



10

AIR

Content

- 10.1 Air
- 10.2 Water (supplementary topic)

Learning Outcomes:

Candidates should be able to:

10.1 Air

- (a) describe the volume composition of gases present in dry air as being approximately 78% nitrogen, 21% oxygen and the remainder being noble gases (with argon as the main constituent) and carbon dioxide
- (b) name some common atmospheric pollutants, e.g. carbon monoxide; methane; nitrogen oxides (NO and NO₂); ozone; sulfur dioxide; unburned hydrocarbons
- (c) state the sources of these pollutants as
 - (i) carbon monoxide from incomplete combustion of carbon-containing substances
 - (ii) nitrogen oxides from lightning activity and internal combustion engines
 - (iii) sulfur dioxide from volcanoes and combustion of fossil fuels
- (d) describe the reactions used in possible solutions to the problems arising from some of the pollutants named in (b)
 - (i) the redox reactions in catalytic converters to remove combustion pollutants (see also 6.1(d))
 - (ii) the use of calcium carbonate to reduce the effect of 'acid rain' and in flue gas desulfurisation
- (e) discuss some of the effects of these pollutants on health and on the environment
 - (i) the poisonous nature of carbon monoxide
 - (ii) the role of nitrogen dioxide and sulfur dioxide in the formation of 'acid rain' and its effects on respiration and buildings
- (f) discuss the importance of the ozone layer and the problems involved with the depletion of ozone by reaction with chlorine containing compounds, chlorofluorocarbons (CFCs)
- (g) describe the carbon cycle in simple terms, to include
 - (i) the processes of combustion, respiration and photosynthesis
 - (ii) how the carbon cycle regulates the amount of carbon dioxide in the atmosphere
- (h) state that carbon dioxide and methane are greenhouse gases and may contribute to global warming, give the sources of these gases and discuss the possible consequences of an increase in global warming

10.2 Water (supplementary topic)

- (a) state that water from natural sources contains a variety of dissolved substances
 - (i) naturally occurring (mineral salts; oxygen; organic matter)
 - (ii) pollutant (metal compounds; sewage; nitrates from fertilisers; phosphates from fertilisers and detergents)
- (b) discuss the environmental effects of the dissolved substances named in (a)
 - (i) beneficial, e.g. oxygen and mineral salts for aquatic life
 - (ii) pollutant, e.g. hazards to health; eutrophication
- (c) outline the purification of the water supply in terms of
 - (i) filtration to remove solids
 - (ii) use of carbon to remove tastes and odours
 - (iii) chlorination to disinfect the water
- (d) state that seawater can be converted into drinkable water by desalination

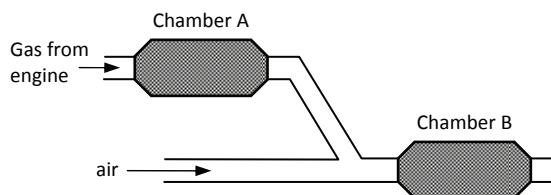
10 • 1 Air

MCQs

07ZZ10-01

10-1-M-01

The diagram below shows a catalytic converter that is installed in a car engine that runs on petrol. It consists of a reductive chamber A and an oxidative chamber B.



Which of the following reaction is most likely to occur in the oxidative chamber?

- A $N_2 + O_2 \rightarrow N_2O_2$
- B $2CO + O_2 \rightarrow 2CO_2$
- C $CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$
- D $Pb + O_2 \rightarrow PbO_2$

07ZZ10-02

10-1-M-02

Which of the following pairs are greenhouse gases?

- A carbon dioxide and carbon monoxide
- B chlorofluorocarbons and ozone
- C chlorofluorocarbons and carbon dioxide
- D carbon dioxide and methane

07ZZ10-03

10-1-M-03

Which gas is not likely to be present in air?

- A carbon dioxide
- B hydrogen
- C oxygen
- D argon

07ZZ10-04

10-1-M-04

Which of the following pairs of air pollutants and their sources is correct?

