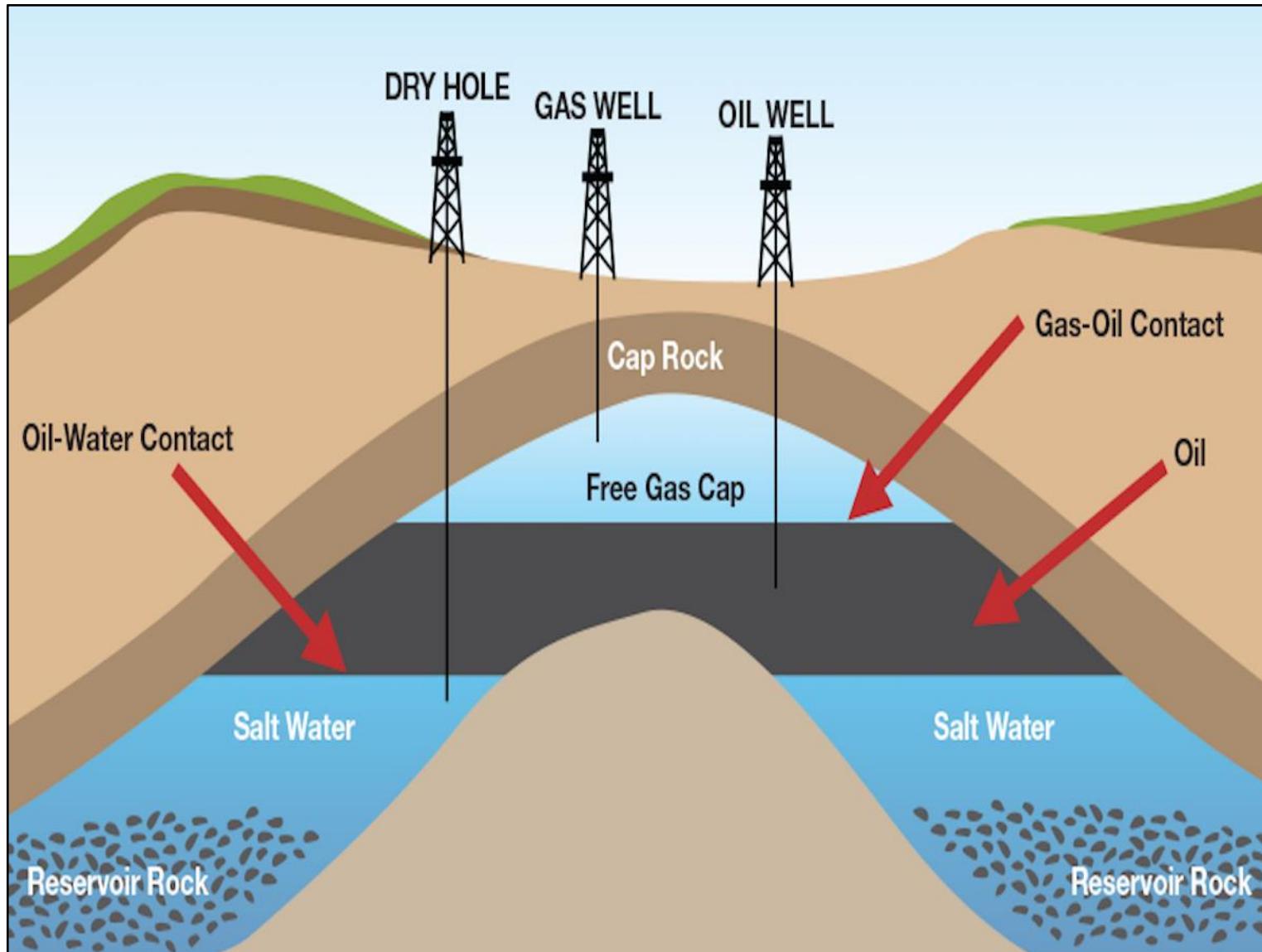


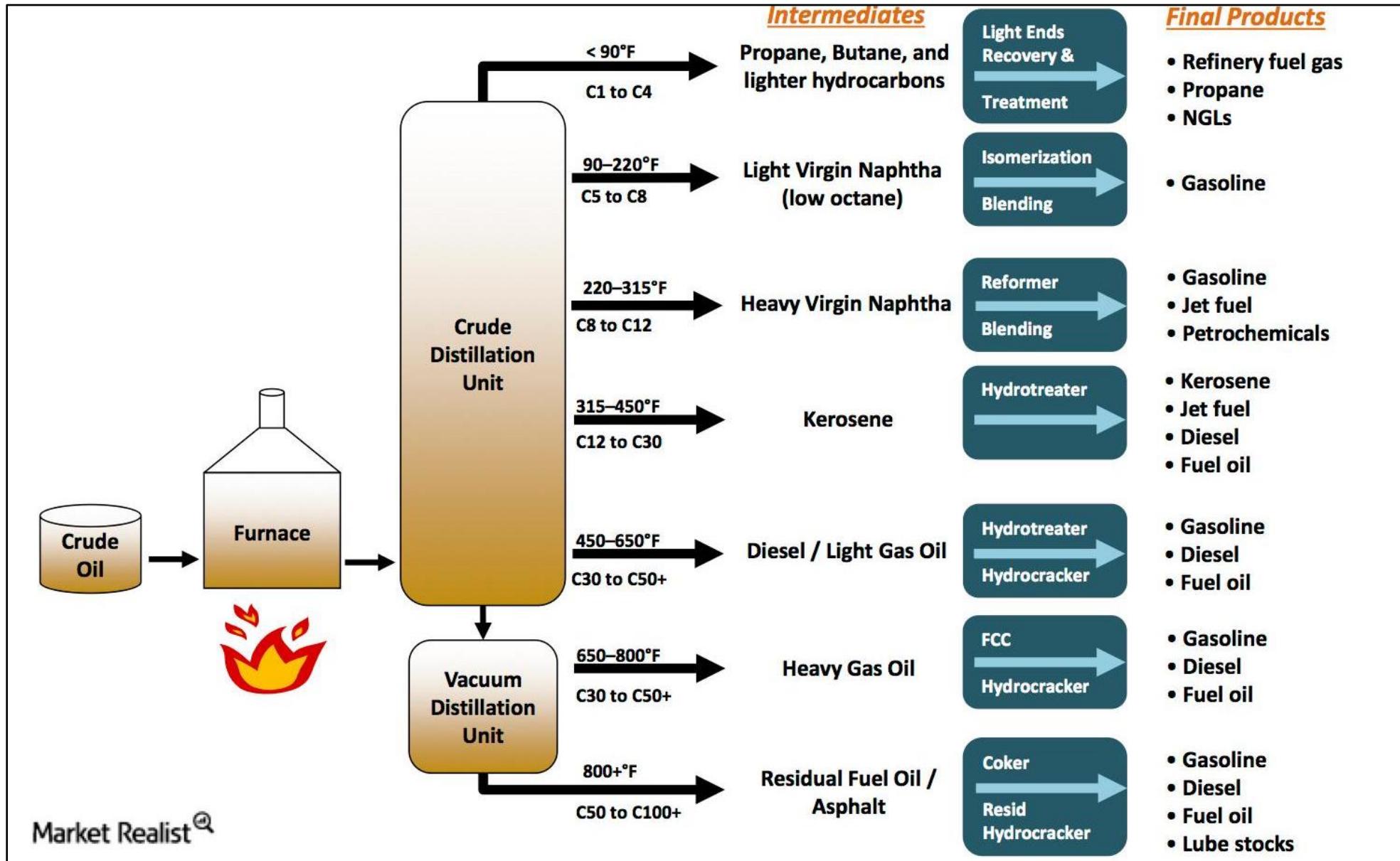
