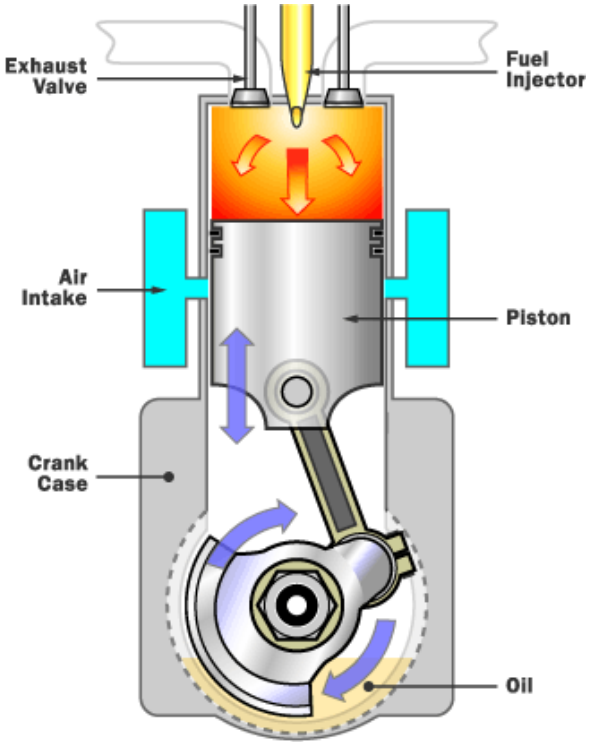
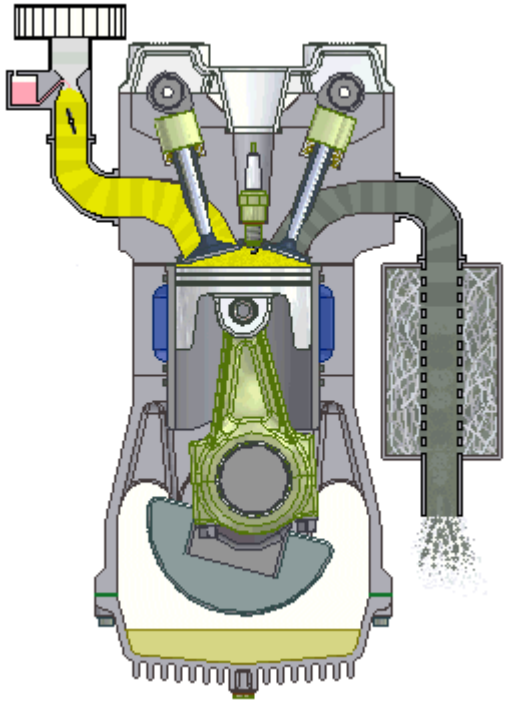
Knocking



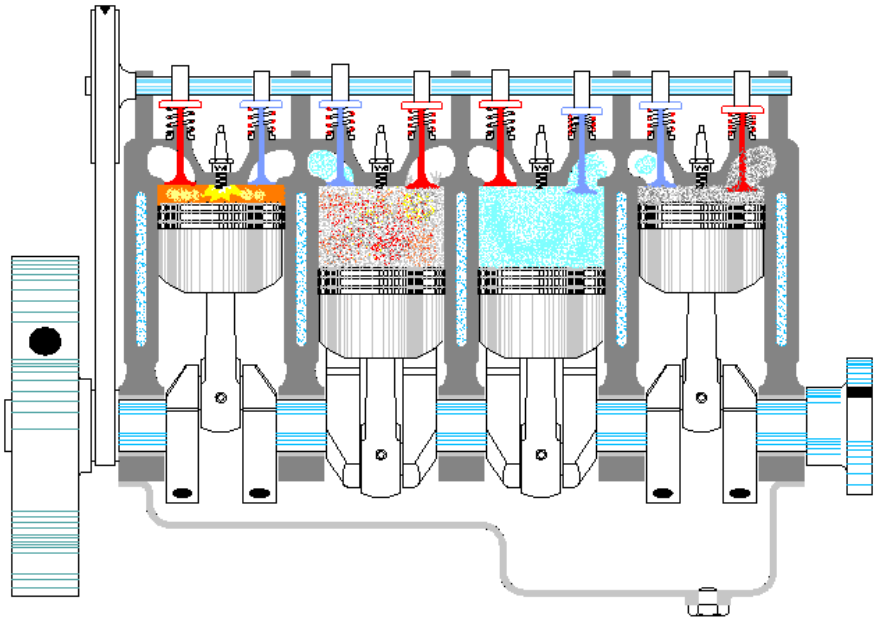
IC engine



An **internal combustion engine** (ICE) is a heat **engine** in which the **combustion** of a fuel occurs with an oxidizer (usually air) in a **combustion** chamber that is an integral part of the working fluid flow circuit