	Pollutant	Source
A	Ozone	Detergents
B	Carbon monoxide	Vehicle engines
C	Methane	Aerosol propellants
D	Nitrogen oxide	Fertilizers

07ZZ10-05

10-1-M-05

The data gives the concentration, in parts of pollutant per billion parts of air, of polluting gases in four different industrialized cities.

In which city are limestone buildings under greatest threat from pollution?

City	Nitrogen dioxide	Ozone	Carbon monoxide
A	17	23	0.03
B	32	30	3.0
C	38	11	0.2
D	45	21	0.01

07ZZ10-06

10-1-M-06

Which of the following about atmospheric pollutants is true?

- A Hydrocarbons react with fluorine to produce a gas that depletes the ozone layers.
- B Ozone at low levels in the atmosphere helps to screen off ultra-violet rays.
- C Sulfur dioxide gas can be removed by reacting it with calcium chloride.
- D Sulfur dioxide gas reacts with rainwater and oxidizes in air to form sulfuric acid which contributes to acid rain.



07ZZ10-07

10-1-M-07

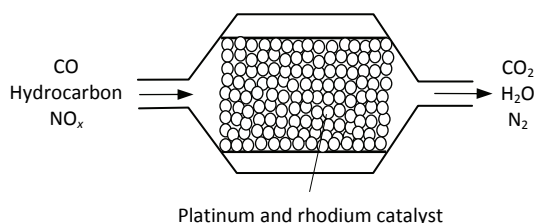
Which of the following gases is not responsible for the formation of photochemical smog?

- A ethene
- B oxides of nitrogen
- C ozone
- D sulfur dioxide

07ZZ10-08

10-1-M-08

The diagram below represents a section of a catalytic converter in the exhaust system of a car. Harmful gases are converted into carbon dioxide, nitrogen and water vapour.



Which processes take place in this catalytic converter?

- I. Carbon monoxide and hydrocarbons react together.
- II. Carbon monoxide and nitrogen oxides react together.
- III. Platinum and rhodium catalyse redox reactions.

- A I, II and III
- B I and II only
- C II and III only
- D I only

07ZZ10-09

10-1-M-09

Why are catalytic converters fitted to car exhausts?

- A To reduce the amount of carbon dioxide emitted.
- B To reduce the amount of nitrogen oxides emitted.
- C To reduce global warming.
- D To improve energy conservation.

07ZZ10-10

10-1-M-10

Methane, sulfur dioxide, carbon dioxide and nitrogen dioxide are gases which affect the atmosphere and the environment.

Which of the following gives the correct source and effect of the gases?

	Gas	Source	Effect
A	Methane	Bacterial decay of vegetable matter	Global warming
B	Sulfur dioxide	Volcanic eruptions	Photochemical smog
C	Carbon dioxide	Combustion of fuels	Acid rain
D	Nitrogen dioxide	Internal combustion engines	Depletion of the ozone layer

10-1-M-11

[Examined in 2013]

The list shows four methods that were suggested for the formation of carbon dioxide.

- 1 action of an alkali on a carbonate
- 2 action of heat on a carbonate
- 3 complete combustion of methane
- 4 reaction of a carbonate with oxygen

Which methods would result in the production of carbon dioxide?

- A 1 and 2
- B 1 and 4
- C 2 and 3
- D 3 and 4

[Teachers' Comments] Response D is the most popular of the wrong answer. Candidates knew that answer 1 was wrong but then, not knowing sufficiently about carbonate chemistry, chose the wrong one of the remaining alternatives.

Questions – 10.1

07ZZ10-11

10-1-Q-01

Three of the most polluting emissions from cars are nitrogen monoxide (NO), carbon monoxide and unburnt hydrocarbons.

The actual concentration of each of these components depends on the mode of operation of the vehicle and the air/fuel ratio that is used.