# **FUELS AND COMBUSTION - 3**

**DR. ANUPAMA SAWANT**

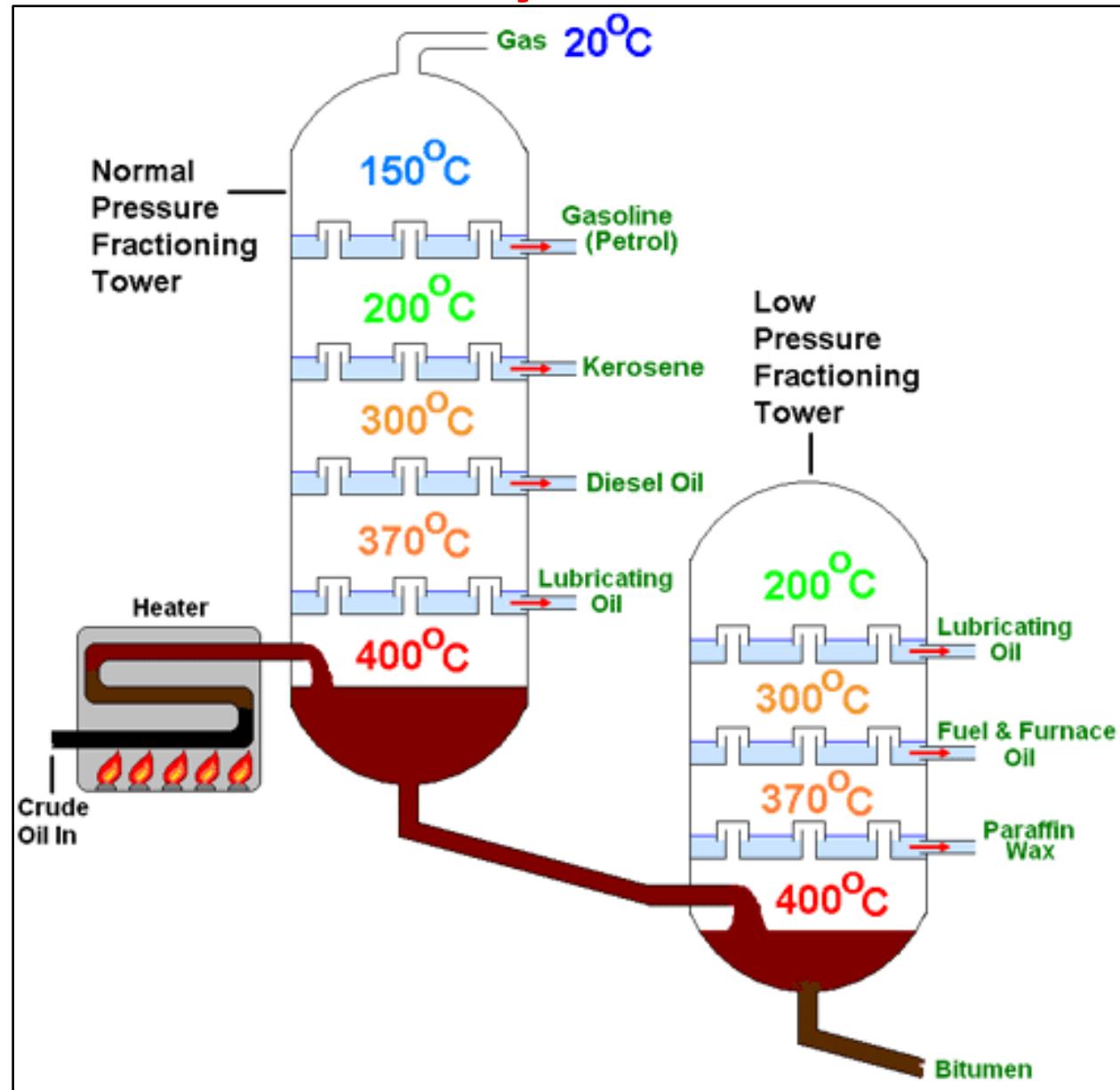
# Mining of petroleum ( Crude Oil)



