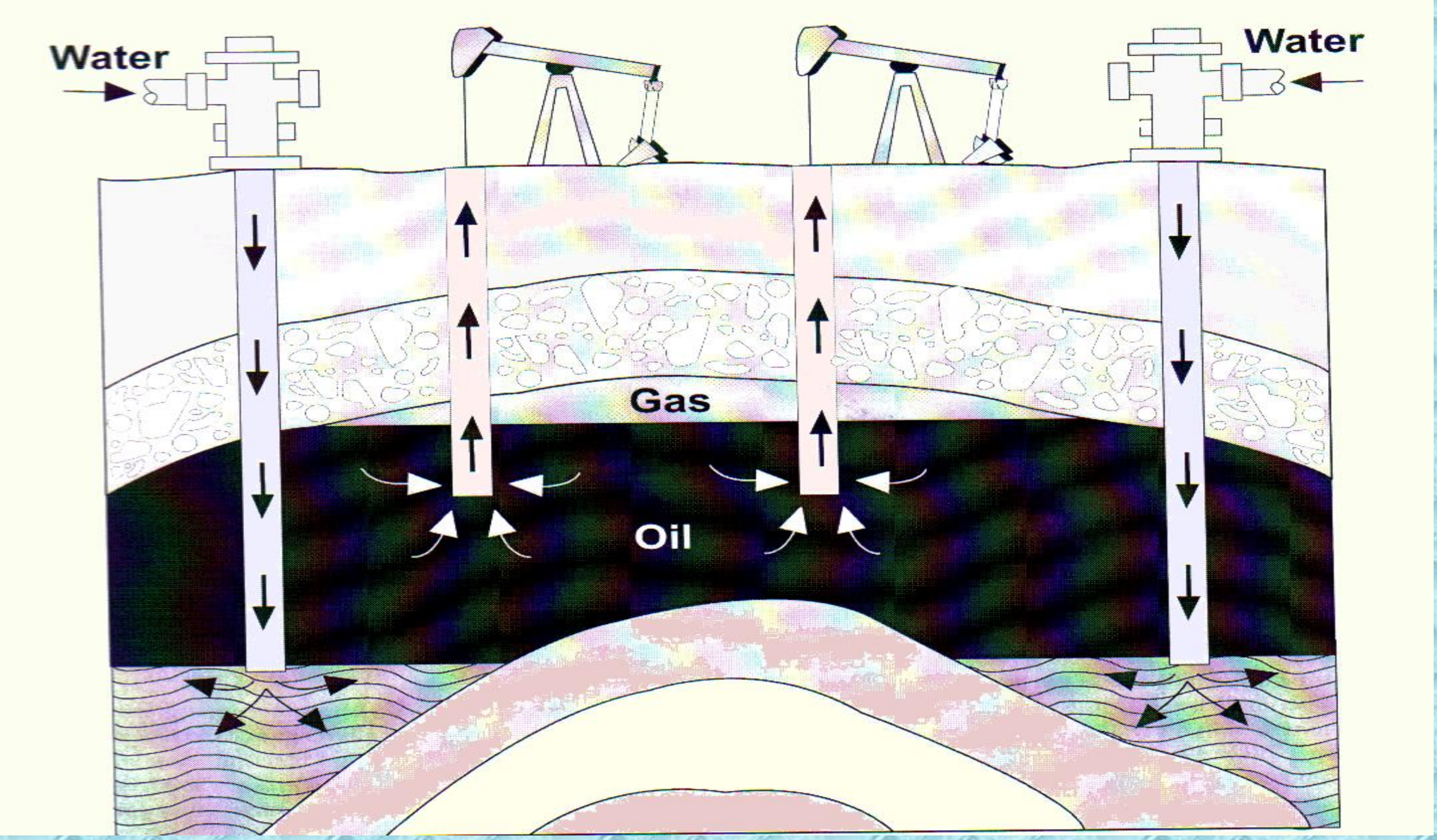
- Drilling

The method depends on the fact that seismic waves have differing velocities in different types of rock.