The following table shows some typical figures. (ppm = parts per million)

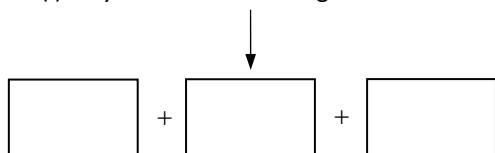
Mode of operation	Air / fuel ratio	Nitrogen monoxide emissions /ppm	Carbon monoxide emissions /ppm	Unburnt hydrocarbons /ppm
Idling engine	15/1	14	4000	550
Accelerating	15/1	3700	1000	60
Idling engine	12/1	10	8000	950
Accelerating	12/1	1000	5000	650

Using the information given in the table, explain why the following affects the concentration of each pollutant gases.

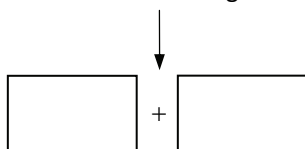
- (a) Idling engine
- Low emissions of nitrogen monoxide.
 - High emissions of unburnt hydrocarbon.
- (b) High air/fuel ratio and accelerating, low emissions of carbon monoxide.
- (c) When nitrogen monoxide, carbon monoxide and unburnt hydrocarbons enter into platinum/rhodium catalytic converter, some possible reactions take place.

Fill in the names of the products formed.

- (i) hydrocarbons + nitrogen monoxide



- (ii) carbon monoxide + nitrogen monoxide



07ZZ10-12

10-1-Q-02

A group of chlorine-containing compounds, CFCs, poses threat to the environment.

- Explain the harm that they cause.
- Suggest the molecular formula for a CFC.



07ZZ10-13

10-1-Q-03

When rain water falls, it dissolves some carbon dioxide and becomes slightly acidic.

Coal and oil both contain some sulfur compounds; when they are burnt, sulfur dioxide is produced as well as other expected compounds. The sulfur dioxide makes the rain water more acidic, whether or not it is oxidized to sulfuric acid.

The combustion of fuels causes the formation of some oxides of nitrogen. These oxides also make water acidic, especially when they are converted to nitric acid.

In parts of the country which have granite rocks, the water remains acidic. In other parts with limestone rocks, the acids are neutralized.

Nitrate pollution of our drinking water is a cause for concern, especially at times of low rainfall. Another pollutant of river and sea water is sewage, which increases the need for oxygen for its degradation.

- Write an equation to show how carbon dioxide in rain water makes it acidic.
- If coal and oil are burnt completely in air, what are the expected products of combustion?
- What is the first product when sulfur dioxide dissolves in water?
- Which oxides of nitrogen lead to the formation of nitric acid?
- Write an equation, and explain how limestone neutralizes an acid.
- Why is nitrate pollution serious at times of low rainfall?
- What can be done to combat pollution of water by sewage?



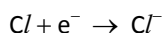


07ZZ10-14

10-1-Q-04

Many scientists believe that the chlorine atoms which come from compounds known as chlorofluorocarbons (CFCs) released to the atmosphere are responsible for the depletion of ozone layer in the upper atmosphere.

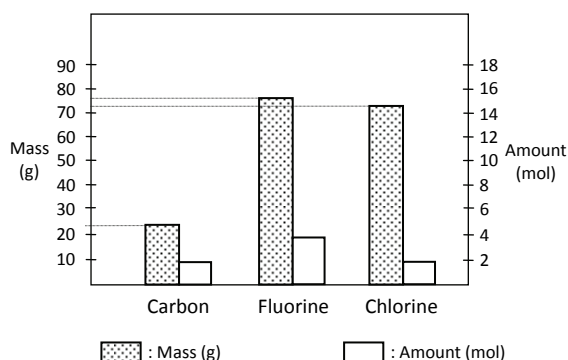
- (a) Ozone is an allotrope of oxygen.
Give the formula of another allotrope of oxygen.
- (b) Ann wants to buy a can of aerosol hairspray. The label says the can contains CFCs.
Jo says that CFCs deplete the ozone layer in the upper atmosphere and that Ann should buy a can of hairspray that does not use CFCs. Ann says that this is just scientific nonsense and still thinks she should buy the cheaper can of hairspray containing CFCs.
- (i) Explain how the chlorine atoms from CFCs cause the depletion of ozone layer in the upper atmosphere.
- (ii) Explain why there is a concern about the ozone layer in the upper atmosphere.
- (c) An American scientist suggested that depletion of the ozone layer in the upper atmosphere could be prevented by aluminium rods suspended below helium balloons.
The rods would be electrically charged and would give electrons to the chlorine atoms from CFCs and turn them into chloride ions.