# Fractional Distillation of Petroleum ( Crude Oil )



# Vacuum Distillation of Heavy oil



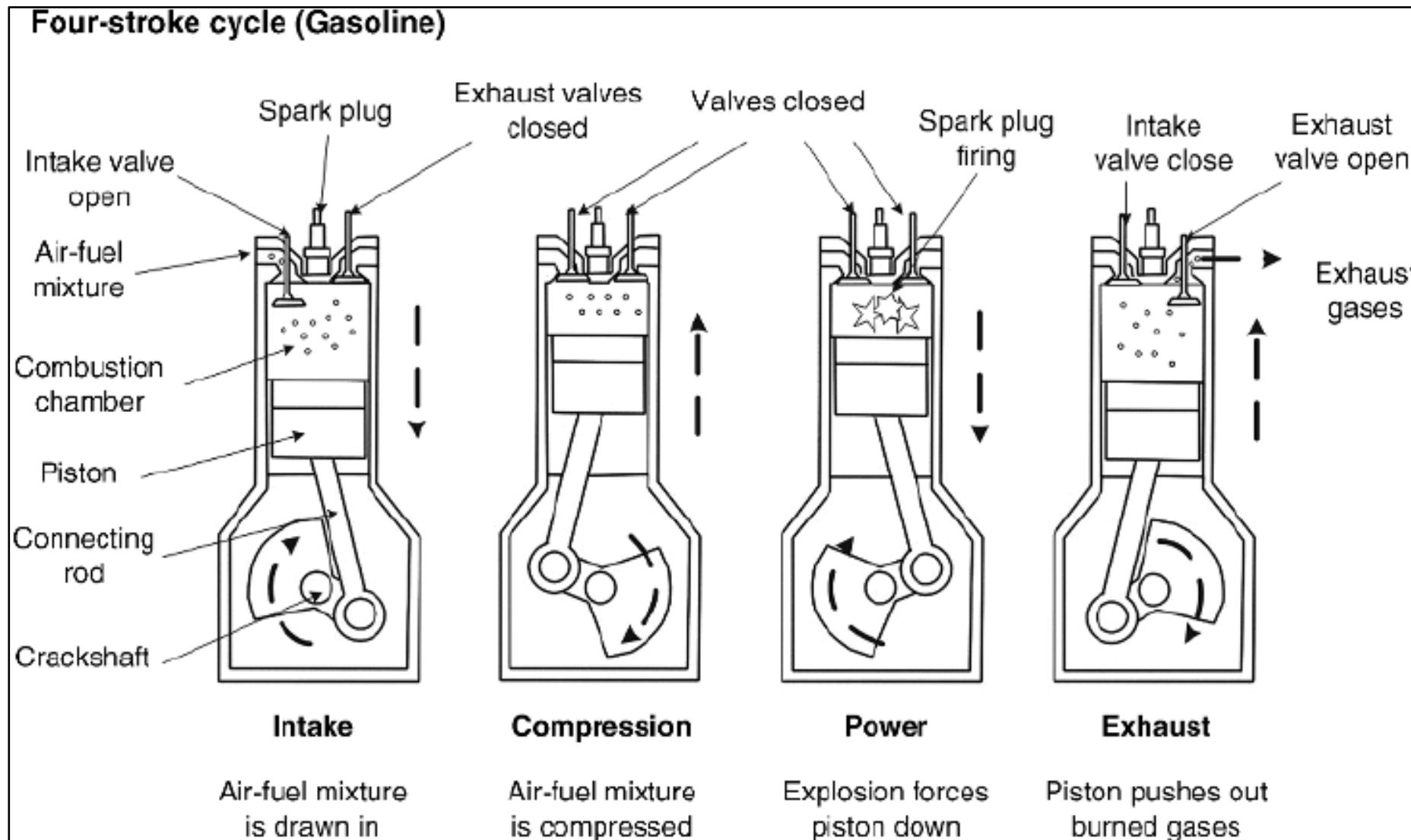
# Refineries



## Petrol ( Gasoline) - Knocking

- Knocking, in an Internal Combustion Engine, is sharp metallic sounds caused by premature combustion of part of the compressed air-fuel mixture in the cylinder.
- In a properly functioning engine, the charge burns with the flame front progressing smoothly from the point of ignition across the combustion chamber. However, at high compression ratio, depending on the composition of the fuel, some of the charge may spontaneously ignite ahead of the flame front and burn in an uncontrolled manner, producing intense high-frequency pressure waves. These pressure waves force parts of the engine to vibrate, which produces an audible knock.
- Knocking can cause overheating of the spark-plug points, erosion of the combustion chamber surface, and rough, inefficient operation.

# Working of Internal Combustion Engine



# Octane Number

- Octane number of a fuel defines percentage of Iso-octane present in the mixture of Iso-octane and n-heptane under standard operating conditions.
- Octane rating signifies the ability to resist auto ignition when used in the gasoline engine.
- Due to compression of air and fuel together, gasoline tends to ignite at the end of compression by spark created by spark plug.
- The fuel having high octane number takes more time to burn but provides maximum efficiency to the gasoline engine
- Opposite to it fuel having low octane number tends to adopt auto combustion easily due to the effect of excess heat and pressure.

# Octane Number

- The octane number of a fuel is measured in a test engine, and is defined as the percentage, by volume, of iso-octane (2,2,4-trimethylpentane, an isomer of octane) in the mixture of iso-octane and n-heptane which would have the same anti-knocking capacity as the fuel under test.
- By definition, iso-octane is assigned an octane number 100 and heptane is assigned an octane number zero.

e.g. gasoline with the same knocking characteristics as a mixture of 90% iso-octane and 10% heptane would have an octane number 90.

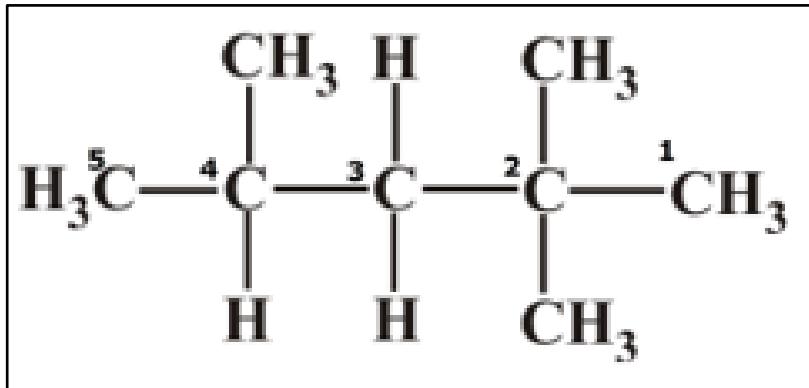
## Note:

1. This does not mean, however, that the gasoline actually contains these hydrocarbons in these proportions. It simply means that it has the same detonation resistance as the described mixture.
2. Because some fuels are more knock-resistant than iso-octane, the definition has been extended to allow for octane numbers higher than 100.