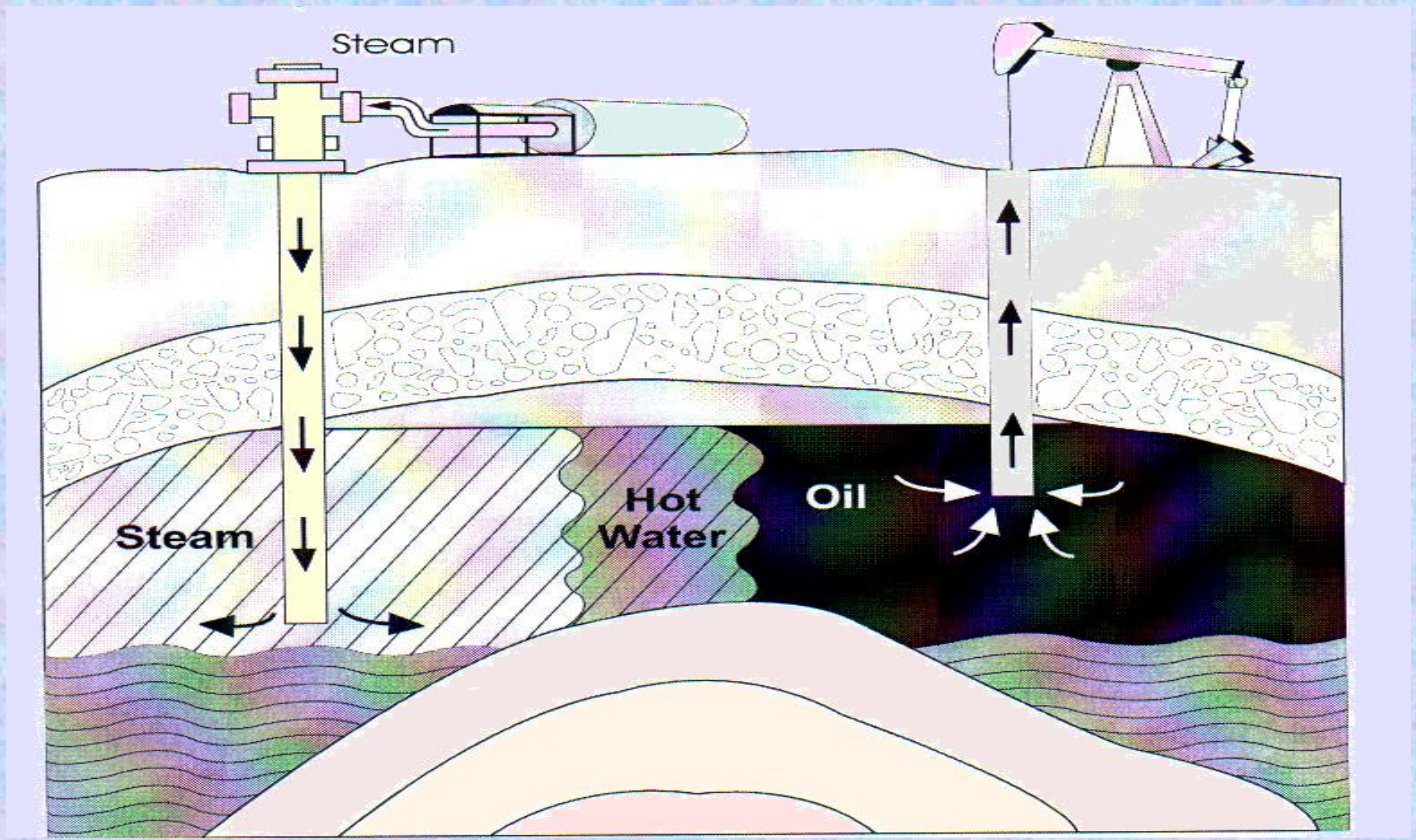
Well conditions

- Pressure at the beginning : Very High ~ 3000 psi
- This pressure decreases with time.
- Later on the well needs to be enhanced.
- Enhancement could be either by water or steam injection.

