O Level Pure Chemistry Structured

Atmosphere Test 1.0

Q1

A catalytic converter is an emissions control device that converts toxic gases and pollutants into less harmful gases.

(a) These days, most cars are installed with catalytic converters that removes carbon monoxide and nitrogen dioxide:

$$2\ NO_2 + 2\ CO \rightarrow N_2 + 2\ CO_2$$

(i) Explain, in terms of oxidation states, why this is a redox reaction.

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.....[2]

(ii) A car company advertises that "catalytic converters are 100% environmentally friendly".

Do you agree with this statement? Explain your reasoning.

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.....[1]

(b) In a typical catalytic converter, a powdered catalyst such as platinum is used to speed up the conversion of gases.

Explain, in terms of reacting particles, why the catalyst is powdered.

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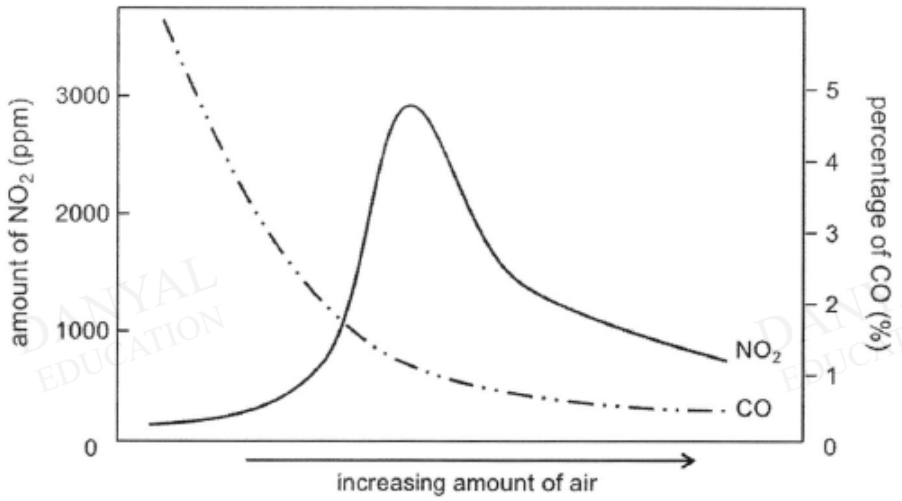
.....[2]

(c) The graph shows how the amount of nitrogen dioxide (measured in ppm) and carbon monoxide (measured in %) vary depending on how much air is present in the car engine.



(i) Describe how the amounts of nitrogen dioxide and carbon monoxide vary with the amount of air in the car engine.

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.....[2]

(ii) Making use of the redox reaction given in **(a)**, and considering how nitrogen dioxide and carbon monoxide are formed in the car engine, explain why the amounts of nitrogen dioxide and carbon monoxide vary in this way.

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.....[3]

[total = 10 marks]

Q2

The atmosphere contains a large number of gases including oxygen, nitrogen, carbon dioxide, sulfur dioxide, oxides of nitrogen, methane and chlorofluorocarbons (CFCs).

(a) Carbon dioxide, methane and CFCs are greenhouse gases.

(i) State **one** effect of an increase in the atmospheric concentration of carbon dioxide and methane.

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.....[1]

(ii) State **one** source of methane gas.

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.....[1]

(iii) State one **other** environmental effect of the presence of CFCs in the atmosphere.

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.....[1]

(b) The formula of one chlorofluorocarbon is $CFCl_3$.
Draw a dot-and-cross diagram to show the bonding in a molecule of $CFCl_3$.
You only need to show outer shell electrons.

[2]

(c) Oxides of nitrogen are produced during the combustion of petrol (gasoline) in a car engine.

(i) Describe the chemical reaction that takes place within a car engine to form nitric oxide, NO.

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.....[1]

(ii) Most of the nitric oxide and other pollutants present in the exhaust gases of a car are removed in a catalytic converter.
Describe the redox reactions that happen within a catalytic converter.

