OZ Test bank

This PowerPoint contains all questions matched with their answers for the topic The Ozone Story – the code with the questions is for the old name for this unit, The Atmosphere.

These Q's are from the old SPEC – so some may not be fully relevant, but, most are.

The Answers are directly underneath the Q's.

Dr A. Johnston, Southampton, 2014

AT10ii

Natural processes in the air can control the concentrations of some types of atmospheric pollutants. Although carbon monoxide emissions increased in the twentieth century, the percentage of carbon monoxide in the troposphere has remained almost constant.

The increased use of cars in the twentieth century is one reason for the increase in carbon monoxide emissions.

Explain the origin of these carbon monoxide emissions.

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.....

..... **[2]**

AT10ii

Incomplete combustion ✓ of hydrocarbons ✓	2	**ALLOW** not enough oxygen or air linked to the idea of combustion / uncomplete combustion Second mark depends on the first. **ALLOW** fossil fuel or named fossil fuel / carbon in the fuel / organic fuel **DO NOT ALLOW** just 'fuel' or carbon as the fuel

AT10ii

Give **two** reasons why carbon monoxide is classed as a polluting gas.

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..... **[2]**

AT10ii

Toxic / poisonous / reduces the capacity of blood to carry oxygen around the body / AW ✓ **AND** *Any one from:* causes (photochemical) smog ✓ oxidised to CO_2 which is a greenhouse gas / reacts with O_2 to form CO_2 which is a greenhouse gas ✓	2	**ALLOW** respiratory problems, but not breathing problems. **IGNORE** harmful / dangerous Answer must have the CO_2 **AND** the greenhouse gas for this alternative. **ALLOW** global warming instead of greenhouse gas.

AT14

The reaction of carbon monoxide with hydroxyl radicals helps control atmospheric carbon monoxide concentrations. Hydroxyl radicals form by the breakdown of water molecules.

Name the type of bond breaking process that occurs to form hydroxyl radicals from water molecules.

..... **[1]**

AT14

Homolytic (fission) / homolysis ✓	1	**IGNORE** 'photochemical dissociation'

ES26iii

The bond enthalpy for the O–H bond is +464 kJ mol^{-1}. Calculate the energy, in Joules, needed to break a **single** O–H bond.

Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}

energy = ... J **[2]**

ES26iii

464 x 1000 ✓ Energy value/6.02 x 10^{23} **AND** a correct evaluation (= 7.71 x 10^{-19} J) ✓	**2**	One mark is for converting from kJ to J (ie: multiplying by 1000) The other is for dividing their energy value by 6.02 x 10^{23} (the Avogadro constant) **ALLOW** 2 or more sig. figs. but rounding must be correct. In order to score the second mark, there must be a correct evaluation of their expression. A completely correct answer on its own scores both marks.

AT22

Calculate the frequency of radiation that is needed to break a single O-H bond.

Give your answer to **three** significant figures.

Planck constant, $h = 6.63 \times 10^{-34}\,J\,Hz^{-1}$

frequency = ... Hz **[3]**

AT22

Answer to **(c)(ii)**/6.63 x 10^{-34} ✓ = 1.16 x 10^{15} ✓ 3 sig. fig. ✓	3	**DO NOT ALLOW** the second mark for evaluating any other expression (eg: answer to **(c)(ii)** x 6.63 x 10^{-34}) **ALLOW** sig. fig. mark for any 3 sig. fig. answer that follows from any calculation (even if their evaluation of their calculation is incorrect). A completely correct answer on its own scores all marks, including the sig. fig. mark.

AT15i

Equation 1.1 represents the reaction of hydroxyl radicals with carbon monoxide to produce carbon dioxide.

$$CO + OH \longrightarrow CO_2 + H \qquad \textbf{equation 1.1}$$

Explain what is meant by the term *radical*.

.....

..... **[1]**

AT15i

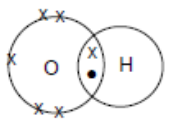
(A particle) with one (or more) unpaired electron(s). ✓	1	Answer must be in the context of an electron as part of some sort of particle. **IGNORE** 'free' or 'lone' or single electron.

AT5i

Draw a '*dot-and-cross*' diagram to show that OH is a radical.

[2]

AT5i



bond electrons ✓

rest of structure ✓

	2	Any symbols can be used to represent the electrons (including the same symbol for all electrons). Candidate does not have to draw circles for electron shells. Non-bonding electrons do not have to be shown in pairs. It **MUST** be clear that a pair of electrons (with any symbols) is being shared between the H and the O for the first mark. **IGNORE** any inner electron shells.