Water injection to enhance oil recovery



Steam injection to enhance oil recovery

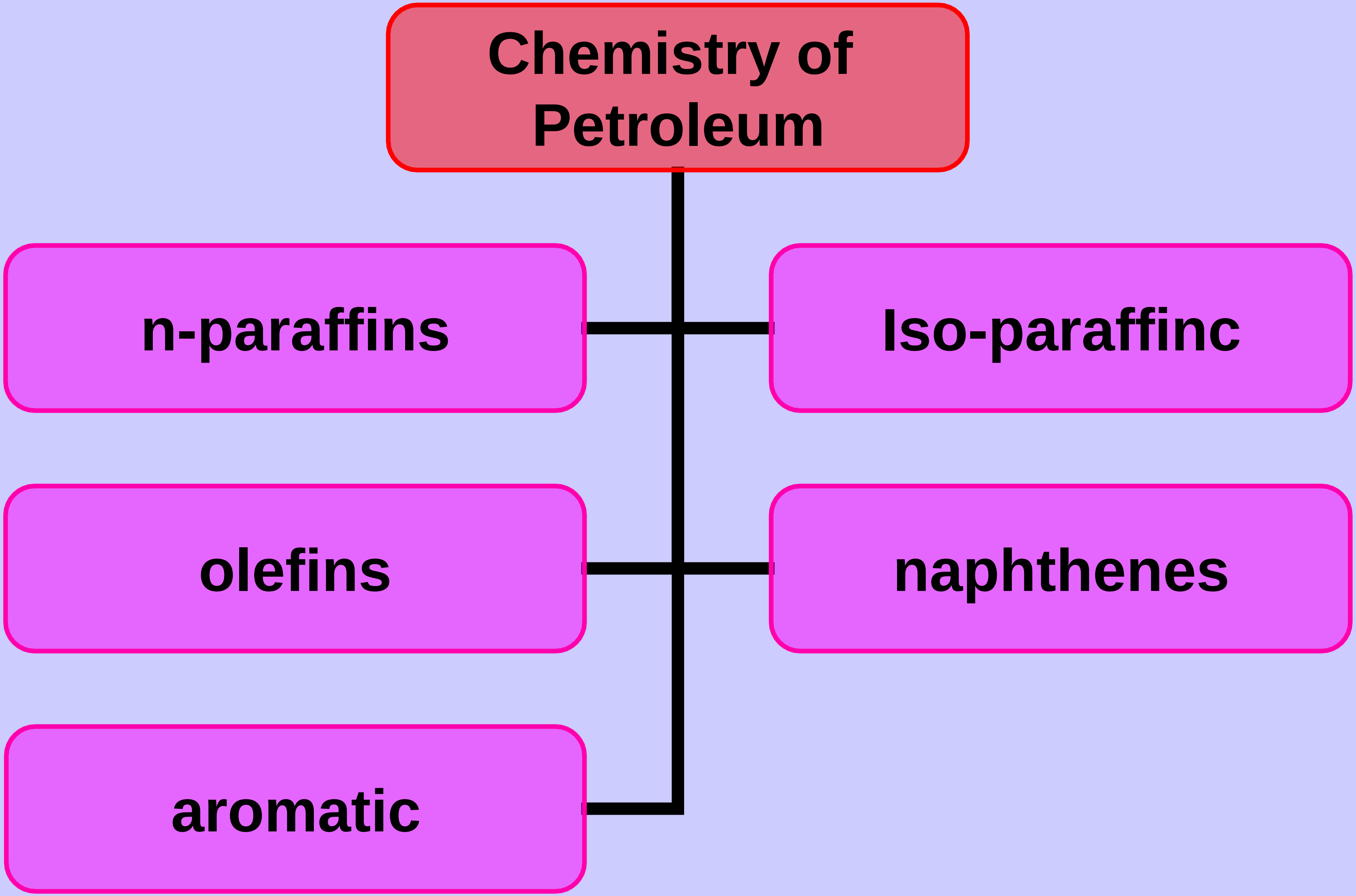


4.Nature of Petroleum Crudes

Classification
Based on the Type of HC^s

Ranging from Gas, methane, to solid paraffin wax or bitumen

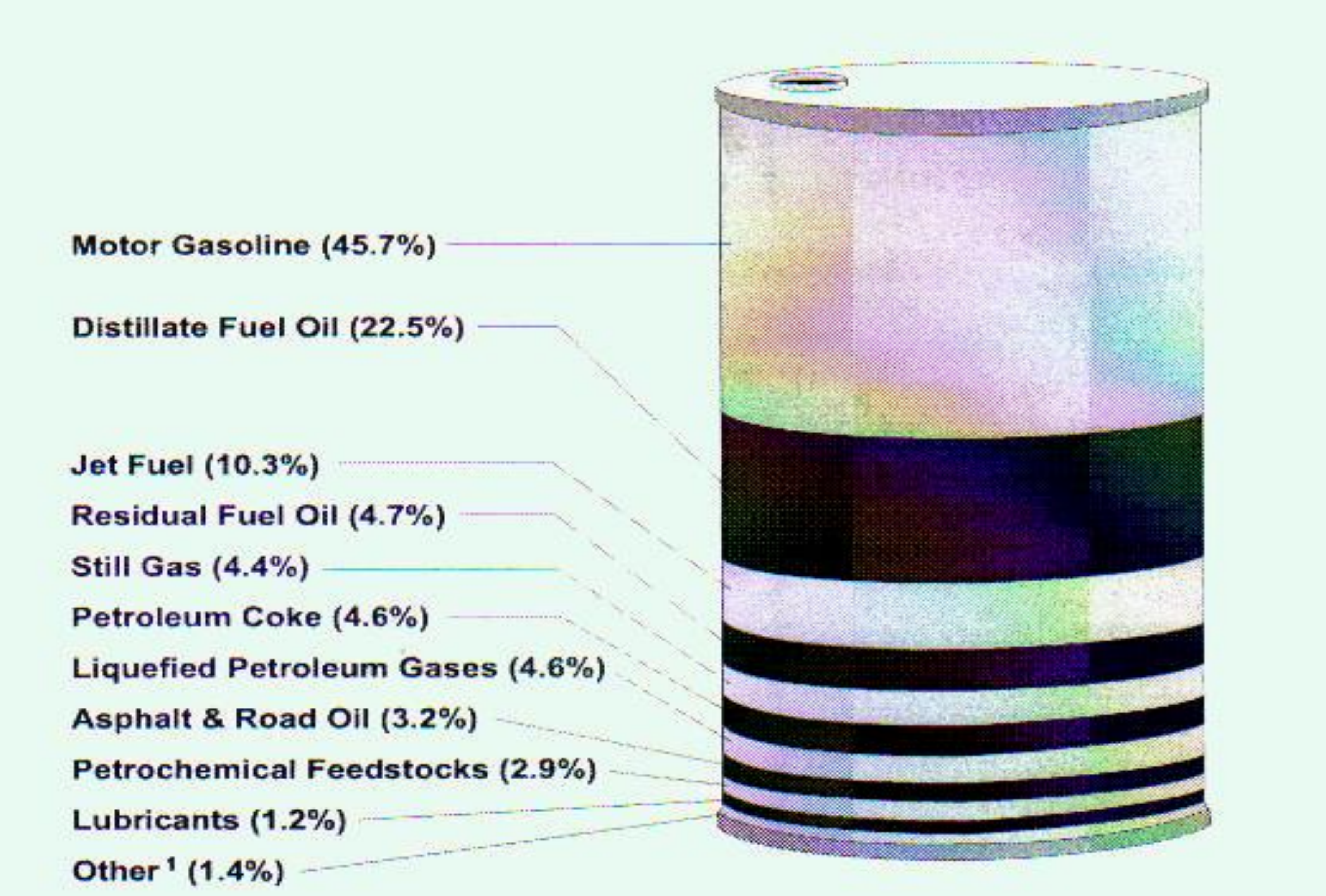
- **Paraffinic**
  If aliphatic > 75% of the whole
- **Naphthenic**
  If naphthenic rings > 70% of the whole
- **Asphaltic or Aromatic**
  If aromatic rings > 60 % of the whole