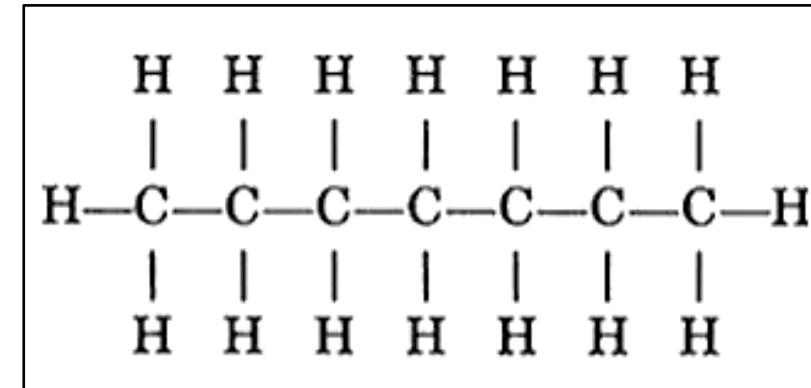
e.g. Racing fuels, LPG, and alcohol fuels such as methanol or ethanol can have octane number of 110 or significantly higher - ethanol's Octane Number is 129

3. Octane rating does not relate to the energy content of the fuel. It is only a measure of the fuel's tendency to burn rather than explode.

# Structures



Iso-octane (2,2,4-trimethylpentane)



n-heptane

# Factors affecting Octane Number

## Factors affecting Octane Number

1. The shorter the chain the higher the octane number

Heptane  $C_7H_{16}$  = 0

Hexane  $C_6H_{14}$  = 25

Pentane  $C_5H_{12}$  = 62

Butane  $C_4H_{10}$  = 94

16

## Factors affecting Octane Number

2. The more branched the chain the higher the octane number

- E.g.  $C_7H_{16}$

- Heptane = 0

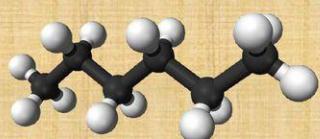
- 2-methylhexane = 65

- 2,3 dimethylpentane = 91

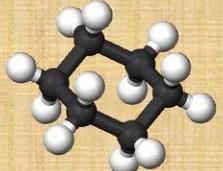
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## Factors affecting Octane Number

3. Cyclic compounds have a higher octane number than straight chain compounds



Hexane = 25

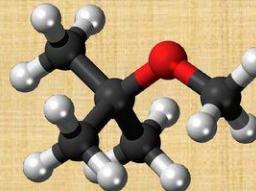
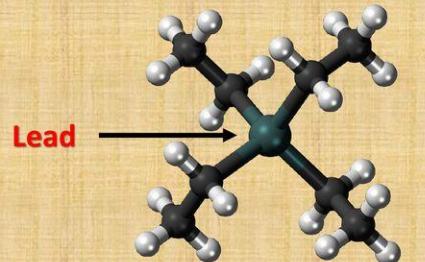


Cyclohexane = 83

18

## Factors affecting Octane Number

4. Adding compounds such as tetraethyl lead or MTBE (methyl tertiary butyl ether)



MTBE      Octane Number = 118

# Antiknocking agents

- Definition:

Anti Knocking agents are the additives added in small quantities in petrol engine to reduce the knocking tendency.

- Typical "octane booster" gasoline additives include tetra-ethyl lead, MTBE and toluene.
- Tetra-ethyl lead (the additive used in leaded gasoline) is easily decomposed to its component radicals, which react with the radicals from the fuel and oxygen that start the combustion, thereby delaying ignition and leading to an increased octane number.
- However, tetra-ethyl lead and its byproducts are poisonous and tetra-ethyl lead's use creates an environmental hazards. In order to help the simultaneous elimination of Pb formed, a small amount of ethylene dibromide (Scavenger) is also added to petrol.



Eventually this Lead bromide is equally harmful to the environment.

## Unleaded Petrol

- Beginning in the 1970s, use of TEL in the United States and most of the industrialized world has been restricted. Its use is currently limited to being an additive to aviation gasoline.
- Now a days most of countries are phasing out leaded fuel and focusing on various anti knock additives. There are three major group of anti knock agents.

### ➤ Aromatics:

Toluene and xylene are the main aromatic organic solvents usually found in anti knock additives. Toluene is a clear, water insoluble liquid. The properties of toluene and xylene are nearly identical. They are both octane boosters. They are also not bad for human health because of carcinogenic nature like benzene.

### ➤ Oxygenates:

Ethanol is most widely blended with gasoline. Similar type of octane enhancement can be obtained by methanol, isopropyl alcohol and tertiary butyl alcohol. The either is most widely used as a gasoline additive by refiners is MTBE (methyl tertiary butyl ether). MTBE is soluble with water therefore its use as an anti knock agent is controversial. ETBE (ethyl tertiary butyl ether) are good octane enhancing ether additives.