Chloride ions would not affect the ozone layer.

Suggest why free chlorine atoms affect the ozone layer but chloride ions do not.

- (d) The graph below shows the mass and amount of carbon, fluorine and chlorine atoms in one mole of a compound of CFCs found in the aerosol can of hairspray.



Using the above information, determine the molecular formula of the compound of CFCs.



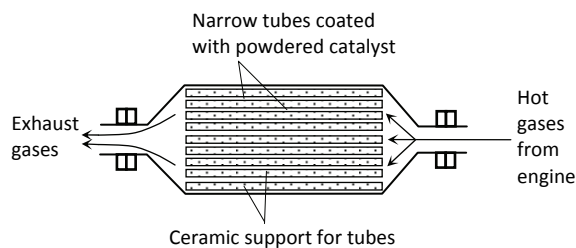
07ZZ10-15

10-1-Q-05

The table below shows some data about the composition of the mixtures of exhaust gases from a car.

Substances in exhaust gases	% by volume
Nitrogen	67.60
Carbon dioxide	12.00
Water vapour	11.00
Oxygen	9.00
Carbon monoxide	0.20
Oxides of nitrogen	0.15
Unburnt hydrocarbons	0.05

- (a) Using the information in the table, calculate the volume of oxygen that has reacted with gasoline if 10 dm^3 of air is used.
- (b) Explain why the exhaust gases from the car contain large amounts of nitrogen, carbon dioxide and water vapour.
- (c) One of the exhaust gases present in large quantity may result in global warming.
Give the name of this gas and describe one environmental consequence of an increase in global warming.
- (d) Pollution from cars is reduced by using catalytic converters.
- (i) Catalysts in the converter increase the rate of reaction. The figure below shows the structure of a catalytic converter.



Give two other reasons why the reactions in the catalytic converters are fast.

- (ii) The table below shows some data about the composition of the mixtures of exhaust gases from two identical cars, one with and one without a catalytic converter.

Substances in exhaust gases	% by volume	
	Car without catalytic converter	Car with catalytic converter
Nitrogen	67.60	67.65
Carbon dioxide	12.00	12.25
Water vapour	11.00	11.10
Oxygen	9.00	9.00
Carbon monoxide	0.20	0
Oxides of nitrogen	0.15	0
Unburnt hydrocarbons	0.05	0

Using the information from the above table, suggest how the catalytic converter helps to reduce air pollution from cars. You should show relevant equations in your answer.

- (iii) Describe how these air pollutants from the car affect the environment.

07ZZ10-16

10-1-Q-06

Scientists have predicted that there will be an increase of 0.8 to 2°C in the Earth's surface temperature by 2008, due to the 'greenhouse effect' caused by some gases in the atmosphere.

- (a) What is meant by the 'greenhouse effect'?
- (b) Name two main gases that cause the 'greenhouse effect'.

07ZZ10-17

10-1-Q-07

- (a) One of the uses of chlorine is in the manufacture of chlorofluorocarbons. Chlorofluorocarbons are often used as propellants in aerosols.

Explain why scientists have been concerned about the use of chlorofluorocarbons in aerosols.

- (b) Difluoromethane, CH_2F_2 , is a hydrofluorocarbon. It is a good substitute for chlorofluorocarbon in aerosols. Draw a 'dot and cross' diagram to show

the bonding in CH_2F_2 . Show only the outermost electrons.

07ZZ10-18

10-1-Q-08

Oxides of nitrogen and carbon monoxide are emitted from the exhaust pipes of cars.