Chemistry of Petroleum
n-paraffins
Iso-paraffinc
olefins
naphthenes
aromatic

Elemental analysis of crude oil or composition

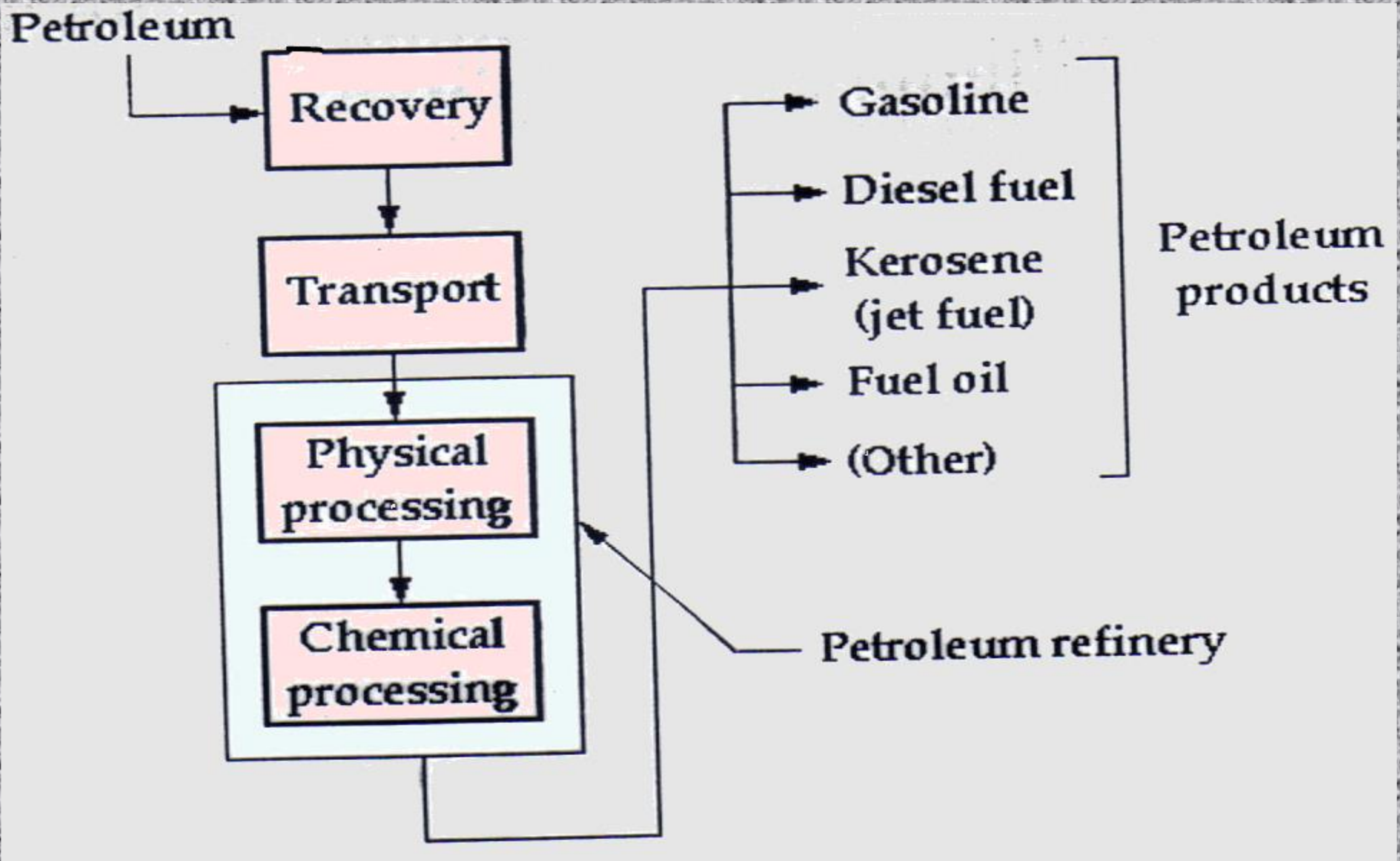
Carbon	80 – 89 %
Hydrogen	12 – 14 %
Nitrogen	0.3 – 1 %
Sulfur	0.3 – 3 %
Oxygen	2 – 3 %

Products from a barrel of petroleum



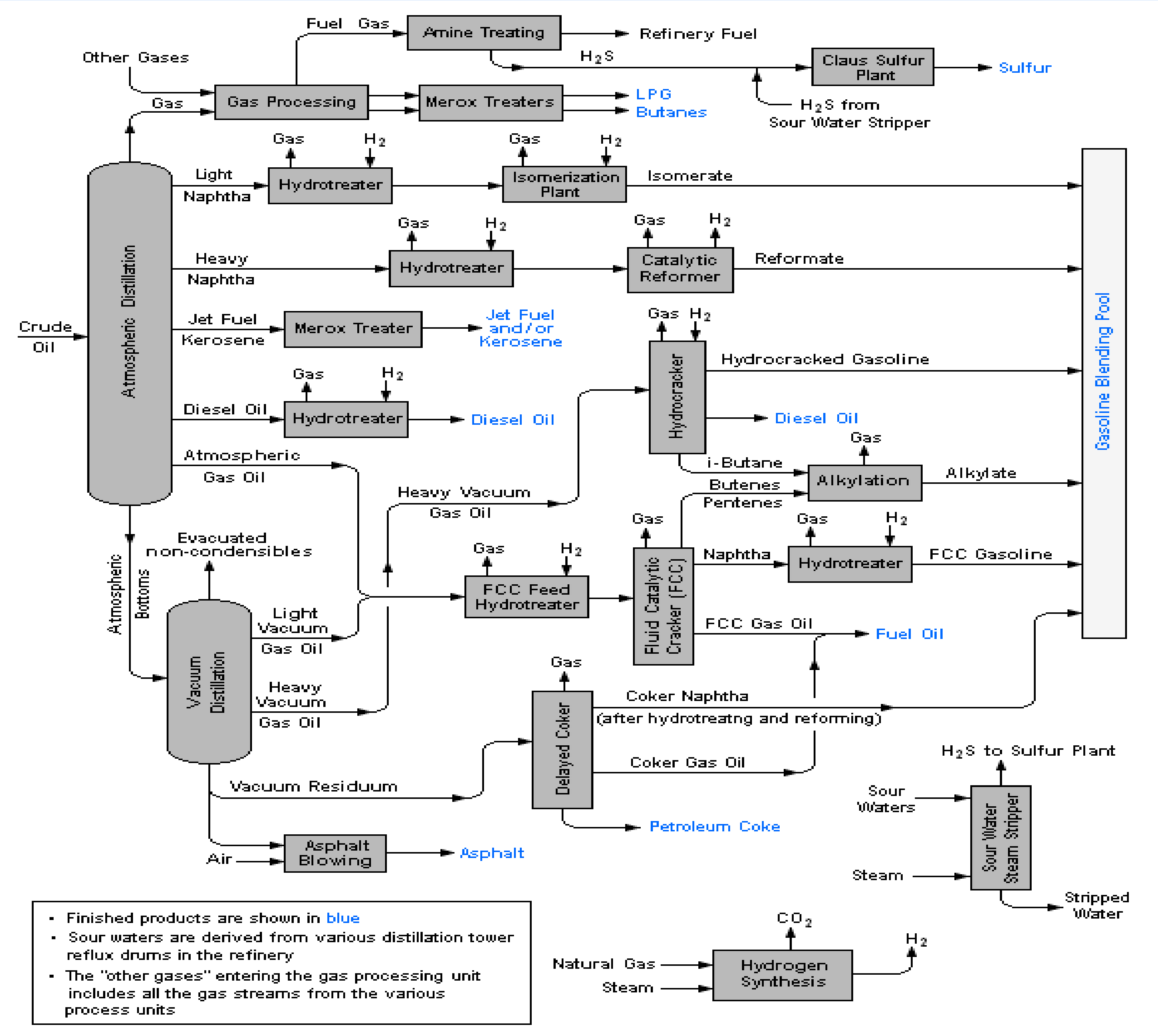
[1] includes: kerosene, naphtha, aviation gasoline , waxes and others