AT15ii

Classify the reaction represented by **equation 1.1** as initiation, propagation or termination. Explain your choice.

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..... **[2]**

AT15ii

propagation ✓

one radical is used and replaced by another / AW ✓

2

ALLOW there is a radical on both sides of the equation.

Mark independently.

AT1
AT2

The reaction represented by **equation 1.1** produces carbon dioxide, which is a gas at room temperature. Silicon dioxide, another Group 4 oxide, is a solid at room temperature.

Explain this difference in terms of bonding and structure.

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..... **[3]**

AT1
AT2

SiO_2: giant covalent / network solid / lattice / whole structure held together by covalent bonds / diagram ✓

CO_2: simple molecular / molecules / O=C=O / AW ✓

comparison of forces: <u>weak</u> intermolecular bonds (or forces) in CO_2 / less energy needed to separate molecules / bonds in SiO_2 are stronger than CO_2 intermolecular bonds (or forces) ✓

3

IGNORE 'intermolecular bonds' in SiO_2 / giant molecule / giant structure
Marks can be given for a labelled / annotated diagram

IGNORE 'covalent'.

Any type of intermolecular bonds can be named and can be abbreviated.
It must be clear that the intermolecular bonds in CO_2 are being discussed, not the covalent bonds.

AT11

Scientists monitor the composition of the Earth's atmosphere. They have found that the concentration of carbon dioxide in dry, unpolluted tropospheric air has increased from 300 ppm to around 380 ppm between 1900 and the present day.

Taking the present day value to be 380 ppm, calculate the **increase** in the percentage of carbon dioxide in the air between 1900 and the present day.

increase in carbon dioxide concentration = ... % **[1]**

AT11

$0.008 / 8 \times 10^{-5}$ ✓ | 1

AT23i
AT23ii
AT23iii
AT23iv

Carbon dioxide is described as a 'greenhouse gas'. Greenhouse gases absorb infrared radiation in the troposphere.

Explain the source of the infrared radiation absorbed by carbon dioxide and the possible link between increased concentrations of carbon dioxide in the troposphere and global warming.

In your answer, you should make it clear how the steps you describe are linked to one another.

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..... **[6]**

AT23i
AT23ii
AT23iii
AT23iv

*Any **four** points from:* 1 Sun emits UV ✓ 2 Earth absorbs some of the energy (from the Sun) / heats up ✓ 3 Earth radiates emits / re-emits IR ✓ 4 (CO_2) absorbs IR radiation ✓ 5 making <u>bonds</u> vibrate (more) ✓ 6 turned into kinetic energy that raises the temperature / transfers kinetic energy to thermal energy or heat or it warms the atmosphere or Earth. ✓ 7 some CO_2 molecules radiate IR (which warms Earth) ✓ **AND** more CO_2 molecules means more radiation is absorbed / more CO_2 means greater temperature increase / enhancing the greenhouse effect / causing global warming / warming the atmosphere / Earth / planet more ✓ **QWC** - *mark for connection of ideas: idea of linking IR absorbtion to vibrations of bonds / increase in temperature (marking point 4 linked to 5 or 6)* ✓	6	**IGNORE** other types of radiation from the Sun. **DO NOT ALLOW** Earth reflects IR in point 3. Award marks for points 5 and 6 if the wrong frequency range of radiation is given as being absorbed in 4. (eg candidate states CO_2 absorbs UV).

AT16

Bromomethane and chloromethane are both present in the atmosphere. Explain how chloromethane causes ozone depletion in the stratosphere **and** suggest why bromomethane has a lower ozone depleting potential than chloromethane.

In your answer, you should use appropriate technical terms, spelled correctly.

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..... **[5]**

AT16

Any two from: 1. chloromethane is not broken down / unreactive in the troposphere / lower atmosphere ✓ 2. but is broken down / photodissociated (in the stratosphere) / AW by ✓ 3. high energy UV / high frequency UV ✓ 4. (breakdown of chloromethane) producing chlorine atoms / chlorine radicals ✓ **AND** (products of chloromethane) <u>catalyse</u> ozone breakdown / AW ✓ C–Br bond is weaker (than C–C*l*) ORA ✓ so can be broken in the <u>troposphere</u> / molecule reacts in the <u>troposphere</u> / reacts before reaching the stratosphere ✓	5	**ALLOW** 'radiation' for 'UV' Points 2 and 4 can be scored from a reaction equation. QWC: To gain this mark, candidate must use the word catalyst or a derivative of it, spelled correctly and used in a grammatically correct way (eg: do not award for 'it catalyse the breakdown of ozone'). **ALLOW** 'catalyze'.

AT19

Scientists working in the 1980s discovered the problem of ozone depletion in the stratosphere when they were studying the Earth's atmosphere over the Antarctic.

The scientists used a new instrument to take a second set of readings for their experiment because they did not think their first results were correct.

Why did the scientists think their results from the first experiment were incorrect?

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..... **[1]**

AT19

(concentration) values were low ✓	1	Answers need to show that values were less and not just different from the expected ones.

PR8

Equation 4.1 represents the reaction that occurs when propene forms from propan-1-ol.

$CH_3CH_2CH_2OH(g) \rightleftharpoons CH_3CH{=}CH_2(g) + H_2O(g) \quad \Delta H = +81\ kJ\ mol^{-1}$ **equation 4.1**

Underline the term below that describes the type of reaction occurring in **equation 4.1**.

addition **elimination** **hydrolysis** **substitution** **[1]**

PR8

Elimination ✓

1

ALLOW any indication of chosen answer (eg: circling).

DO NOT ALLOW the mark if more than one answer has been chosen.

PR11ii

Give the reagents and conditions required for the reaction represented by **equation 4.1**.

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..... **[3]**

PR11ii

reagent	conditions
sulfuric / phosphoric acid ✓	heat / reflux ✓ concentrated ✓
OR	
alumina / silica / pumice / porous pot ✓	heat ✓ with (propan-1-ol) vapour ✓

3

ALLOW correct formula for reagent.

ALLOW temperatures over 100°C for the heat mark

Sulfuric acid **AND** alumina: **CON** reagent mark (but can still score condition marks).
Clear alternatives (ie: sulfuric acid **OR** alumina) scores the mark.

ALLOW c. for concentrated.
Aqueous / water **CONs** the concentrated mark.

The conditions marks may only be awarded if candidate has written an appropriate reagent, even if they have made a small mistake, eg: sulfuric without acid, or wrong formula (like A1O)

(Concentrated) sulfuric acid with dichromate and heat scores zero.

IGNORE references to pressure conditions.

AT8

The reaction represented by **equation 4.1** can reach a position of dynamic equilibrium. Explain what is meant by the term *dynamic equilibrium*.

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..... **[2]**

AT8

rate of forward reaction = rate of back reaction ✓

concentrations of reactants and products remain constant / closed system ✓

2

IGNORE references to steady state.

AT9iii

Describe and explain the effect of the following changes on the equilibrium amount of propene produced in the reaction represented by **equation 4.1**.

Increasing the total pressure of the reaction system.

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..... **[2]**

AT9iii

amount of propene produced decreases ✓ (increased pressure) pushes (position of) equilibrium to the left/to the reactants / side with fewest molecules ✓	2	**MUST** mention equilibrium for the second mark. Mark independently.

AT9ii

Carrying out the reaction at a higher temperature.

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..... **[2]**

AT9ii

amount of propene produced increases ✓ (increased temperature) pushes (position of) equilibrium in the endothermic direction / to the right / to the products ✓	2	**MUST** mention equilibrium for the second mark. Mark independently.

AT3ii

Describe and explain what happens to the **rate** of the reaction represented by **equation 4.1** if the pressure is increased.

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..... **[3]**

AT3ii

*Any **three** from:* 1. increased pressure increases number of particles per unit of volume ✓ 2. more collisions occur ✓ 3. (more collisions) per unit of time ✓ 4. rate increases/gets faster ✓	3	**ALLOW** 'particles are closer together' for the first point **DO NOT ALLOW** 'reactants are closer together'. More frequent collisions / collisions occur more often covers two points ✓✓ **IGNORE** more likely to collide / greater chance of collisions in point 2.

PR10ii

AT9ii

The phenylethene monomer is made by passing ethylbenzene vapour over a heated catalyst at a low pressure. **Equation 2.1** represents the reaction that occurs.

$$C_6H_5CH_2CH_3(g) \rightleftharpoons C_6H_5CHCH_2(g) + H_2(g) \quad \Delta H = +117\,kJ\,mol^{-1} \qquad \textbf{equation 2.1}$$

Describe and explain the effect of the following changes on the **yield** of phenylethene produced in the equilibrium represented by **equation 2.1**.

Carrying out the reaction at a higher temperature.

In your answer, you should use technical terms, spelled correctly.

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.....

..... **[2]**

PR10ii

AT9ii

Amount of phenylethene / product increases **OR** higher yield ