O Level Pure Chemistry Structured

Atmosphere Test 2.0

Q1

The amount of carbon monoxide present in air can be detected and measured by the reaction with a white crystalline solid called iodine pentoxide, I_2O_5. The chemical equation for the reaction is given as:

$$5CO(g) + I_2O_5(s) \rightarrow I_2(s) + 5CO_2(g)$$

(a) Describe a change that can be observed for the reaction.

.....[1]

(b) State a source of carbon monoxide and explain how it is produced.

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.....[2]

(c) Explain why it is important to have a reliable chemical test for carbon monoxide.

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.....[2]

[Total: 5]

Q2

Fig. 5.1 shows the reactions that lead to the depletion of ozone layer.

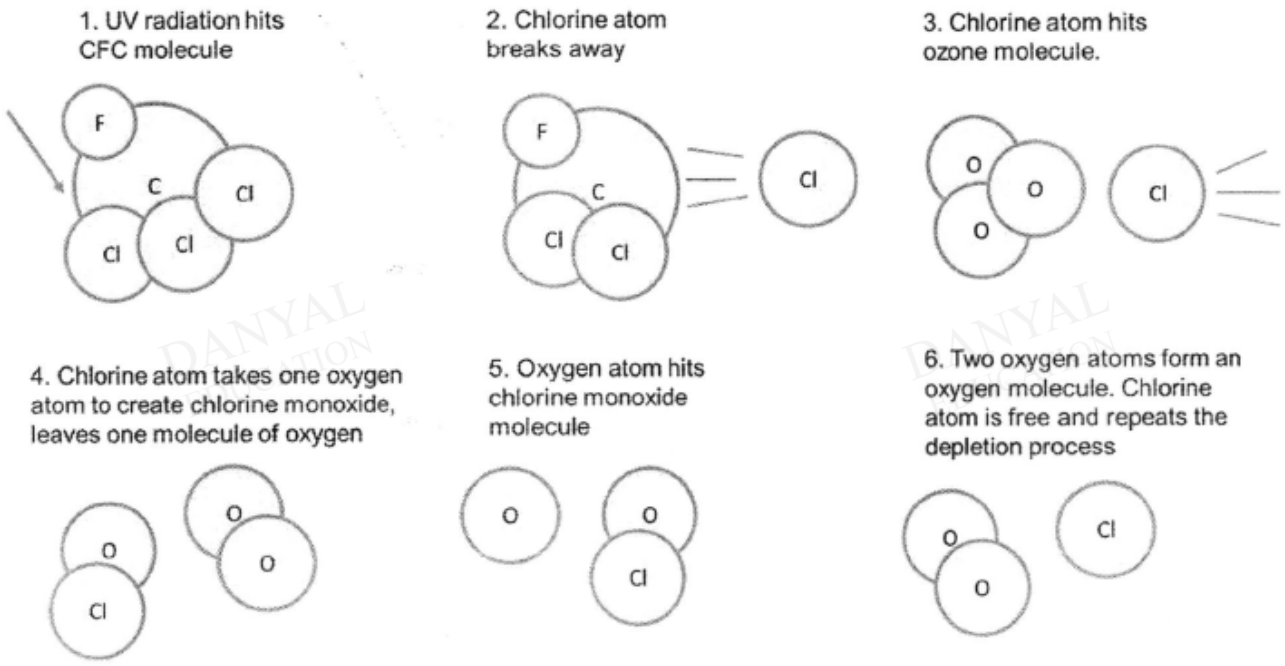

Fig. 5.1

(a) Identify an endothermic reaction in Fig. 5.1 and provide evidence to support your answer.

.....

..... [2]

(b) Suggest why a small amount of CFC is sufficient to threaten the depletion of the ozone layer.

.....

..... [2]

(c) With reference to Fig. 5.1, suggest whether the C – F bond is stronger or weaker than the C – C*l* bond.

.....

[1]

Fig. 5.2 shows an impact of ozone depletion.

Fig. 5.2

(d) Explain how ozone depletion causes the impact shown in the cartoon.