IC engine

- In an internal combustion engine, a mixture of gasoline vapour and air is used as a fuel.
- After the initiation of the combustion reaction by spark in the cylinder, the flame should spread rapidly and smoothly through the gaseous mixture, thereby the expanding gas drives the piston down the cylinder.



IC engine – Compression ratio

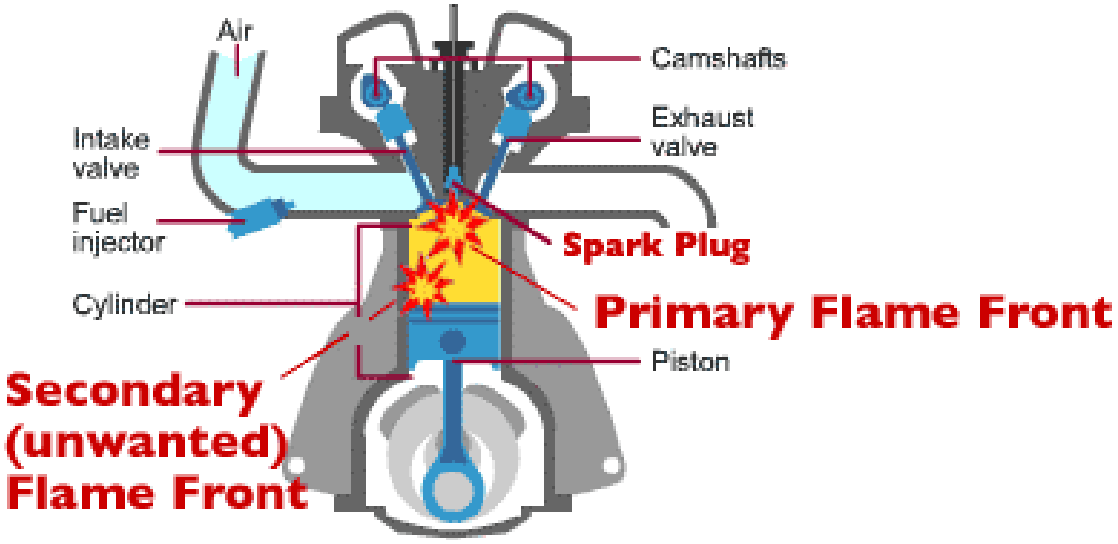
- **The ratio of the gaseous volume in the cylinder (V_1) at the end of the suction stroke to the volume (V_2) at the end of compression-stroke of the piston is known as the 'compression ratio'.**

V_1 being greater than V_2, the CR is > 1

- The CR indicates the extent of compression of the fuel-air-mixture by the piston.
- Efficiency of IC engine increases with compression ratio.

IC engine – Knocking

- In certain circumstances, due to the presence of some constituents in the gasoline used, the rate of oxidation becomes so great that the last portion of the fuel-air mixture gets ignited instantaneously producing an explosive violence, known as '**knocking**'.



Knocking – Rattling noise or sharp metallic noise produced by internal combustion engine
– Loss of energy and engine lifetime

Knocking in IC engine

Knocking – Reasons and Effects

Reasons

- If the IC Engine chamber is not getting the appropriate mixture of air and fuel combining together for combustion, then it will result in inconsistent fuel burn.

Chemical structure and Knocking

- The tendency of fuel constituents to knock is in the following order;

Straight chain paraffins > **Branched chain paraffins (iso-paraffin)** > **Olefins** > **Cyclo paraffins (naphthenes)** > **Aromatics**

Effects

- **The knocking results in loss of efficiency, since this ultimately decreases the compression ratio.**
- **The cylinder wall and piston get damaged.**