### ➤ Organo-metallic compounds:

Organometallic compounds have environmental and health issues of human.

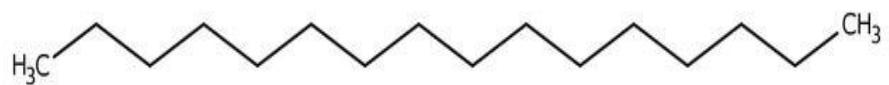
## Cetane Number

- The cetane number of a fuel is defined as the volume percent of n-hexadecane (Cetane) in a blend of cetane and 1-methyl naphthalene (  $\alpha$  – methyl naphthalene ) that gives the same ignition delay period as the test sample.

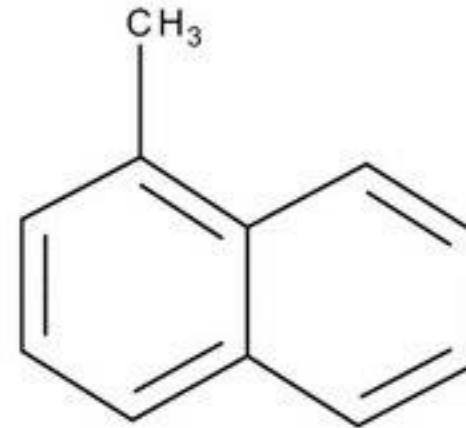
e.g. A fuel with a cetane number of 50 will have the same performance in the engine as a blend of 50% cetane and 50% 1-methylnaphthalene.

- The Cetane Number is a measure of a fuel's ignition delay, the time period between the start of injection and the first identifiable pressure increase during combustion of the fuel. In a particular diesel engine, higher cetane fuels will have shorter ignition delay periods than lower cetane fuels.
- Cetane number of a diesel engine fuel is indicative of its ignition characteristics. Higher the cetane number better it is in its ignition properties.
- Cetane number affects a number of engine performance parameters like combustion, stability, drivability, white smoke, noise and emissions of CO and HC.

# Structures



**Cetane ( n- hexadecane )**



**1- methyl naphthalene**

## Comparison between Octane Number and Cetane Number

Octane Number	Cetane Number
<ul style="list-style-type: none"><li>Octane number measures the performance of <u>gasoline</u>.</li><li>Octane Number measures the <u>ability of a fuel to resist pre-ignition</u> of the gasoline.</li><li><u>Higher Octane number gives better quality</u> petrol</li><li>Fuel having <u>higher octane number tends to ignite rapidly gives fewer tendencies to knock</u> in Gasoline engine.</li><li>Octane number is decided according to the <u>ignition of Iso-octane</u> which is 100 and zero for <u>n-heptane</u></li></ul>	<ul style="list-style-type: none"><li>Cetane number measure the performance of the <u>diesel</u>.</li><li>Cetane Number measures the <u>ignition delay</u> of the diesel</li><li><u>Higher Cetane number defines better quality</u> diesel.</li><li>Fuel having <u>higher cetane value shows readily ignition and gives fewer tendencies to knock</u> in the diesel engine</li><li>Cetane rating is measured according to the <u>ignition of the cetane</u> which is 100 and <u>1-methylnaphthalene</u> which is zero</li></ul>

## Catalytic Converter

- A catalytic converter is a large metal box, bolted to the underside of your car, that has two pipes coming out of it. One of them (the converter's "input") is connected to the engine and brings in hot, polluted fumes from the engine's cylinders (where the fuel burns and produces power). The second pipe (the converter's "output") is connected to the tailpipe (exhaust). As the gases from the engine fumes blow over the catalyst, chemical reactions take place on its surface, breaking apart the pollutant gases and converting them into other gases that are safe enough to blow harmlessly out into the air.
- One very important thing to note about catalytic converters is that they require you to use unleaded fuel, because the lead in conventional fuel "poisons" the catalyst and prevents it from taking up the pollutants in exhaust gases.