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[2]

[Total: 7 marks]

Q3

3 There are a range of atmospheric pollution problems currently threatening the Earth's general environment. The increased use of fossil fuels has a negative effect on the health of the environment in terms of air and water pollution.
Of all the fossil fuels, coal is the least expensive for its energy content. However, burning coal in electric power plants is a major source of carbon dioxide emissions. It also releases substantial amounts of methane. The U.S. Environmental Protection Agency's Clean Power Plan, as well as the low cost of natural gas, is leading older coal plants to close and reducing interest in new coal plants. Alternative sources of energy used as fuels are thus constantly sought after to meet the increasing demands of human activities.

Figure A below shows the changes in the type of fuel used between 1990 and 2002.

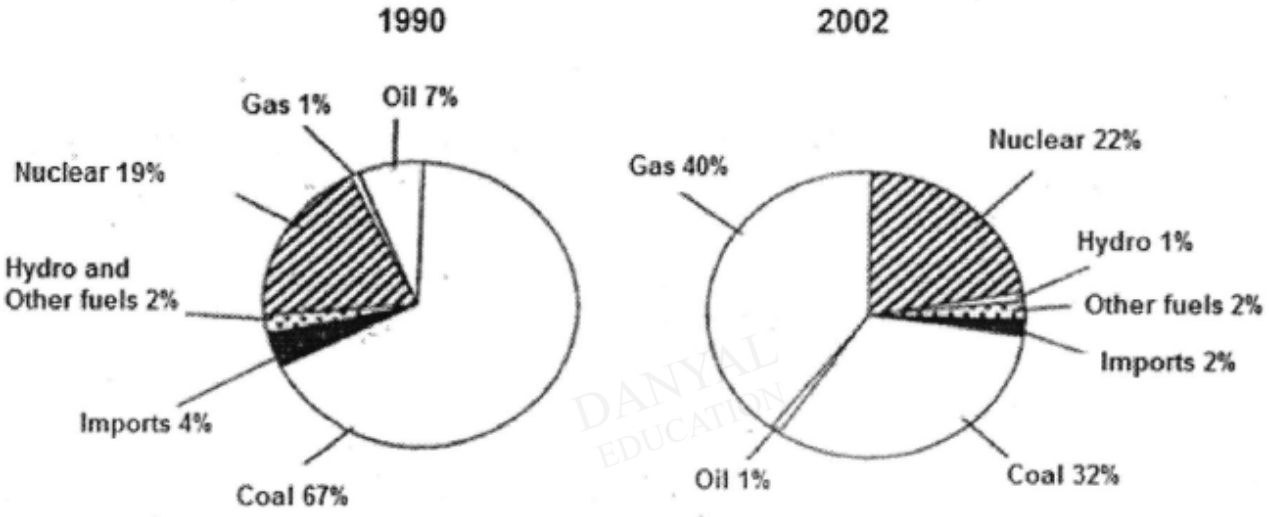

Figure A

Air pollution is caused by solid particles and poisonous gases in the air. These substances are called air pollutants, which include carbon monoxide and unburnt hydrocarbons.

Figure B shows the relationship between the air : fuel ratio and the production of air pollutants by the vehicle engines.