Petroleum Flow diagram

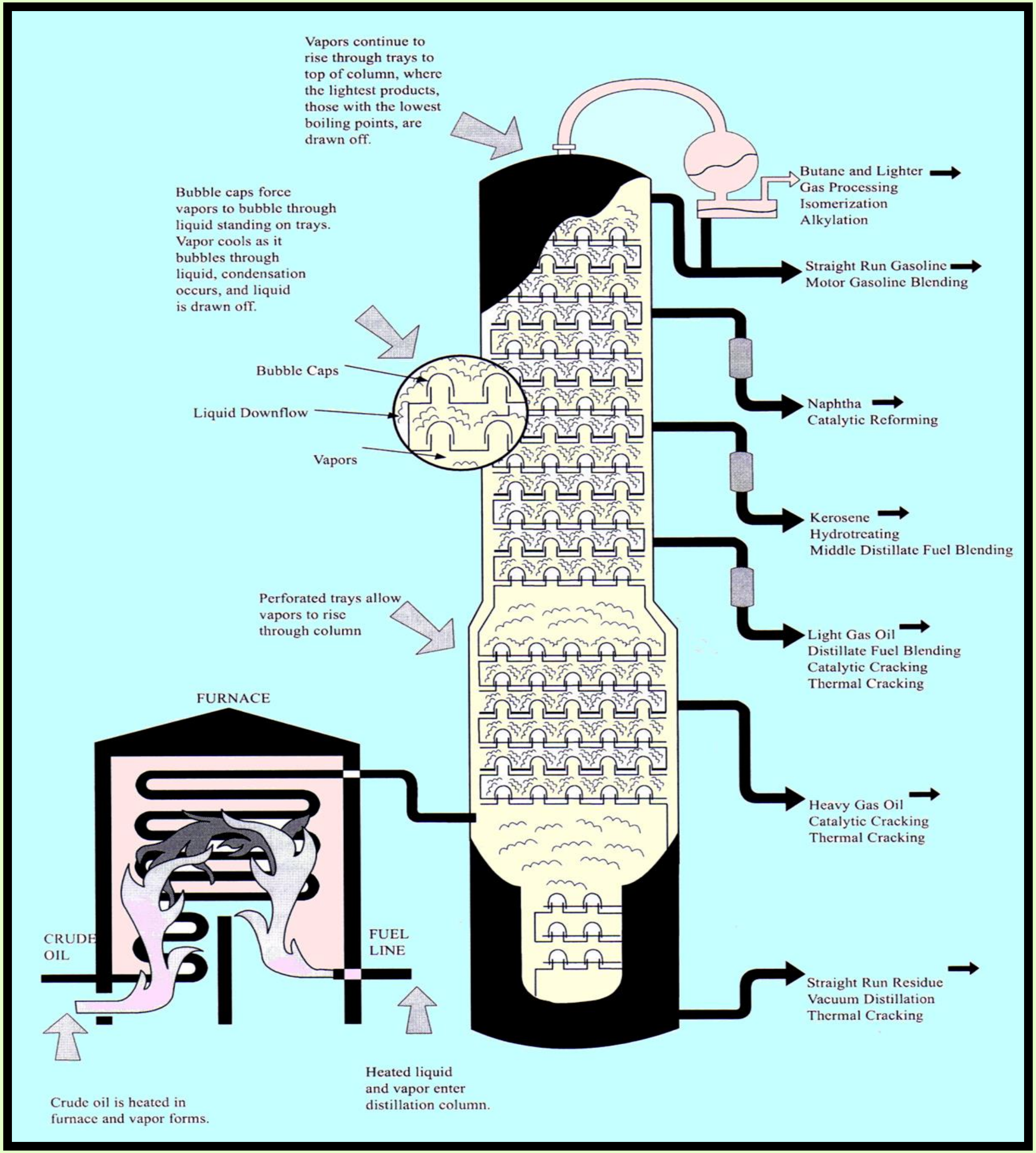


Petroleum fractions

- Gases
- LPG ($C_3 + C_4$)
- Gasoline 30-65 °C
- Naphtha 65-250 °C
- Kerosene 150-250 °C
- Gas oil (LGO, HGO) 250-400 °C
- Lube oil From Vacuum unit
- Fuel oil 325-400 °C
- Residue (HFO, Asphalt) 400-550°C
- Petroleum Coke



