

Catalytic Converter

Segment1

I am Dr. Mohamed Al Kateeb from Jordan University for Science and Technology, Irbid –Jordan.

We will talk today about a very sensitive topic that touches the life of each of us. And we will see how a science like chemistry can be helpful in solving this problem or reducing its impacts. Our topic today is about human being;

For a human to live ordinary life, he needs three things; food, water, and air.

Do you know how long can a human live without food, or water or air?

As you know, humans can survive without food for a few weeks, without water only for seven days, but he will not survive without air more than few minutes.

The question now, what is air? And where is it found?

Air is a mixture that surrounds the earth; it forms the atmosphere layer which has a height of 750 Km from earth surface. 78% of the atmosphere is nitrogen gas, 21% is oxygen, the remaining amount is other gases such as water vapor and carbon dioxide in very small fractions, and some noble gases. Any change in these percentages is considered air pollution. To know what air pollution let is us watch this movie.

After watching this movie, we can see that air pollution resources can be divided into; steady resources and mobile resources.

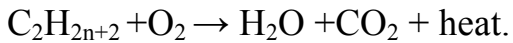
Steady pollution resources are three major types; power station, oil refinery, factories, while the mobile resources include vehicles such as airplanes, boats and ships, cars and trains. In this module we will consider the vehicles since it is found all around us, in any place we go. Your generation cannot imagine life without vehicles. However vehicles produce lots or air pollution. Can human decrease this source of air pollution? The answer is yes, using a small device placed in auto exhausts

I will leave you now for few minutes to discuss air pollution and its impacts on human life.

Segment 2

Welcome back dear students.

I am sure you have noticed that burning oil or fossil fuels is the main source of air pollution these days. Oil is made of hydrocarbons that include carbon and hydrogen, when burned it produces energy used by human in many fields such vehicles and energy production. But there other products of this reaction in addition to energy including carbon dioxide and water vapor, as you can see from this equation.



This equation show the ideal burning reaction, nevertheless the real burning that happens in car engines where its burns in the presence of air instead of oxygen. As previously mentioned, air is a mixture of oxygen and nitrogen, so in addition to ideal burning products which carbon dioxide and water vapor, two other by products are produced , these are harmful for the environment including nitrogen oxides and carbon monoxide.

let us see how we can produce these compounds , and weather they are harmful or environmentally friendly.



As mentioned before, the carbon dioxide and water vapor natural components of the atmospheric air, therefore they are not poisonous, however the presence of carbon dioxide in higher percentage than usual in the atmosphere lead to raising earth's temperature which is known as global warming. On the other hand water vapor does not have any impact on the environment.

But nitrogen oxides are poisonous gases, that we must get rid of and or reduces it as much as possible.

Carbon monoxide is produced as a result of incomplete burning of fossil fuels due to oxygen deficiency for example in car engines, nitrogen monoxides is produced by of reaction of oxygen and nitrogen under high temperature and pressure.

In addition to these products, car exhaust includes also some unburned hydrocarbons which are very harmful for the environment which results for incomplete burning of fossil fuels in car engines.

After we have seen how burning of fossil fuels happens and knowing that it a major source of air pollution, let us take a break again and discuss the origin of fossil fuels. And where is it found? And I will be back.

Segment 3

Welcome again dear students, I think you have concluded that oil is made of hydrocarbons which are found underground or under seas; this material was formed before millions of years.

One of the theories states that oil is formed as a result death and burial of microscopic living things before millions of years. This matter or living things that was buried quickly in the absence of oxygen and was exposed to high temperature and pressure, so these materials decomposed into simple compounds and produced a black chemical called kerosene which is black viscous chemical that remained underground for many years and was exposed to high pressure and temperature and decomposed to simpler chemicals . If the pressure and temperature are much higher then the natural gas will be produced.

But if pressure and temperature are less than that, then oil is produced.

As you probably have heard form news, there are different types of fuel.