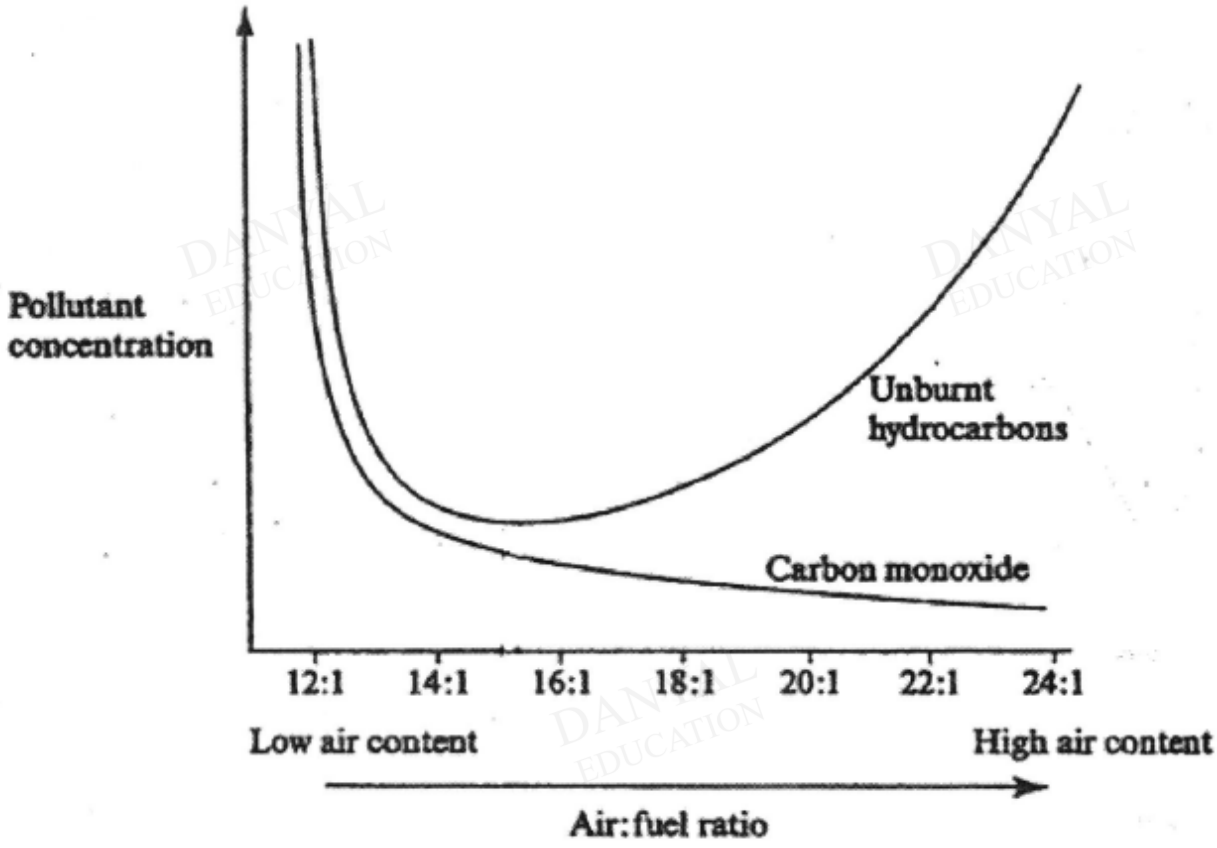

Figure B

(a) Using information provided, give two main changes in the type of fuel used over 12 years from 1990 to 2002. Suggest an explanation for these changes.

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.....[3]

(b) Using the information from **Figure B**, describe and explain the trend for the carbon monoxide curve.

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.....[3]

(c) Estimate the optimum air : fuel ratio to minimise pollution by carbon monoxide and unburnt hydrocarbons.

.....[1]

(d) (i) Name another air pollutant not mentioned in the graphs which is also produced by the vehicle engines.

.....[1]

(ii) Name the device fitted in cars which is used to remove both the emissions of carbon monoxide and the pollutant you named in **(d) (i)** from the car engine. Write an equation for this reaction.

.....

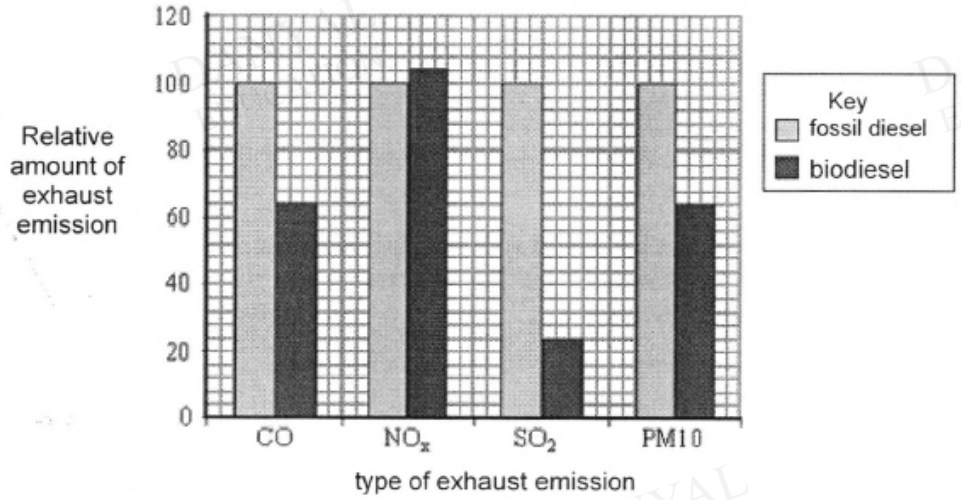
.....[2]

Q4

Diesel obtained from crude oil is often called fossil diesel.
Biodiesel can be made from many vegetable oils.