Fuel Gas
Amine Treating
Refinery Fuel
H_2S
Claus Sulfur Plant
Sulfur
Other Gases
Gas
Gas Processing
Merox Treaters
LPG
Butanes
H_2S from Sour Water Stripper
Gas
H_2
Light Naphtha
Hydrotreater
Isomerization Plant
Isomerate
Heavy Naphtha
Catalytic Reformer
Reformate
Crude Oil
Atmospheric Distillation
Jet Fuel Kerosene
Merox Treater
Jet Fuel and/or Kerosene
Hydrocracker
Hydrocracked Gasoline
Gasoline Blending Pool
Diesel Oil
Atmospheric Gas Oil
i-Butane
Alkylation
Alkylate
Heavy Vacuum Gas Oil
Butenes
Pentenes
Evacuated non-condensibles
Atmospheric Bottoms
FCC Feed Hydrotreater
Fluid Catalytic Cracker (FCC)
Naphtha
FCC Gasoline
Light Vacuum Gas Oil
FCC Gas Oil
Fuel Oil
Vacuum Distillation
Delayed Coker
Coker Naphtha
(after hydrotreatng and reforming)
Coker Gas Oil
H_2S to Sulfur Plant
Sour Waters
Sour Water Steam Stripper
Vacuum Residuum
Petroleum Coke
Air
Asphalt Blowing
Asphalt
Steam
Stripped Water
CO_2
Natural Gas
Hydrogen Synthesis
• Finished products are shown in blue
• Sour waters are derived from various distillation tower reflux drums in the refinery
• The "other gases" entering the gas processing unit includes all the gas streams from the various process units



Crude Distillation Unit

Special Tests on Liquid Fuels

1. **Distillation (crude oil and Products) ~ 10, 50, and 90 % are of greatest important; TBP curve**.
2. Gravity (°API; hydrometer; crude oil; products).
3. Viscosity (crude oil, gas oil, fuel oil, lube oil, residue).
4. Flash and Fire points (crude oil, kerosene, gas oil and fuel oil).
5. Calorific value **& total Heat of combustion***

*** See the given figure**

Special Tests on Liquid Fuels

6. Reid vapor pressure (LPG, Gasoline)
   ⇒shows the tendency of gasoline to create 'vapor lock' or vapor bubbles in the lines.
7. Pour and freezing points (crude oil, kerosene, lube oil).
8. Octane number
9. Water and sediment
10. Ash content, sulfur content, carbon residue

Pour point

- The pour point of a crude oil, or a petroleum fraction, is the lowest temperature at which the oil will pour or flow when it is cooled, without stirring, under standard cooling conditions.
- Pour point represents the lowest temperature at which oil is capable of flowing under gravity.
- It is one of the important low-temperature characteristics of high-boiling fractions. When the temperature is less than the pour point of a petroleum product, *it cannot be stored or transferred through a pipeline*.

Octane number

- Normally the fuel - air mixture should burn smoothly and rapidly by sparking.
- In some cases, as a result of compression, the fuel-air mixture may get heated to a temperature greater than its ignition temperature and **spontaneous combustion** occurs even before sparking. This is called ***pre-ignition.***
- Further, the spark also is emitted which makes the combustion of the rest of the mixture faster and explosive. Therefore, a sudden badly controlled burning and explosion results a characteristic metallic or rattling sound from the engine. This is called **knocking or detonation** .
- Knocking lowers the efficiency of engine which results in loss of energy.
- The **chemical structure** as well as the properties of the fuel plays a significant role in this phenomena.

Note 1

Chemical Structure and Knocking

The knocking tendency decreases as follows :

n-alkanes ⟶ isoparaffins ⟶ olefins ⟶ naphthenes ⟶ aromatics

n-alkanes have lowest antiknock value. So the presence of maximum quantity of aromatics and minimum quantity of n-alkanes is desirable in petrol.