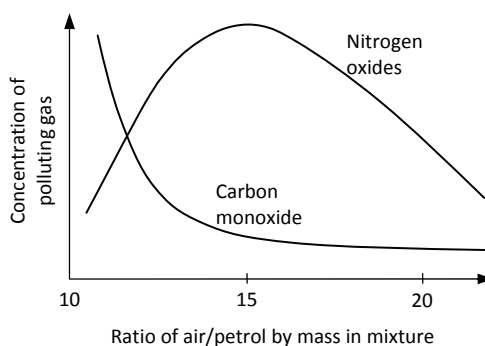
- (a) (i) Explain the presence of carbon monoxide and nitrogen in the exhaust of cars.
- (ii) Describe one harmful effect if oxides of nitrogen are released into the atmosphere.
- (b) Catalytic converters are fitted to the car exhaust pipes to promote the reaction between nitrogen oxides and carbon monoxide to produce two relatively harmless gases. Name the gases and write a balance chemical equation for the reaction.

07ZZ10-19

10-1-Q-09

In a car engine, oxides of nitrogen and carbon, and petrol vapour, is mixed with air and combustion takes place.

- (a) Name the two main products of combustion of petrol in an excess of air.
- (b) The amount of air mixed with petrol vapour in a car engine can be varied. Two pollutants in the exhaust gases from a car are carbon monoxide and nitrogen oxides. The graph below shows how the amounts of these pollutants in the exhaust gases depend on the composition of the air/petrol mixture.



- (i) Explain how carbon monoxide and nitrogen oxides are produced in the car engine.
- (ii) Describe how the concentration of carbon monoxide varies as the air/petrol ratio is increased in the engines.



(iii) It was found that cars produced the maximum amount of energy when the air/petrol ratio is about 15. Suggest why the maximum amount of nitrogen oxides is produced under this condition.

(c) Name one other gaseous pollutant produced by car engines, other than carbon monoxide and nitrogen oxides.

07ZZ10-20

10-1-Q-10

Coal-fired power stations emit sulfur dioxide into the atmosphere. Sulfur dioxide is a pollutant that damages the environment.

(a) How does sulfur dioxide damage the environment?

(b) One method of removing the sulfur dioxide is to absorb it in a slurry of magnesium hydroxide to produce magnesium sulfite, MgSO_3 .

(i) Write an equation, with state symbols, for the reaction that occurs.

(ii) What type of reaction is taking place in (i)?

(c) The magnesium sulfate is later heated to drive off the sulfur dioxide, leaving magnesium oxide which can be recycled.

(i) Write an equation, with state symbols, to show how sulfur dioxide is released.

(ii) Give one use for the sulfur dioxide that is given off.

(d) Another method to remove sulfur dioxide is to use limestone to absorb the gas to produce gypsum, calcium sulfate.

Suggest one disadvantage that this method has over the above method.

07ZZ10-21

10-1-Q-11

The molecular formula of chlorofluorocarbons (CFCs) can be worked out using a rule called the 'rule of 90'.

Example:

To find the molecular formula of CFC-11:

You add 90 to the number 11: $90 + 11 = 101$

The first digit of the result is the number of carbon atoms (C), the second digit is the number of hydrogen

atoms (H) and the third digit is the number of fluorine atoms (F).

This means that CFC-11 has 1 carbon atom, 0 hydrogen atom and 1 fluorine atom.

The number of chlorine atoms can then be worked out using the following formula:

$$\text{Number of chlorine atoms} = 2(\text{C} + 1) - \text{H} - \text{F}$$

In this case, number of chlorine atoms

$$= 2(1 + 1) - 0 - 1 = 3$$

Hence the molecular formula of CFC-11 is CCl_3F .

(a) Calculate the percentage by mass of chlorine in CFC-11.

(b) Use the 'rule of 90' to work out the molecular formula of CFC-132.

(c) CFC-132 can exist as different isomers. Draw the full structural formulae of any two isomers of CFC-132.

(d) Explain why there is a great concern about the release of CFCs into the atmosphere.

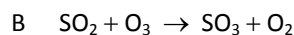
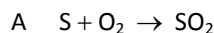
(e) HCFs are safe alternatives to CFCs.

Give the names of the three elements present in HCFs and suggest why HCFs are safe alternatives to CFCs.

10-1-Q-12

[Examined in 2012]

(a) The equations A and B below show two reactions which lead to the formation of acid rain.



(i) Write a word equation for reaction A. [2]

(ii) Which two of the following statements about reaction B are correct?

Tick two boxes. [2]

SO_2 is oxidised to SO_3

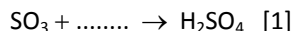
SO_2 is reduced to SO_3

O_3 is reduced to O_2

O_3 is oxidised to O_2

<input type="checkbox"/>
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- (iii) Complete the equation to show how an aqueous solution of sulfuric acid, H_2SO_4 , is formed from SO_3 .



- (b) Describe and explain the effect of sulfuric acid on buildings made from limestone (calcium carbonate). [3]
- (c) State one effect of acid rain other than on buildings. [1]

[Total: 9]

[Teachers' Comments] Many parts of this question were well answered. Equation writing was generally good and many understood which species were oxidised and which were reduced in a given equation. As in previous sessions, environmental chemistry was not well known. In part (b) few candidates scored full credit for explaining the effect of acid rain on buildings made from limestone. Many concentrated on the formation of acid rain rather than explaining the reaction. Candidates should be advised to look out for keywords in the question, such as 'explain' or 'describe', and be able to understand the difference between them.

- (a) (i) Most candidates obtained at least some credit for the word equation. The commonest answer was sulfur oxide rather than sulfur dioxide. Some confused sulfur with sodium. A few candidates tried to write equations without + signs or the arrow between the reactants and product, or included unnecessary numbers in their answers, e.g. 2sulfur dioxide, oxygen₂. A number included oxygen as a product. This may have been because the candidate was looking at equation B rather than equation A.
- (ii) Many candidates scored full credit. The commonest errors were ticking only one box or ticking the second and fourth boxes (oxidation and reduction the wrong way round).
- (iii) A majority of the candidates gave the correct answer. The commonest errors were to suggest H_2 or OH . These candidates presumably did not realise that the question was about counting atoms so that there are an equal number of each type on each side of the equation.
- (b) Few candidates gave convincing answers to this question. Many referred to buildings collapsing, melting, being destroyed, trapping people inside, burning and in more than one case causing electrical shock waves. The word 'corrosion' was often incorrectly used instead of 'erosion'. In many answers, the candidates gave a good description of

how acid rain forms without referring to the effects on the buildings.

- (c) Fewer than half the candidates were able to give an appropriate effect of acid rain other than on buildings. Some simply reiterated acidification of limestone as described in part (b). A considerable number gave one word answers such as 'plants' or 'animals' without further qualification.





10 • 2

Water (supplementary topic)

10 – 9

MCQs

07ZZ10-22

10-2-M-01

Which of the following is added to remove tastes and odours in the purification of the water supply?

- A alum
- B carbon
- C chlorine
- D fluorine



07ZZ10-23

10-2-M-02

Large amounts of decaying vegetation is harmful to fish in rivers because they _____.

- A produce nitrogen compounds
- B add nitrogen gas to water
- C decrease the amount of oxygen in the water
- D would form acidic water with a pH value of less than 3



07ZZ10-24

10-2-M-03

Which of the following is **not** a problem caused by the excessive use of soluble fertilizers close to a river?

- A growth of algae increase
- B number of bacteria decreases
- C concentration of dissolved oxygen decreases
- D amount of sunlight reaching aquatic plants decreases



07ZZ10-25

10-2-M-04

Nitrates from fertilizers used on farmland cause pollution.

Why do nitrates pollute rivers?

- A Nitrates are salts.
- B Nitrates are very soluble in water.
- C Nitrates contain oxygen.
- D Nitrates ions are negatively charged.



07ZZ10-26

10-2-M-05

What is the purpose of using activated carbon in the purification of water?