Tiny particles of solids are produced when the fuel does not burn completely. This increases the level of particulates (PM10) in the atmosphere. These particles are small enough to pass through the throat and nose and enter the lungs.

One research project compared the exhaust emissions when fossil diesel or biodiesel were used as fuels. Some of the relative amounts of these exhaust emissions are shown in the bar chart.



(a) **(i)** Using the data given, compare the exhaust emission between fossil diesel and biodiesel.

_____

_____

_____ [2]

(ii) Exhaust emissions from fossil diesel cause more harm to human health than those from biodiesel. Explain why.

_____

_____

_____

_____ [2]

(b) Some scientists suggest that biodiesel is ***carbon neutral***. Explain why.

_____

_____

_____ [2]

(c) Refrigerants are substances used to cool refrigerators and freezers. Until recently, many of the compounds used as refrigerants were chlorofluorocarbons (CFCs), but these are now known to form chlorine radicals. One such compound is $CFCl_3$.

$$CFCl_3 \xrightarrow{\text{UV light}} CFCl_2 + Cl$$

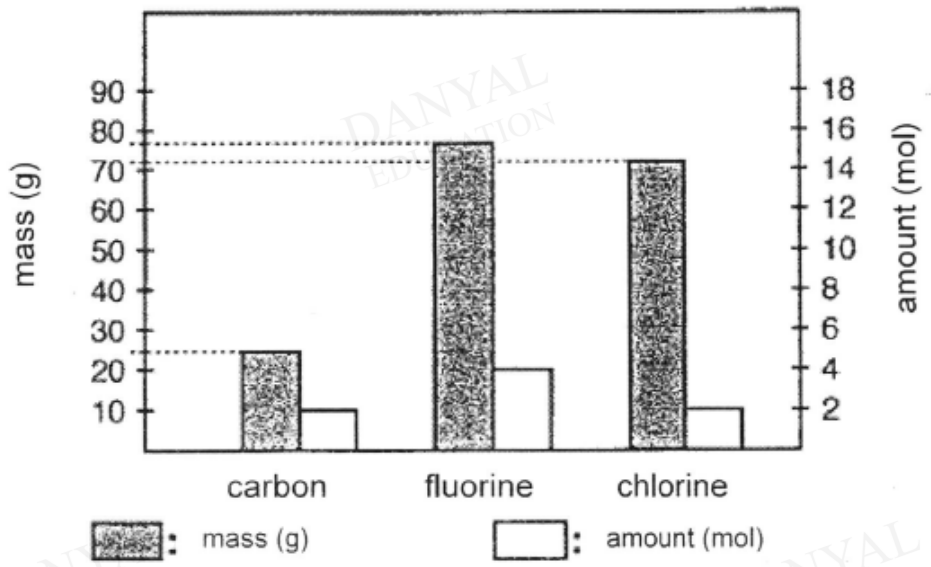
The Cl atom reacts with ozone in a two-step reaction.

Step 1: $Cl + O_3 \rightarrow ClO + O_2$
Step 2: $ClO + O \rightarrow Cl + O_2$

(i) One molecule of $CFCl_3$ can destroy thousands of ozone molecules. Explain why.

[2]

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



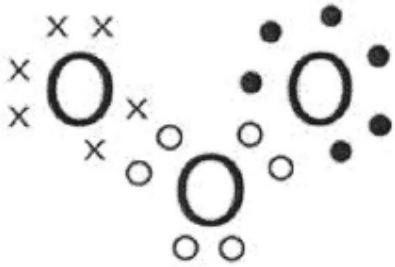
Using the above information, determine the molecular formula of this CFCs compound.