Note 2

***Octane number** (Measurement of knocking in SI engines)*

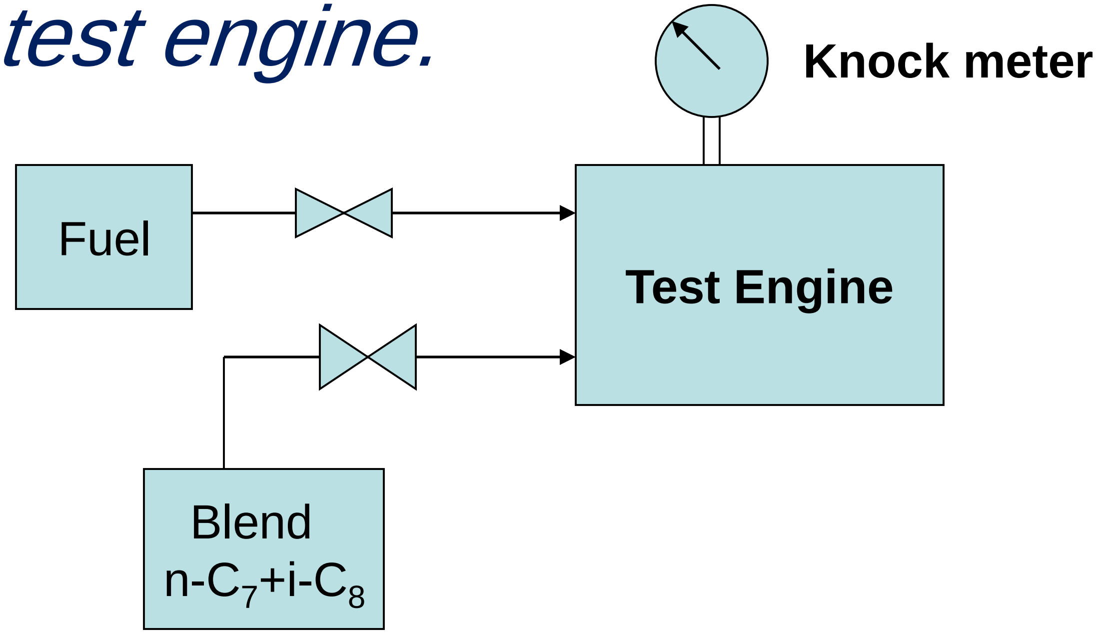
Octane number expresses the knocking characteristics of petrol. n - heptane (a constituent of petrol) knocks very badly, so its anti-knock value has been given zero. On the other hand, iso-octane (also a constituent of petrol) gives very little knocking, so its anti-knock value has been given 100.

Conclusion & Definition

- ***Percentage of iso-octane present in iso octane & n-heptane mixture, which matches the same knocking characteristics of gasoline mixture test sample.***
- If a petrol sample behaves like a mixture of 60% iso-octane and 40% n-heptane, its octane number is taken as 60.

Octane Number = 90

- *A gasoline of 90 octane number means the percentage by volume of iso-octane in a blend of iso-octane and n-heptane is 90 that knocks with the same intensity as the gasoline being tested in a standardized test engine.*



Heating Value

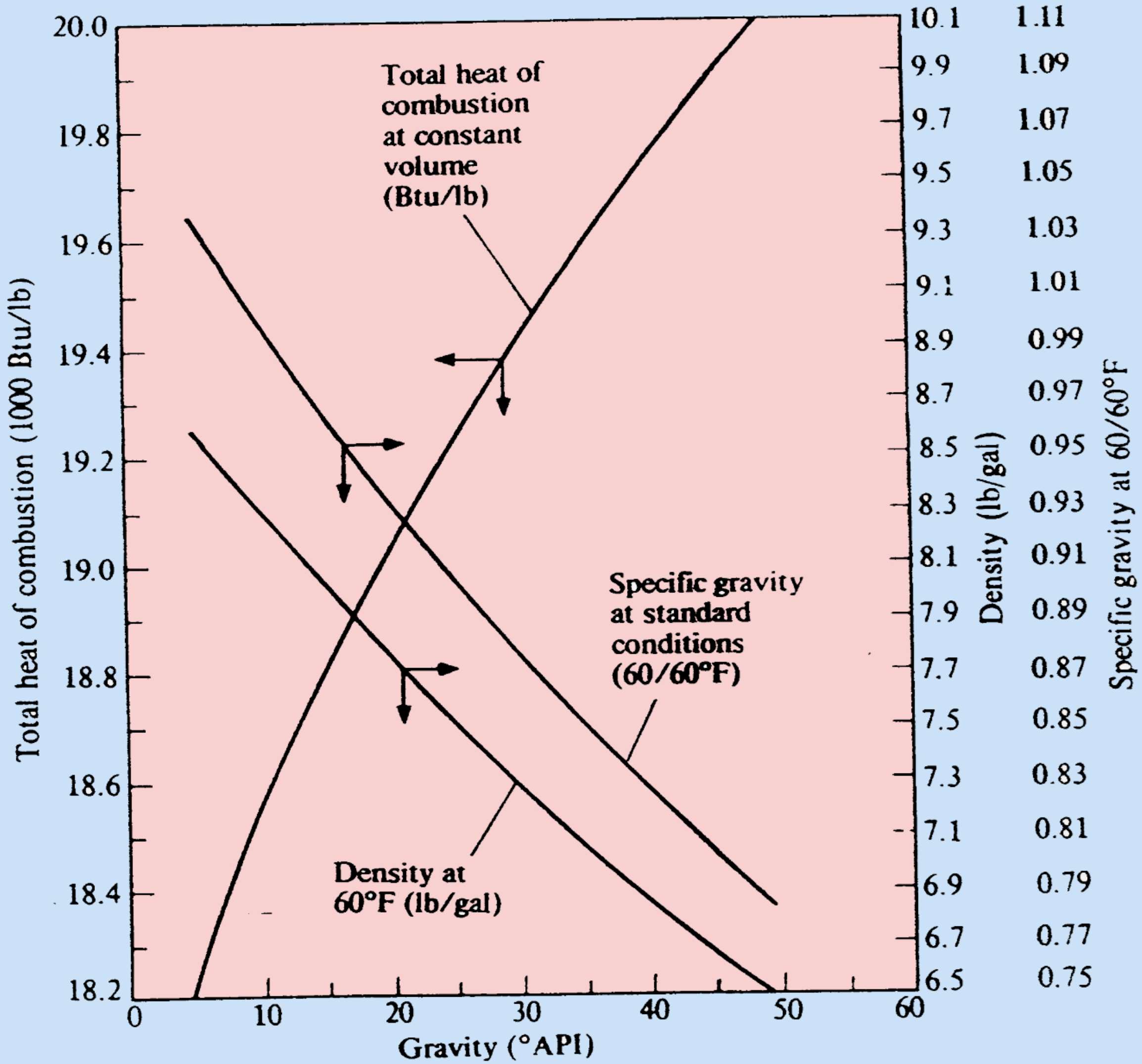
- Heating value is related to API gravity through the following empirical Equation:

$$HHV = 17{,}645 + 54 \times {}^{o}API, \quad Btu/lb$$

$$HHV - LHV = 1032\,(M + 9H_2O), \quad Btu/lb$$

- The next slide HHV, Sp. gr., density and total heat of combustion in terms of API gravity for petroleum derivatives.