## Catalytic converters ( contd...)

### Working

- Inside the converter, the gases flow through a dense honeycomb structure made from a ceramic and coated with the catalysts ( Rhodium). The honeycomb structure means the gases touch a bigger area of catalyst at once, so they are converted more quickly and efficiently.
- Typically, there are two different catalysts in a catalytic converter:
- One of them tackles nitrogen oxide pollution using a chemical process called reduction (removing oxygen). This breaks up nitrogen oxides into nitrogen and oxygen gases (which are harmless, because they already exist in the air around us)

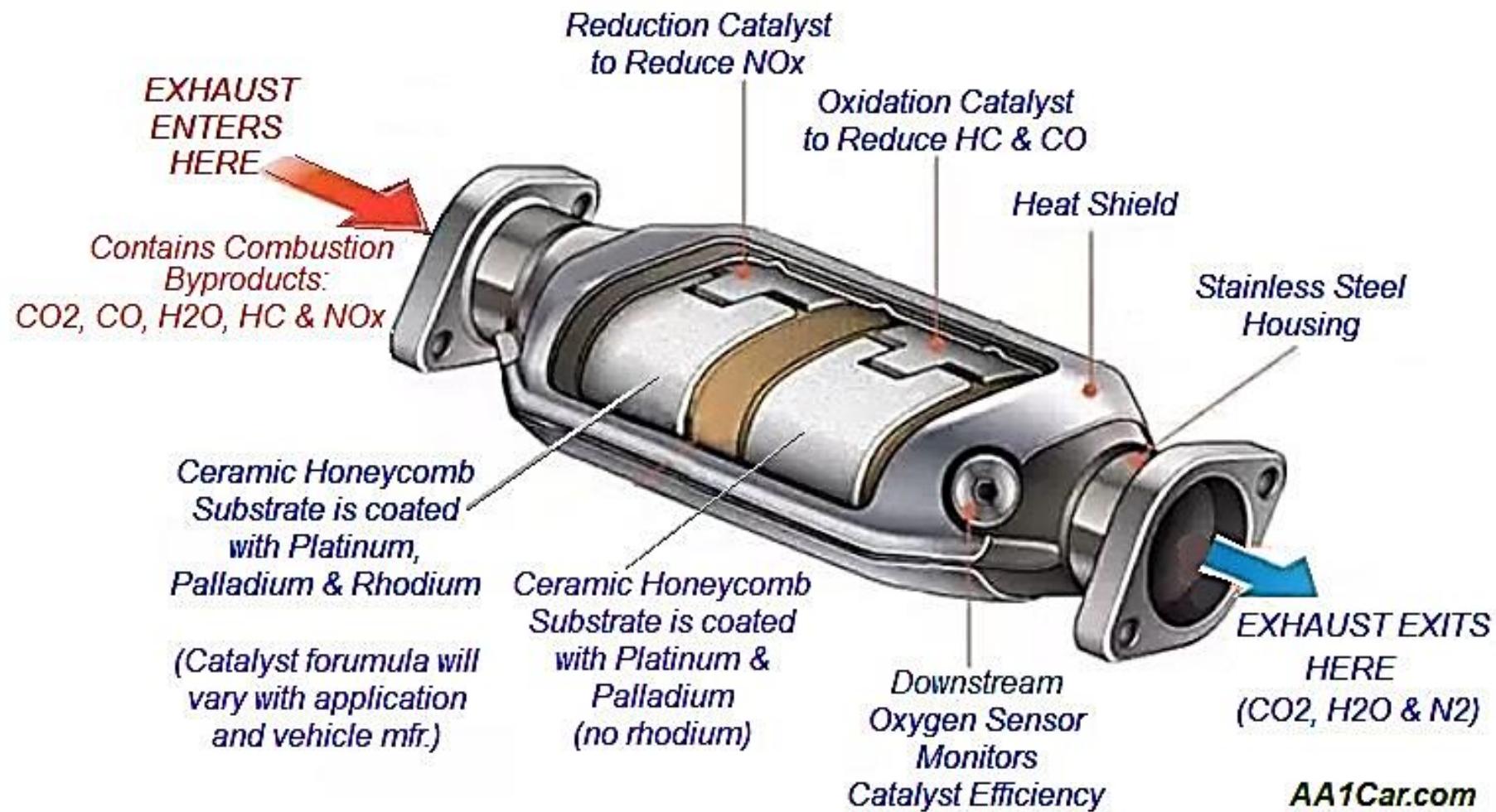


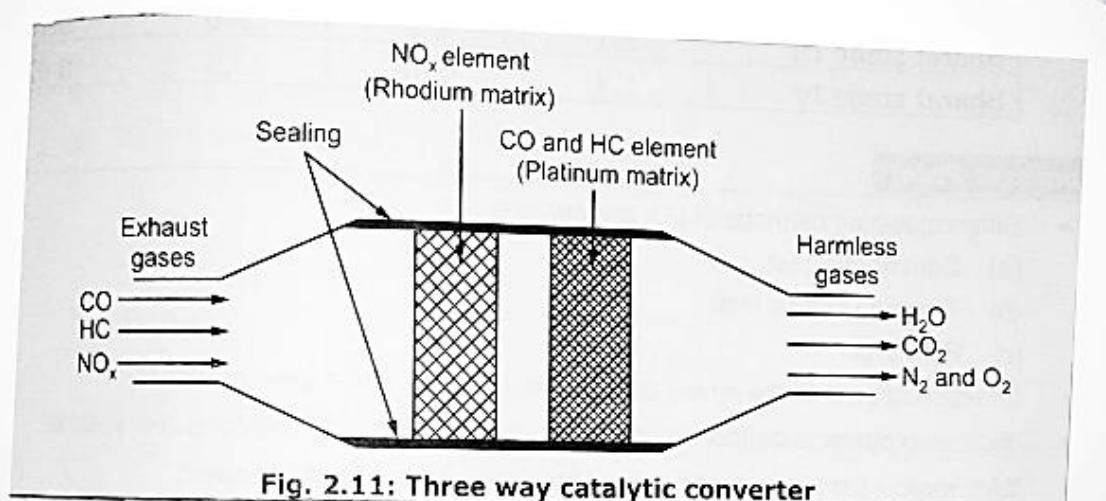
- The other catalyst works by an opposite chemical process called oxidation (adding oxygen) and turns carbon monoxide into carbon dioxide. Another oxidation reaction turns unburned hydrocarbons in the exhaust into carbon dioxide and water.



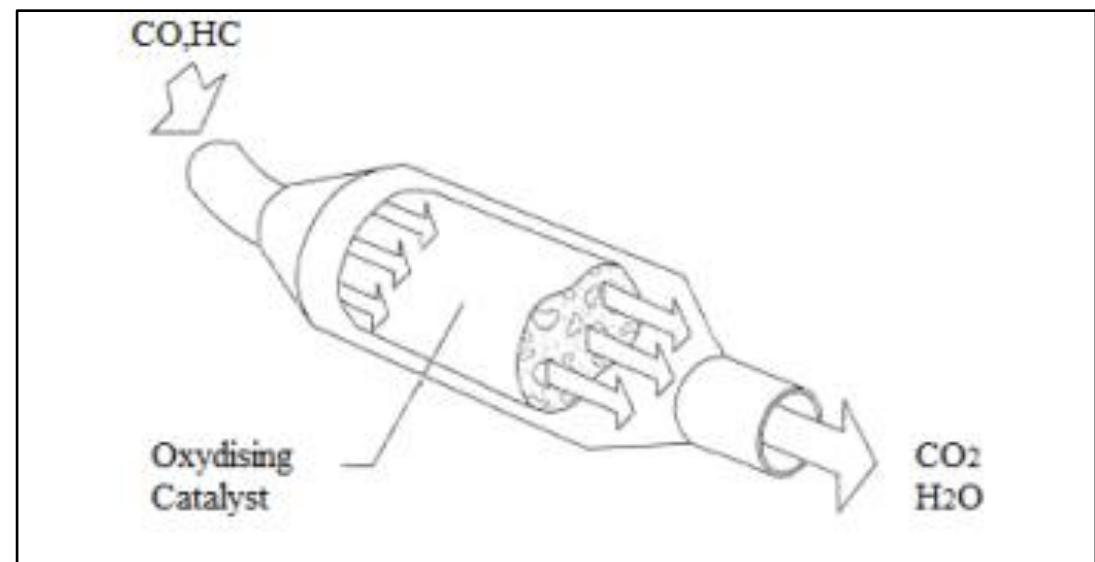
- In effect, three different chemical reactions are going on at the same time. That's why we talk about three-way catalytic converters. (Some, less-effective converters carry out only the second two (oxidation) reactions, so they're called two-way catalytic converters.) After the catalyst has done its job, what emerges from the exhaust is mostly nitrogen, oxygen, carbon dioxide, and water (in the form of steam)

# Catalytic Converter Operation





## Three way catalytic converter



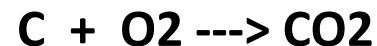
## Two way catalytic converter

## COMBUSTION OF FUEL (NUMERICALS)

1. A solid fuel has C = 80%, H = 12%, O = 8%. Calculate the minimum quantity of air required for complete combustion of 1 kg of fuel

Solution:

Constituent	% by weight	Weight per kg
C	80	0.80
H	12	0.12
O	8	0.08



$$12 \quad 32$$

$$0.8 \text{ ---- } 2.13 \text{ kg}$$



$$2 \quad 16$$

$$0.12 \text{ ---- } 0.96 \text{ kg}$$

$$\text{Total amount of oxygen required} = 2.13 + 0.96 = 3.09 \text{ kg}$$

$$\text{Net amount of oxygen required} = 3.09 - 0.08 = 3.01 \text{ kg}$$

Air contains 23% oxygen by weight,

$$\text{Amount of air required} = (3.01) \times 100/23$$

$$= 13.09 \text{ kg}$$