[2]

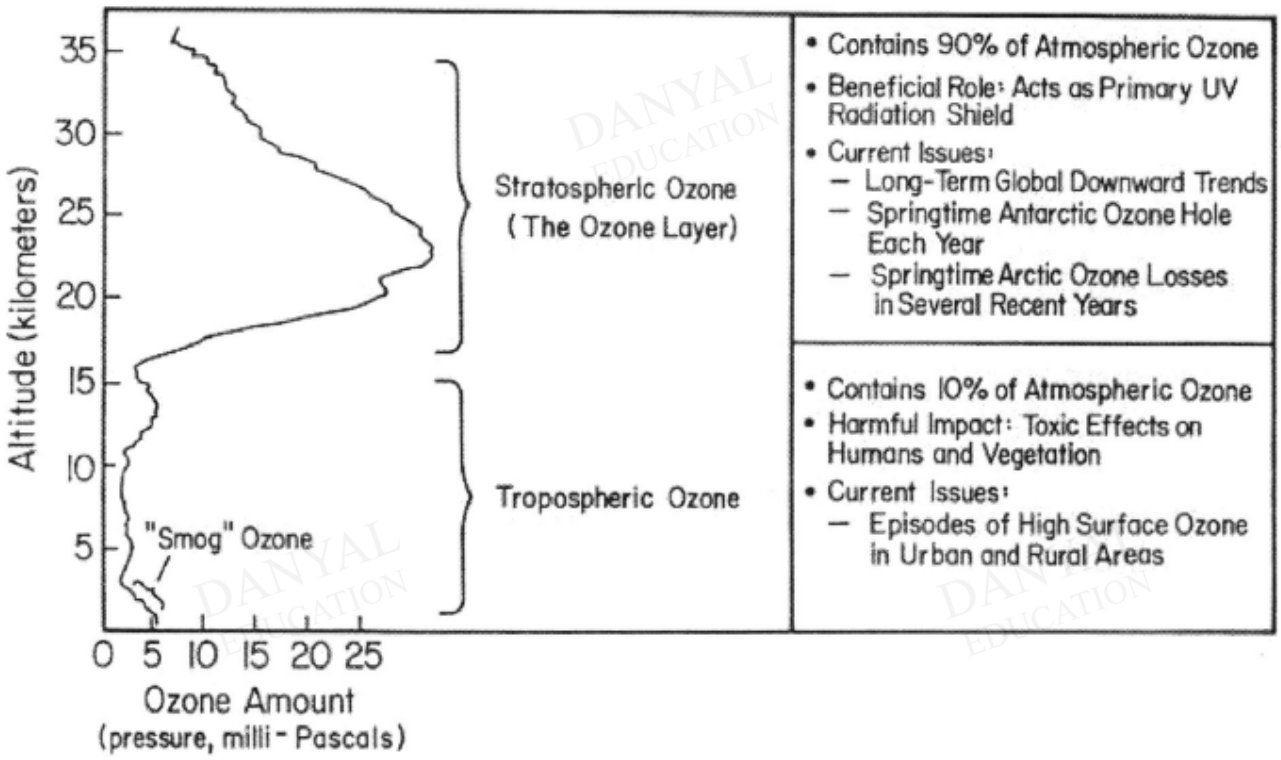
Q5

Ozone, O_3 is a much less stable triatomic form of oxygen.

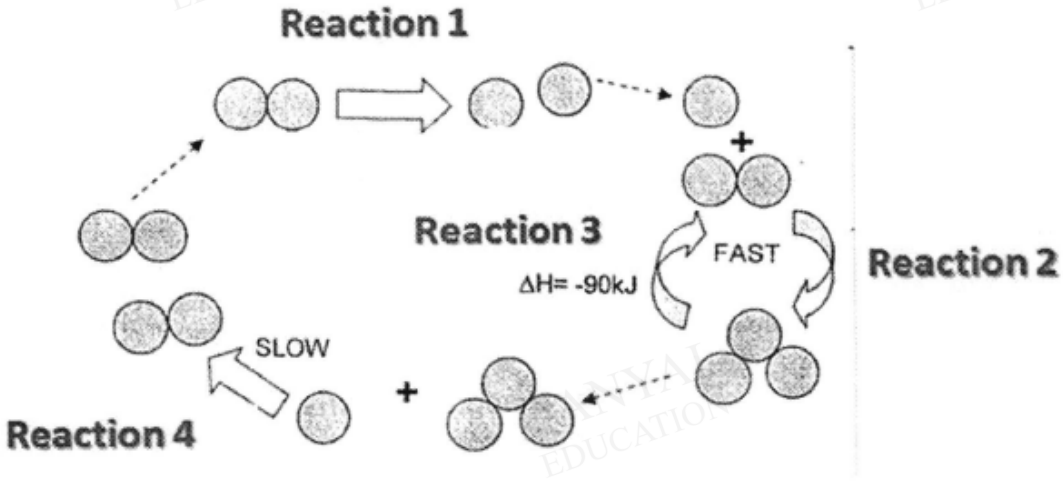
The diagram below shows the bonding in ozone molecules.



It is a pale blue gas present at low concentrations throughout the atmosphere (around 0.375 parts per million for O_3 compared to 21% for O_2).
In the troposphere, ozone is an air pollutant which can damage the respiratory systems of humans and other animals. The ozone in the stratosphere however is beneficial.
The diagram below shows how the concentration of ozone varies in the troposphere and stratosphere.



Ozone is formed as part of a natural cycle similar to nitrogen and carbon cycle. The first step in the formation of ozone is the decomposition of an oxygen molecule into two atoms by low energy ultraviolet (UV) light (reaction 1). The higher the altitude, the faster is this reaction. Each of these oxygen atoms can combine with another oxygen molecule to form an ozone molecule (reaction 2). The rate of reaction 2 is faster where the pressure is higher. The ozone molecule formed absorbs UV radiation and splits to form an oxygen atom and oxygen molecule which produces a lot of heat (reaction 3). For every mole of ozone that splits up, 90 kJ of energy is given off. Reactions 2 and 3 rapidly interconvert oxygen atoms and ozone. There is another slow reaction, though, which is known to destroy both oxygen atoms and ozone (reaction 4).
Reactions 1 to 4 are summarised in the figure below.



dotted arrow ------> indicates a molecule or an atom from one reaction goes on to take part in another reaction
solid arrow ⟹ indicates reactions
● - indicate one oxygen atom

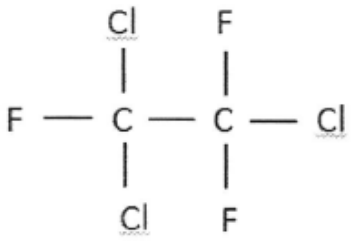
Chlorofluorocarbons, CFCs, destroy ozone in the upper atmosphere. Once the CFC vapour reaches the upper atmosphere the following reactions occur in order.

Reaction 5: $CFC + UV\ light \rightarrow CFC\ fragment + Cl$

Reaction 6: $Cl + O_3 \rightarrow ClO + O_2$

Reaction 7: $ClO + O \rightarrow Cl + O_2$

One example of CFC is the compound CFC 113. CFC 113 is an inert, synthetic compound used in the electronics industry. The figure shows the structure of CFC 113 below.



Some data about the bond strength in these molecules are given below.

Bond	bond strength/ kJ per mole
C – Cl	330
C – C	346
C – F	450
C – H	412

(a) Calculate the percentage of ozone in the atmosphere. [1]

(b) At which altitude is the rate of ozone formation maximum? [1]

_____

(c) With the help of information provided, suggest why the stratosphere is a warmer layer than the troposphere. [2]

_____

_____

_____

_____

(d) Which two reactions, 5, 6 or 7, when taken together are equivalent to reaction 4 which destroys the ozone and oxygen atoms? [1]

_____

(e) The energy of the UV light is equivalent to 400 kJ per mole.

(i) When CFC 113 is decomposed by UV light, are chlorine atoms or fluorine atoms formed? Explain. [2]

_____

_____

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_____

(ii) Suggest a further bond change you would expect to occur in CFC 113 molecule. [1]

_____

_____

(f) The formation of ozone in the upper atmosphere can be represented by a single equation shown below. [1]

$$3O_2\,(g) \rightarrow 2O_3\,(g)$$

What is the value for enthalpy change for the reaction shown?