Heat of combustion & specific gravity



$$°API = \frac{141.5}{\text{Specific gravity at } 60/60°F} - 131.5$$

Fuel oil grades and specifications

In general, there are 6 classes of fuels that remain in the distillation column in petroleum refineries after the removal of LPG and gasoline.

Oil Grade	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
API gravity	> 35	> 26				
Commercial name	Kerosene	Diesel **L.G.O**	**H.G.O**	Fuel Oil	Fuel Oil	Bunker C
Sulfur content %	S< 0.5	S< 1.0				
Local Sulfur Content, %		S = 1.5				S = 4

Liquid Fuel Properties

Commercial fuels	Molecular weight	Specific gravity, °API	Flash point, °F	Higher heating value, kJ/kg†
Available fuel oils:				
No. 1 fuel oil	...	42.0	100	46,070
No. 2 fuel oil	...	34.0	100	45,260
No. 4 fuel oil	...	22.5	130	43,820
No. 5 fuel oil	...	18.0	130	43,170
No. 6 fuel oil	...	14.5	150	42,330
Gasolene	126	60.0	0	47,120
Methanol	32	47.3	60	22,675

Shale oil

- Similar to 'paraffin base' crude oil
- Heavy oil (after fractionating) can be cracked under pressure to yield heavy gasoline (ON=60, sp.gr= 0.723) diesel oil and pitch.

Bitumen

- asphaltic base
- sp.gr = 1.002
- sulfur: 4-5 % ; CV: $42 MJkg^{-1}$

Coal Tar

Tar could be distilled to

a. light oil BP up to 170°C (gasoline, naphtha)

b. carbolic oil 170-230°C (phenol, naphthalene)

c. creosote oil 230-270°C (motor spirit, tars)

d. Anthracene oil 270-320 °

e. residual pitch

Uses of oil

- domestic heating and lighting
- steel making
- engines, generators of electricity
- production of gas
- raw material in the chemical industries
- furnaces (burning of oils)

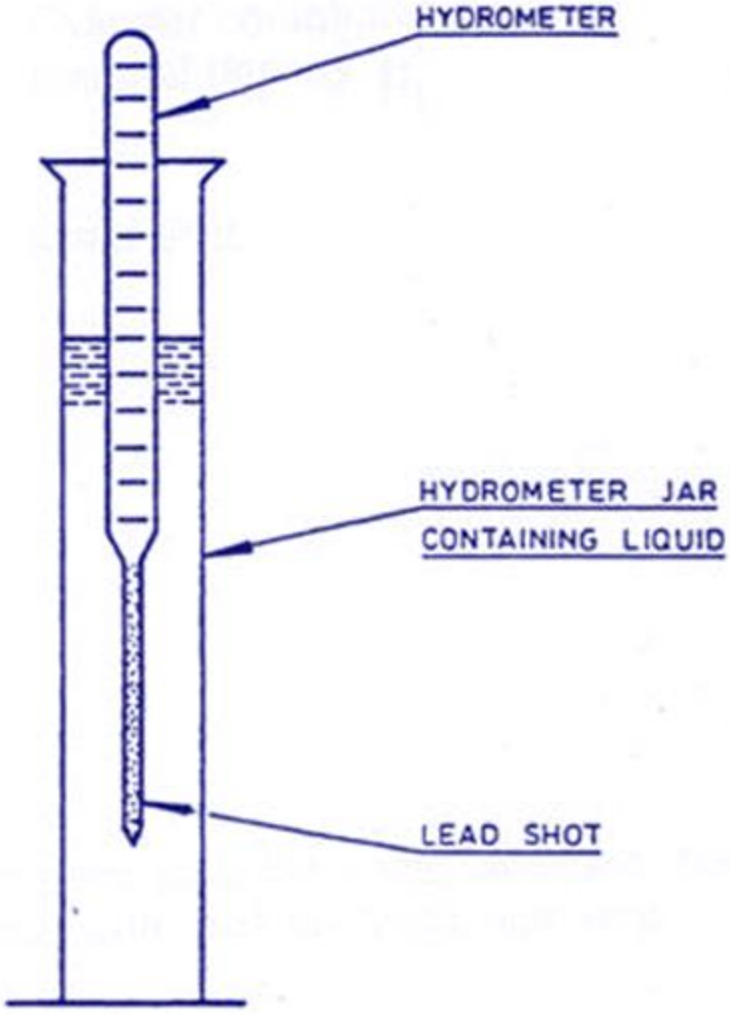
Cetane number

- Cetane number or CN is a measure of a fuel's ignition delay, the time period between the start of injection and the first pressure increase or rise during combustion of the fuel.
- Higher cetane fuels will have shorter ignition delay periods than lower cetane fuels.
- Cetane numbers are only used for the relatively light distillate diesel oils.

Cetane number ‘CN’ _ Definition

CN denotes the percentage (by volume) of cetane (Hexadecane) in a combustible mixture (containing cetane and 1-methylnapthalene) whose ignition characteristics match those of the diesel fuel being tested.

Note - Hydrometer



A hydrometer is an instrument used to measure the relative density (or specific gravity) of liquids that is, the ratio of the density of the liquid to the density of water.