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.....[2]

(d) Nitrogen dioxide is one of the causes of acid rain.
Two moles of nitrogen dioxide react with one mole of water to make an aqueous solution of two acids only.
One of these acids is nitric acid.
Deduce the formula of the other acid.

.....[1]

[Total: 9]

Q3

Oxides of nitrogen in the upper atmosphere cause damage to the ozone layer.

Nitrogen monoxide, NO, damages the ozone layer by reacting with ozone in a two-step reaction.

$$NO + O_3 \rightarrow NO_2 + O_2 \qquad \text{step 1}$$
$$NO_2 + O_3 \rightarrow NO + 2O_2 \qquad \text{step 2}$$

(b) One nitrogen monoxide molecule can destroy thousands of ozone molecules.
Use the equations for steps 1 and 2 to explain why.

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[2]

(c) Using the equations for steps 1 and 2, derive the equation for the **overall** reaction.

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[1]

(d) Oxides of nitrogen are removed from car exhaust emissions by catalytic converters.
In a converter, the oxides of nitrogen react with carbon monoxide.
Nitrogen and carbon dioxide are produced and released into the atmosphere.

Suggest **two** potential environmental hazards that may arise from the car exhaust emissions, should the catalytic converters fail to work.

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[2]

Q4

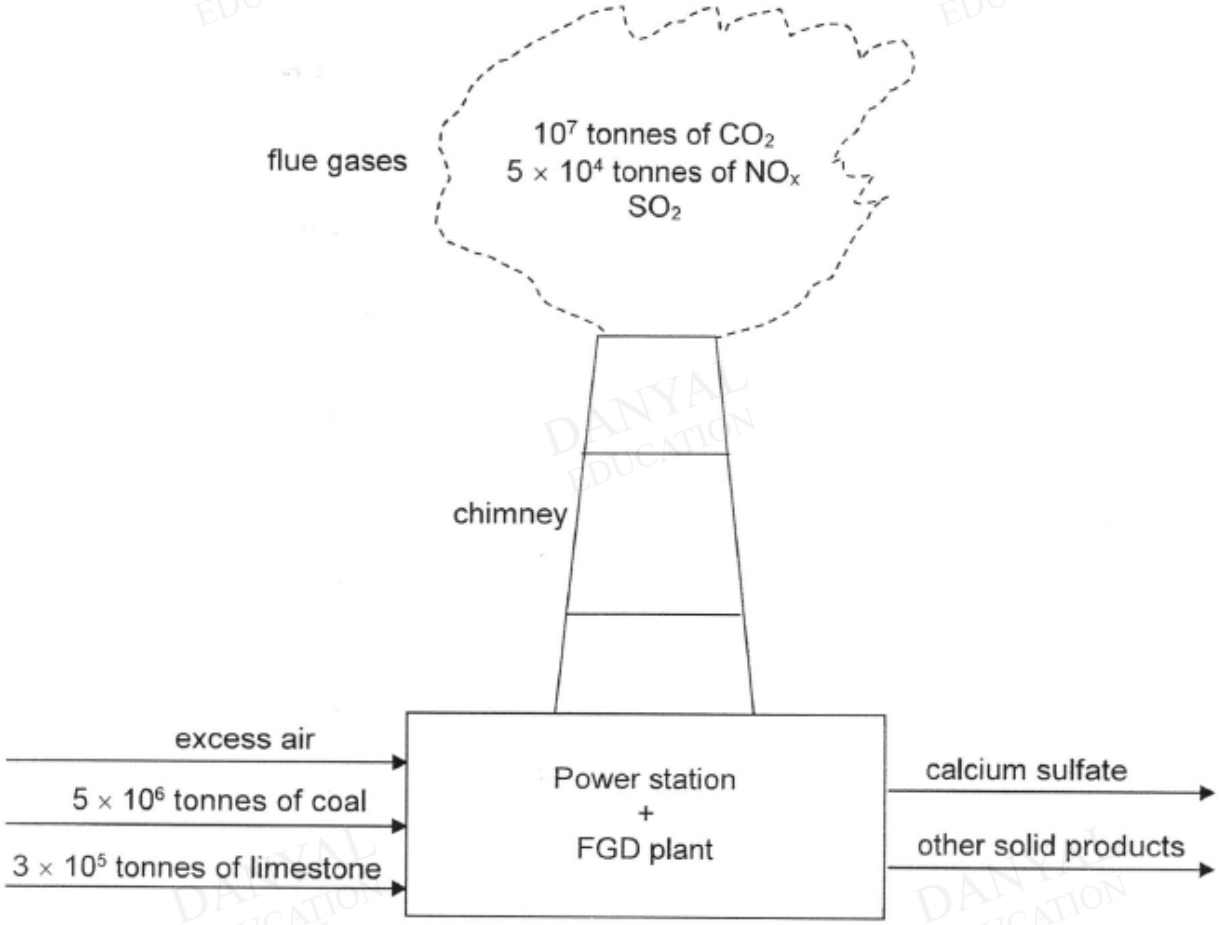
Part 1

A coal-fired power station is fitted with a Flue Gas Desulphurisation (FGD) plant, which removes sulfur dioxide from the waste gases. In the FGD plant, the waste gases are treated with powdered limestone ($CaCO_3$). The limestone reacts with sulfur dioxide producing calcium sulfite ($CaSO_3$) and carbon dioxide.

$$CaCO_3 + SO_2 \rightarrow CaSO_3 + CO_2$$

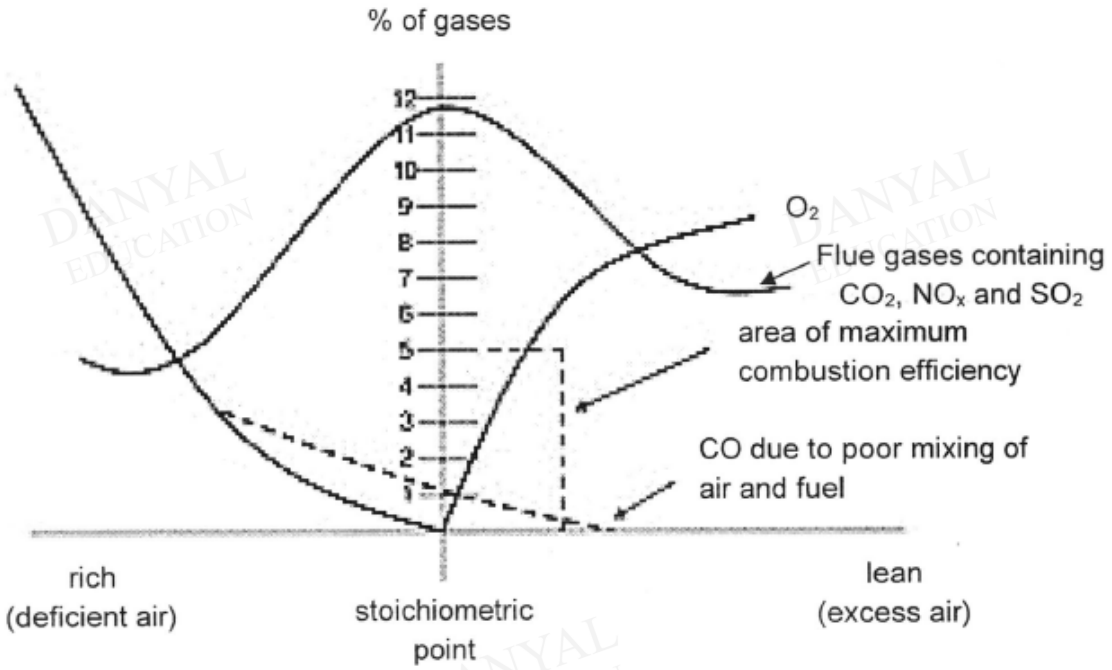
The calcium sulfite is then oxidised by air to form solid calcium sulfate.