- A To remove tastes and odours
- B To disinfect the water
- C To cause coagulation of solid particles
- D To neutralize acidic substances in water



Answer keys:**10 • 1****MCQ**

10-1-M-01	B
10-1-M-02	D
10-1-M-03	B
10-1-M-04	B
10-1-M-05	D
10-1-M-06	D
10-1-M-07	D
10-1-M-08	C
10-1-M-09	B
10-1-M-10	A
10-1-M-11	C

Questions**10-1-Q-01**

- (a) (i) Oxides of nitrogen emissions are the lowest during idle as the temperature of the engine is low
(ii) rate of combustion of hydrocarbons is low
- (b) most carbon monoxide would be oxidized into carbon dioxide in an oxygen-rich environment
- (c) (i) Carbon dioxide, water and nitrogen
(ii) Nitrogen and carbon dioxide gas

10-1-Q-02

- (a) CFCs deplete ozone layer
(b) CF_2Cl_2

10-1-Q-03

- (a) $\text{CO}_2(g) + \text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{CO}_3(aq)$

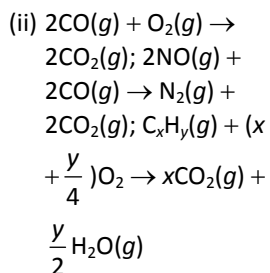
- (b) Carbon dioxide and water
(c) sulfurous acid
(d) NO and NO_2
(e) $\text{CaCO}_3(s) + \text{H}_2\text{SO}_4(aq) \rightarrow \text{CaSO}_4(s) + \text{CO}_2(g) + \text{H}_2\text{O}(l)$
(f) promote rapid growth of algae
(g) proper disposal of sewage

10-1-Q-04

- (a) O_2
(b)(i) CFCs compounds decomposes to produce Cl_2
(ii) ozone reduces skin cancer/ cataracts
(c) 7 valence electrons/ full octet structure
(d) $\text{C}_2\text{F}_4\text{Cl}_2$

10-1-Q-05

- (a) 1.1 dm^3
(b) Oxides of nitrogen are converted into nitrogen in the catalytic converter. Carbon monoxide is oxidized to carbon dioxide, and the unburnt hydrocarbons are combusted to produce carbon dioxide and water
(c) carbon dioxide
(d) (i) high temperature/ catalyst



- (iii) Carbon monoxide causes breathing difficulties. Unburnt hydrocarbons

causes photochemical smog and irritation to the eyes and lungs. Oxides of nitrogen contribute to acid rain

10-1-Q-06

- (a) greenhouse gases trap heat radiation
(b) methane, carbon dioxide

10-1-Q-07

- (a) CFC destroy the ozone layer

10-1-Q-08

- (a) (i) CO is due to incomplete combustion of hydrocarbons. Oxides of nitrogen are formed when oxygen molecules, reacts with nitrogen gas
(ii) acid rain
(b) nitrogen and carbon dioxide

10-1-Q-09

- (a) carbon dioxide and water
(b) (i) CO is due to incomplete combustion of hydrocarbons. Oxides of nitrogen are formed when oxygen molecules, reacts with nitrogen gas
(ii) decreases
(iii) increase in the concentration of oxygen atoms
(c) sulfur dioxide

10-1-Q-10

- (a) acid rain

- (b) (i) $\text{SO}_2(g) + \text{Mg}(\text{OH})_2(s) \rightarrow \text{MgSO}_3(s) + \text{H}_2\text{O}(l)$
(ii) neutralization reaction
(c) (i) $\text{MgSO}_3(s) \rightarrow \text{SO}_2(g) + \text{MgO}(s)$
(ii) manufacture sulfuric acid
(d) stable to heat

10-1-Q-11

- (a) 77.5%
(b) $\text{C}_2\text{H}_2\text{F}_2\text{Cl}_2$
(d) Chlorine atoms will destroy the ozone layer
(e) carbon, hydrogen, fluorine/ no chlorine

10-1-Q-12

- (a) (i) sulfur + oxygen \rightarrow sulfur dioxide
(ii) SO_2 is oxidised to SO_3 ; O_3 is reduced to O_2
(iii) H_2O
(b) H_2SO_4 reacts with CaCO_3 in a neutralisation with CO_2 released
(c) harms organisms in lakes

10 • 2**MCQ**

10-2-M-01	B
10-2-M-02	C
10-2-M-03	B
10-2-M-04	B
10-2-M-05	A