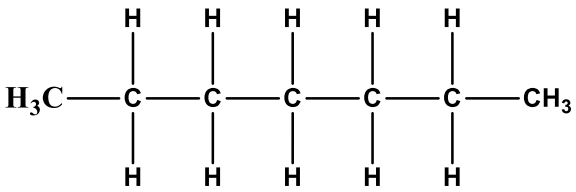
Knocking – Gasoline & Diesel fuel

Octane Number Vs Cetane Number

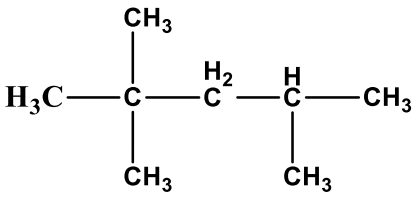
Octane Number	Cetane Number
Octane number is a measure of the performance of a fuel	Cetane number is the measure of the delay of the ignition of a fuel
Important for predicting the knocking of an engine	Important for predicting the ignition of an engine
Given for gasoline	Given for diesel
Octane rating is done considering the octane number of isooctane as 100	Cetane rating is done considering the ignition of cetane

Octane Number

- The most common way of expressing the **knocking characteristics of a combustion engine fuel is by 'octane number'**, introduced by Edger.
- A measure of the resistance of petrol and other fuels to autoignition n-heptane, knocks very badly and hence, its anti-knock value has arbitrarily been given zero.
- Isooctane (2, 2, 4-trimethyl pentane) gives very little knocking , so its anti-knock value has been fixed as 100.
- Octane number is defined as the % of isooctane in a mixture of n-heptane and isooctane which has the same knocking characteristics of the petrol under the same set of conditions.



n-Heptane

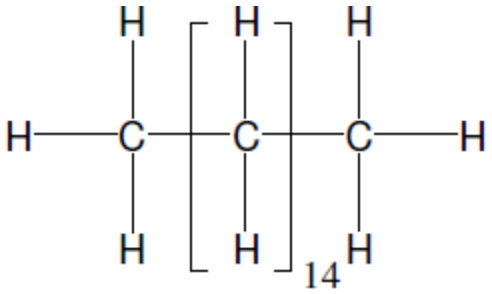


Isooctane

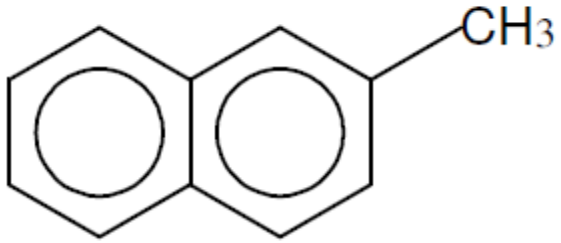
Greater the octane number, greater is the resistance of knocking

Cetane Number

- **The suitability of a diesel fuel is determined by its cetane value**, which is the percentage of hexadecane in a mixture of hexadecane and 2-methyl naphthalene, which has the same ignition characteristics as the diesel fuel sample, under the same set of conditions.



n-hexadecane (cetane No.=100)



2-Methyl naphthalene (cetane No.=0)

The cetane number of a diesel fuel can be raised by the addition of small quantity of certain "pre-ignition dopes" like alkyl nitrites such as ethyl nitrite, iso-amyl nitrite, acetone peroxide.