The diagram below shows the masses of substances used, and produced, by such a coal-fired power station with an FGD plant in one year.



Part 2

FGD plant operators have used combustion flue gas analysis for decades as a method of optimizing boiler combustion fuel/air ratios. By measuring the amount of excess oxygen and/or carbon monoxide (CO) in the flue gases, the plant can be tuned to operate at the best heat rate and lowest oxides of nitrogen levels. Operation at best efficiency also inherently produces the least amount of carbon dioxide.



Combustion at stoichiometric point as seen in the graph above occurs when all of the fuel is reacted with just the right amount of oxygen in the combustion air so that no fuel is left unburned and no oxygen remains in the flue gas. Any air that is not used to combust the fuel is called "excess air".

(a) Using the information given in **Part 1**, calculate the maximum mass of sulfur dioxide which could be removed by the given amount of limestone in the FGD plant.

[3]

(b) Using the information given in **Part 1**, briefly describe the reaction that provides the energy used in the power station.

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..... [1]

(c) Using the information given in **Part 2**, describe and explain the percentage of carbon monoxide and oxygen at stoichiometric point.

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..... [3]

(d) Explain why the percentage of flue gases are at their maximum at stoichiometric point.

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..... [3]

[Total: 10]

Q5

The information below is about the extraction of zinc.

The method of extraction of zinc has changed, as different ores containing the element have been discovered, and as technology has improved.

Extraction Process 1

In the earliest process, calamine (impure zinc carbonate) was heated with charcoal in earthenware pots. This two-stage process gives a low yield of zinc.

$$ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$$

$$ZnO(s) + C(s) \rightarrow Zn(s) + CO(g)$$

Extraction Process 2

A new two-stage process was developed using zinc sulfide ores. All of the waste gases from this process were released into the atmosphere.

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

$$ZnO(s) + C(s) \rightarrow Zn(s) + CO(g)$$

Extraction Process 3

This uses the electrolysis of aqueous solutions of very pure zinc sulfate. The first step in this process is the same as the first step in Extraction Process 2. The second step uses sulfuric acid made from SO_2 collected in the first step. The third step involves the electrolysis of zinc sulfate solution to form pure zinc.

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

$$ZnO(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2O(g)$$

$$ZnSO_4(aq) \rightarrow Zn(s) \quad \text{[electrolysis]}$$

The electrolysis of zinc sulfate solution can be carried out by using graphite or zinc as anode. When zinc is used, the anode needs to be replaced frequently.

(b) Suggest which of the three extraction processes is the most environmentally friendly. Give a reason for your answer.

[3]