(g) Draw the full structural formula for ozone molecule. [1]

Answers

Atmosphere Test 2.0

Q1

(a)	White solid turns purplish-black/black/purple; A: solid turns purplish-black/black/purple R: a black solid is formed	[1]
(b)	Incomplete combustion of fossil fuels; When there is insufficient oxygen; A: alkanes, alkenes, carbon containing substances/fuels, carbon R: air for oxygen	[1] [1]
(c)	Carbon monoxide is a colourless and odourless gas; Can cause death at high levels within minutes/ breathing difficulties/ binds to haemoglobin to form carboxyhaemoglobin;	[1] [1]

Q2

A5(a)	Step **2**. This is where the Cl atom breaks away from the compound as UV radiation is **absorbed** in order to **break** the C – Cl bond.	**2**
(b)	At the end of the reaction to convert ozone to oxygen, chlorine atom is **regenerated** and can be **used again to convert more ozone to oxygen** to repeat the depletion process.	**1** **1**
(c)	C – F bond is stronger. (As UV rays is only able to break C – Cl bond but not C – F bond.)	**1**
(d)	Ozone layer absorbs harmful UV rays from the sun. If ozone layer is depleted, the earth will be exposed to harmful UV rays which can cause skin cancer in human.	**1** **1**

Q3

3a	In 1990, solid fuel like coal was the most common type of fuel used because usage of coal dropped by 2 times (67% in 1990 to 32% in 2002) [1] In 2002, usage of gaseous fuel increased because usage increased by 39% (1% in 1990 and 40% in 2002) [1] Reason:**Burning of coal produces more carbon dioxide and methane than gas fuels.** These are greenhouse gases which can contribute to global warming.
b	• High concentration of carbon monoxide at air : fuel ratio of 12:1 due to low level of oxygen present, leading to higher tendency of incomplete combustion.[1] • Concentration of carbon monoxide decreased sharply from air : fuel ratio of 12:1 to 14:1 and decreased gradually after air fuel ratio of 14.1. [1]

	• As air content increased to 24:1, greater amount of oxygen is available for complete combustion, thus decreasing the concentration of carbon monoxide. [1]
c	15:1 (accept range between 14: 1 to 16: 1)
di	Oxides of nitrogen / nitrogen dioxide / nitrogen monoxide [1]
dii	**Use of catalytic converter** [1] $2NO + 2CO \rightarrow N_2 + 2CO_2$ [1]

Q4

(a) **(i)** The amounts of CO, SO_2 and PM10 emissions are lower when using biodiesel than fossil diesel. [1] On the contrary, the amount of NOx exhaust emission is higher when burning biodiesel than fossil diesel. [1] [2]

(ii) There is more amount of CO produced. CO is a pollutant which binds irreversibly with haemoglobin in red blood cell to form carboxyhaemoglobin, impairing its ability to transport oxygen causing breathing difficulties and death. [1]

There is more SO_2 produced. SO_2 irritate the eyes and lungs and causes breathing difficulties [1] [2]

(b) Burning of biodiesel releases CO_2 to the atmosphere. [;]
Biodiesel is formed from plants which absorb CO_2 in the atmosphere during photosynthesis. [;]
Hence there is no net increase of CO_2 in the atmosphere. [;]

3;[2]
1-2; [1] [2]

(c) **(i)** One molecule of $CFCl_3$ produces a Cl atom under UV light which reacts with one molecule of O_3 to form one molecule of ClO [1]

Another Cl atom is regenerated when one molecule of ClO reacts with an O atom. [1] [2]

(ii) From graph,

	C	F	Cl
moles	2	4	2
simplest ratio	1	2	1

The empirical formula is CF_2Cl.[1]

From graph,

	C	F	Cl
Mass of 1 mole of compound/g	24	76	71

Mr of CFCs = 171

n = 2

Molecular formula is $C_2F_4Cl_2$ [1]

Q5

a		0.375 / 1000 000 x 100 % = 0.0000375 %	1
b		23 km (accept 22 to 24)	1
c		Energy produced by splitting of ozone [1] Comparison of stratosphere and troposphere – higher conc of ozone, UV shield, faster reaction 3 as pressure lower at higher altitude [1]	2
d		Reactions 6 and 7 (both correct)	1
e	i	Chlorine atoms [1] The UV light has sufficient energy to break the C-Cl bond(330 kJ/mol) but not able to break the C-F bond (450 kJ/mol) [1]	2
	ii	The C – C bond will also break.	1
f		2 x 90 kJ/ mol = +180 kJ/mol	1
g		O = O – O	1