Anti-knocking Agents

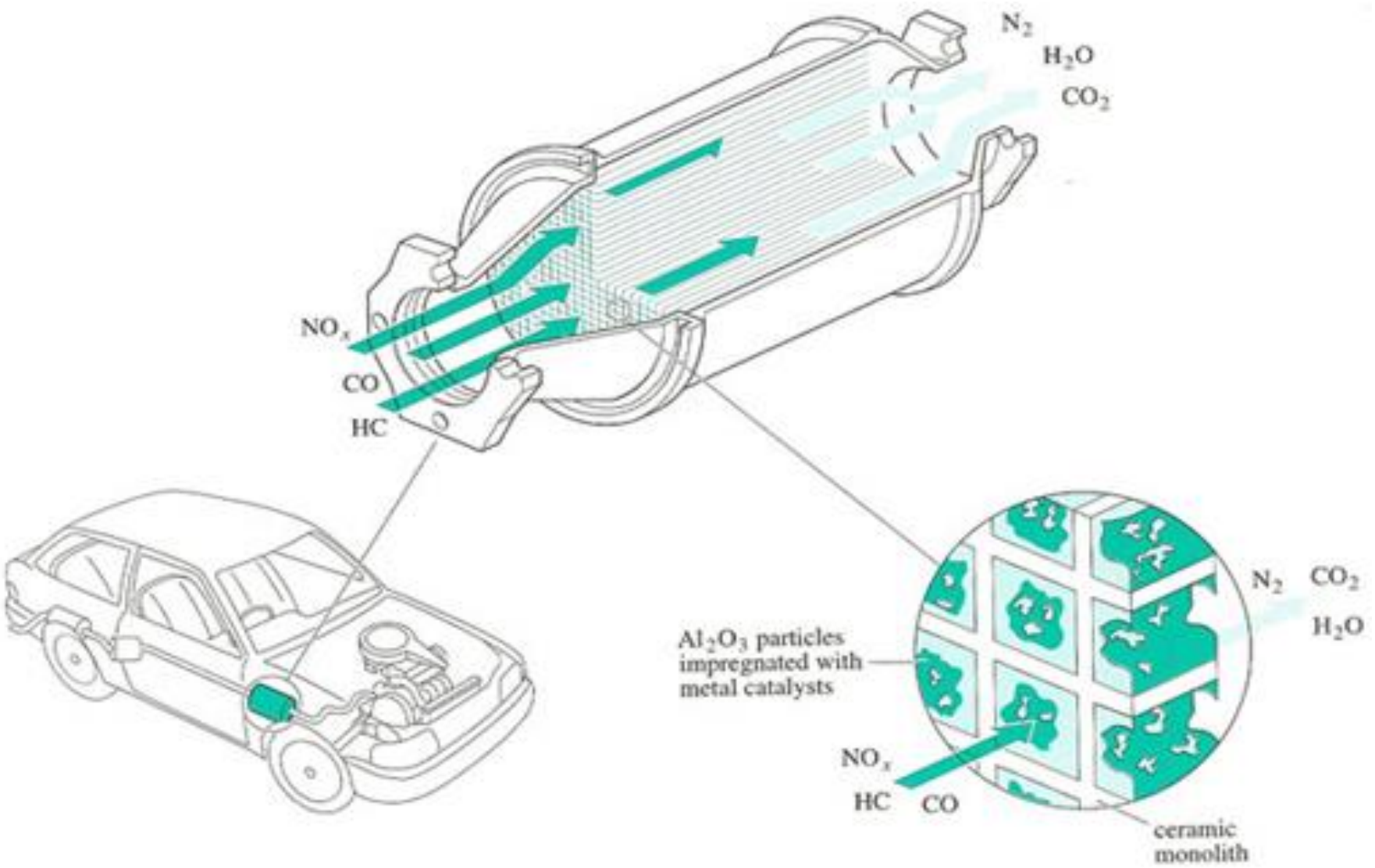
Improvement of anti-knock characteristics of a fuel

- The octane number of poor fuels can be raised by the addition of tetra ethyl lead $(C_2H_5)_4Pb$ or TEL and diethyl telluride $(C_2H_5)_2Te$.
- TEL is converted into a cloud of finely divided lead and **lead oxide** (litharge) particles in the cylinder, thereby reducing the oxidation.
- Deposit of lead oxide is harmful to the engine life, **ethylene dibromide** is added to remove the lead oxide formed as lead bromide along with exhaust gases.
- **Emission of Lead:** **Damages the environment**

Unleaded petrol: Alternative methods

- Addition of high octane compounds like isopentane, isooctane, ethyl benzene, isopropyl benzene, **methyl tertiary butyl ether** (MTBE). Among these MTBE is more preferred because it contains oxygen in the form of ether group and supplies oxygen for the combustion of petrol in internal combustion engines there by reducing the extent of peroxy compound formation.

Three-way catalytic converter



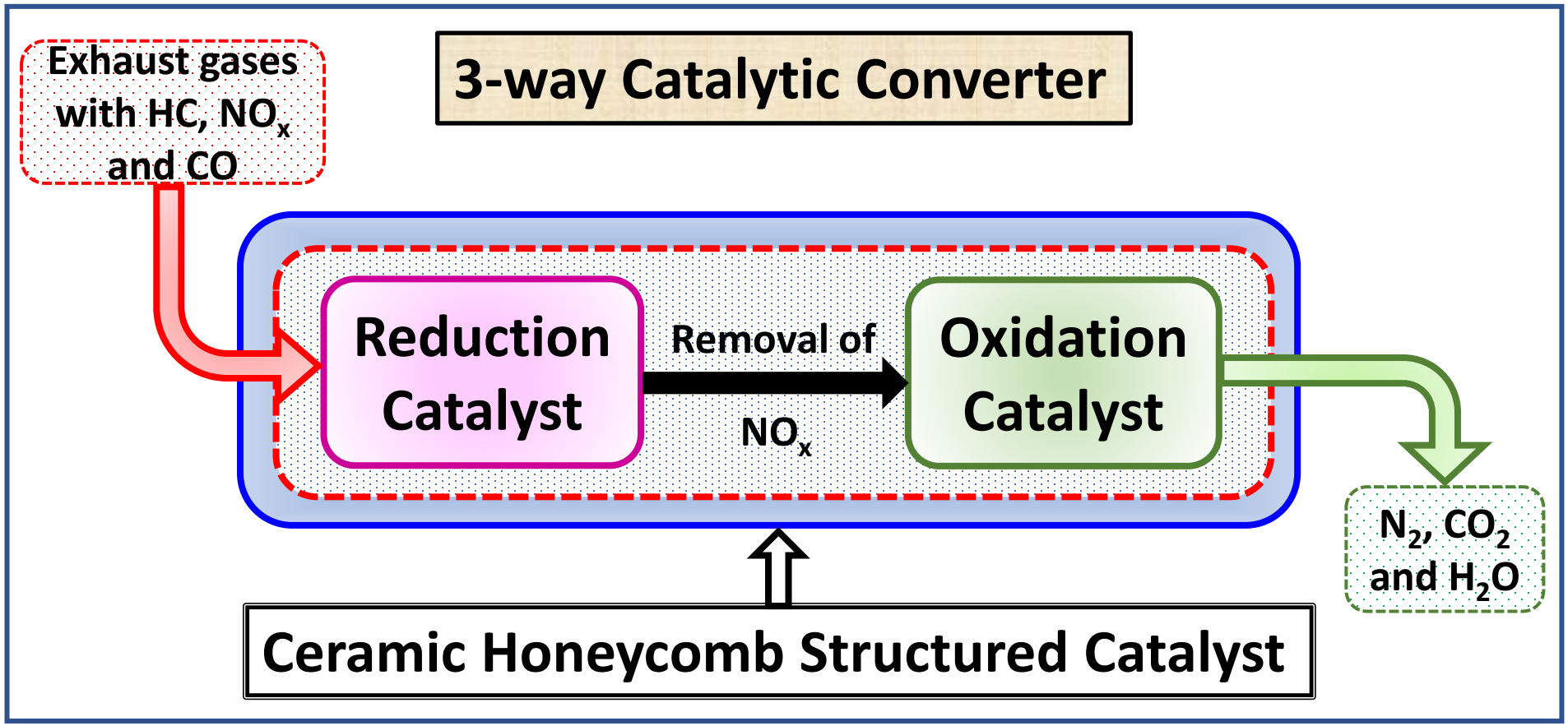
Three-way catalytic converter

Components

- The current three-way catalyst is generally a multicomponent material, containing the precious metals rhodium, platinum and (to a lesser extent) palladium, ceria (CeO_2), γ-alumina (Al_2O_3), and other metal oxides.
- It typically consists of a ceramic monolith of cordierite ($2Mg{\cdot}2Al_2O_3{\cdot}5SiO_2$) with strong porous walls enclosing an array of parallel channels.
- For example, Cordierite is used because it can withstand the high temperatures in the exhaust, and the high rate of thermal expansion encountered when the engine first starts – typically, the exhaust gas temperature can reach several hundred degrees in less than a minute.
- The reduction catalyst is made of platinum and rhodium while the oxidation catalyst is made of platinum and palladium. Both the catalysts have a ceramic honeycomb structure.

Working of Three-way catalytic converter

- A three-way catalytic converter makes use of two catalysts to convert harmful gases to harmless gases.
- They are: **Reduction Catalyst** & **Oxidation Catalyst**



Function of Three-way catalytic converter

Stage 1 – Reduction Catalyst:

- The exhaust gases are first sent over the reduction catalyst (which is made of platinum and rhodium). It converts oxides of nitrogen (NO_x) to nitrogen (N_2) and oxygen (O_2).

$$2NO \rightarrow N_2 + O_2$$

$$2NO_2 \rightarrow N_2 + O_2$$

Stage 2 – Oxidation Catalyst:

- Exhaust gases that are free of oxides of nitrogen (NO_x) are then sent over the oxidation catalyst (made of platinum and palladium). The oxidation catalyst coverts carbon-monoxide (CO) and hydrocarbons (HC) in the gases into carbon-di-oxide (CO_2) and water (H_2O).

$$2CO + O_2 \rightarrow 2CO_2$$

$$HC + O_2 \rightarrow CO_2 + H_2O$$