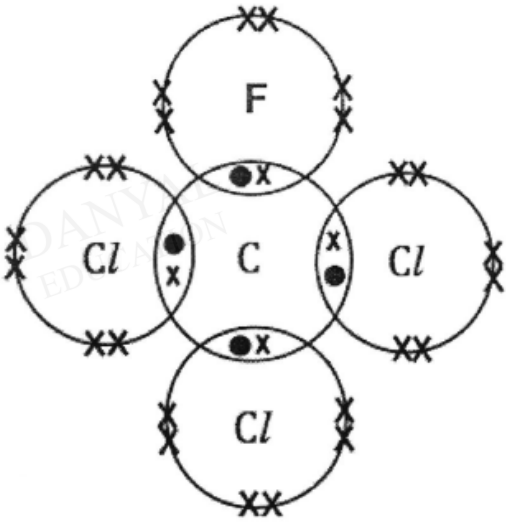
Answers

Atmosphere Test 1.0

Q1

(a)(i)	This is a redox reaction because nitrogen is reduced as its oxidation state decreases from +4 in NO_2 to 0 in N_2, [1] and carbon is oxidized as its oxidation state increases from +2 in CO to +4 in CO_2. [1]	[2]
(a)(ii)	No, I do not agree. Carbon dioxide is still produced in the catalytic converter, which can cause global warming.	[1]
(b)	When the catalyst is powdered, the reacting surface area is larger/greater, [1] resulting in a higher frequency of effective collisions, and thus a faster speed/rate of reaction. [1]	[2]
(c)(i)	As the amount of air increases, the percentage of CO decreases exponentially to less than 1%. [1] The amount of NO_2 initially increases with the amount of air, but later decreases when there is even more air. [1]	[2]
(c)(ii)	The more air, the more oxygen present. Hence, the percentage of CO decreases when there is more oxygen because the CO will react with oxygen to form CO_2. (any explanation that has the correct idea that less incomplete combustion takes place) [1] The more air, the more oxygen and nitrogen present. Hence, the increased amounts of oxygen and nitrogen will react to produce more NO_2. [1] However, when there is a lot of NO_2, it will react with the CO present to form N_2 and CO_2, hence causing the amount of NO_2 to decrease. [1]	[3]

Q2

A6 a(i)	Global warming/ ice caps melting/ sea level rising	1
(ii)	One source of methane is rotting vegetation.	1
(iii)	CFCs cause ozone depletion.	1
b		Minus 1 mark for each mistake
c(i)	Reaction of nitrogen with oxygen at high temperature produces nitric oxide.	1
(ii)	Nitric oxide is reduced to form nitrogen gas. Carbon monoxide is oxidised to form carbon dioxide.	1 1
d	HNO_2	1

Q3

(b) No loss in NO molecules. [1]
The NO molecules removed in step 1 (after reacting with ozone) are regenerated in step 2 (in reaction with more ozone). [1]

(c) $2O_3 \rightarrow 3O_2$ [1]

(d) *'Catalytic converters fail to work' means release of oxides of nitrogen and carbon monoxide into the atmosphere.*
Accept any valid health or environmental hazards due to oxides of nitrogen and carbon monoxide.

Suggested answers:

- Release of carbon monoxide poses danger of carbon monoxide poisoning. Inhalation of carbon monoxide prevents haemoglobin from absorbing oxygen and may lead to suffocation / organ failure / headaches. [1]
- Release of oxides of nitrogen may result in formation of acid rain, which leads to corrosion of buildings / structures. [1]

Q4

(a)	No. of moles of $CaCO_3 = \frac{3\times10^5\times10^6}{100} = 3\times10^9$ From the given equation, 1 mole of $CaCO_3$ removes 1 mole of SO_2 No. of moles of SO_2 removed = **3×10^9** Max. mass of SO_2 removed = $3 \times 10^9 \times 64$ = **1.92×10^5 tonnes**	[1] [1] [1]
(b)	The **combustion of coal** (or fuel) is exothermic which produces the energy needed in the power station.	[1]
(c)	Carbon monoxide – 1% (from graph) Poor mixing of oxygen in air and coal (fuel) caused **incomplete combustion of coal**, hence producing traces of carbon monoxide Oxygen – 0% (from graph) **All the coal (fuel) has reacted with the oxygen** so that no fuel is left unburned and no oxygen remains in the flue gas 1 mark for quoting the right % values of carbon monoxide & oxygen	[1] [1] [1]
(d)	**Carbon dioxide** All the coal (fuel) is combusted completely to form high amount of carbon dioxide gas **Sulfur dioxide** Coal contains **sulfur as an impurity**. When coal burns completely, a high amount of sulfur dioxide is produced. **Oxides of nitrogen** The furnace in FGD plant is at **high temperature, nitrogen and oxygen** from the air will react/ combined to form oxides of nitrogen	[1] [1] [1]

Q5

(b)	Process 3. (with at least one reason) SO_2 is used to make sulfuric acid. *(Any answer)* No CO is produced, unlike processes 1 and 2. CO causes headaches / fatigue /breathing difficulties / death / Reduces ability of haemoglobin to transport oxygen SO_2 from process 2 may irritate the eyes / lungs / Cause breathing difficulties / inflammation of the lungs (bronchitis) / Reacts with water in the atmosphere to form acid rain, which corrodes buildings and harms aquatic life and plants (R: no air pollutant is released to the environment.)	1 1 1