Light crude oil which is made of short hydrocarbons, while heavy crude oil is made of long chains of hydrocarbons. Some kinds of oil are rich in circular compounds but it is not as useful as the heavy or light oil are. All these kinds are contain complex of organic matter that must be fractured before used in cars as fuel or energy power plants or else.

It is though that oil is produced at one location but migrates to another called oil traps. These are formed in porous rocks that are able to hold the hydrocarbon compounds in its pores. Oil traps are where oil fields are dug to extract oil.

Now after we have seen that oil forms from carbon and hydrogen, is there any other element that is available in oil? If yes, what are these elements and where did it come from?

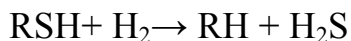
I will leave you now to discuss this with your friends and I will see you soon.

Segment 4

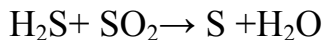
Sulfur removal and Claus method

I think you find out that crude oil contains elements such as nitrogen and sulfur which also come out from living organic matter that makes up oil. Living things contain amino acids that are rich in nitrogen and sulfur in addition to carbon and hydrogen. There is a wide range of sulfur compounds such as thioal, thiophene, sulphide, and disulphide available in oil. These compounds come from decomposing of living things that make up oil, except that it is found in limited amounts.

Because burning fuel that contains sulfur produces sulfur oxides, which is against the international standards. Therefore sulfur needs to be extracted from oil during oil refinery. The sulfur is extracted by a process called hydrodesulphurization of oil. In this process organic matter containing sulfur compounds is converted into hydrogen sulfide by reacting with crude oil with hydrogen gas. This reaction needs catalysts and high heat and pressure according to the following equation.



But the produced hydrogen sulfide is a toxic gas that can be converted to sulfur and water according to the Claus process. In this process part of hydrogen sulfide is burned producing sulfur dioxide; then two gases react together according to the following equation:



This reaction needs a catalyst. Its final products are environmentally friendly.

In the class the teacher will ask about the possibility of changing the toxic gases produced from the cars engines into environment friendly.

Segment 5

The catalytic convertor

Welcome back dear students, It is difficult at this stage to understand the how we can convert toxic gases into chemicals that are lower toxicity.

The answer for this question is found in the device I have showed at the begging of the module. This burial placed inside the car exhaust, inside this burial a small device known as the catalytic convertor. The catalytic convertor is a device responsible for converting toxic gases including carbon monoxide and nitrogen oxides into lower toxic chemicals. Let us explore this segment and the next one this device and how it works.

The catalytic convertor is a small device but very expensive because it contains expensive metals. Due to its high price the convertor is made in a net shape - as you can see in this net- that is plated with effective substances made from valuable metals as you can see in this piece; the paint here represent the effective substance at which happens the reaction.

I have brought a part of a real catalytic convertor taken from a car. It looks like a bee hive; the effective substance is placed on these small holes. The effective substance is divided into two parts; oxidant and reductant.

In chemistry, the catalyst is substance that helps to speed up the reactions without being used in the reaction, so it is neither reactant nor products of the reaction therefore it will not be consumed.

Now I want to ask you: what are the valuable metals used in the catalytic convertor? I will leave you for few minutes and come back to you.

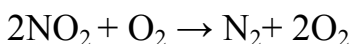
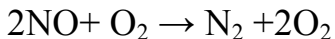
Segment 6

Dear students, welcome back

In this last segment, we will introduce the components of the catalytic convertor and how it works.

The catalytic convertor is made of valuable metals as mentioned before including platinum, rhodium, and palladium; all these metals are more expensive than gold. How does the device work? The device is made of two parts; part one holds the reduction catalyst, the other part holds oxidation catalysts.

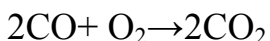
In the first part is the reducing convertor; in which nitrogen oxides are reduced into nitrogen and oxygen according to the following equations



According to this equation, nitrogen monoxide reacts with oxygen molecule in the presence of the catalyst producing a nitrogen molecule and two oxygen molecules. As for nitrogen dioxide it will also react with oxygen in the presence of the same catalyst to producing nitrogen and oxygen, to elaborate on that let us watch the following scene.

This is the metal surface of the catalyst, we can see that the beginning nitrogen monoxide is absorbed then oxygen atoms will be released to combine with the another molecule of oxygen producing 2 oxygen molecules, then two nitrogen atoms combine to produce a nitrogen molecule that will be released from surface.

As for what happens in the oxidization convertor where the carbon monoxide reacts with oxygen giving two molecules of carbon dioxide, to elaborate this process let us watch the following scene.



This plate is made of platinum where carbon monoxide is initially absorbed releasing oxygen atoms that react with another molecule of carbon

monoxide to produce two molecules of carbon dioxide that are released into the atmosphere.

In this process we have converted nitrogen oxides and carbon monoxide from toxic gases into less toxic gases found in air which are carbon dioxide, nitrogen, and oxygen; the major components of the atmosphere.

We have seen two parts of the catalytic convertor; but the catalytic convertor have a third part which very important, let us see its importance in this figure:

This figure show the three parts of the catalytic convertor; part A, B, and C.

A and B are the reducing and oxidization catalysts, part C is sensitive to oxygen and it connected to the car's computer, if the amount of oxygen reaching the car engines is undersupplied, the sensor detects that and gives orders to the car's engine to increase the oxygen uptake, once the oxygen amount increases then the fuel burning will improve and the toxic gases will be less.

Dear students we have noticed in this lecture that catalytic convertor converts toxic gases produced from the cars' exhausts which include nitrogen oxides and carbon monoxide into less toxic substances found in the environment. Extraction of sulfur form oil before refining eliminate the possibility of formation sulfur oxides and this way the car burning becomes easier, and the hazardous products are less.

This is only one of the methods used to protect the environment from vehicles.

As homework, please try to think of other solutions from this problem; there are many solutions for this problem used in different parts of the world.

See you.

Teacher's guide

This module is suitable for the secondary school students. It aims at motivating students in about chemistry. This modules also aim to raise students awareness that chemistry helps in solving some environmental problems; one of which is air pollution by gases released from car exhausts , it is important that students know some chemical reactions , and some element symbols , and differentiate solid , liquid , gases.

Burning oil happens in car engines produces some toxic gasses such as carbon monoxide and nitrogen oxides and unburned hydrocarbons. In this module I have explained the catalytic convertor and how it works to reduce the gas pollutants produced by cars.

My suggestions for the break in between the segments are;

Break one: introduce air pollutants sources including:

Particulate pollutants: smoke, car exhausts gases, dust, pollen grains, cement, sand, pesticides.

Gases or toxic and suffocating vapors including chlorine, carbon monoxide, nitrogen oxides, sulfur dioxide, ozone.

Bacteria, germs, mold produced by decomposing plants and animals and some human waste.

Natural and artificial radiations.

You can discuss their impacts on human life, and diseases in the respiratory system as well as its impact on plants and animals.

Break two:

In the second part we have to discuss the formation of oil, which underground and under water and oceans, we will discuss one of the theories that explain the origin of oil and discuss it with the students. Components of living organisms must also be discussed.

Break three

Oil is made of organic matter that is produced from converting the living things into hydrocarbons that contains carbon and hydrogen, as well as other elements such as sulfur and nitrogen in a form of organic compounds. Where ever oil is found some sulfur is also found. Definitely some sulfur is produced from decaying of living things that forms oil, because these things are made of compounds containing sulfur such as amino acids.

Break four

In this break students will discuss how to get rid of gases released form the car exhausts, such as improving burning conditions in car engine.

Collected the gases in a box or converting into other elements, this will be discussed in this module

Break five:

The substances used in the catalytic convertor are expensive metals such as platinum, palladium; some other metals can be used such as gold and silver. Or we can increase the effectiveness of some elements to be adequate for this purpose.

Break six

Homework

There are many solutions for car exhaust gases; we have talked about one of them in this module. Students may have a research after completion of the modules for other solutions such as

These could be:

- Use other kinds of fuel such as natural gas, ethanol, of a mixture of ethanol and gasoline;
- Use cars that operate by solar energy;
- Use hybrid cars.

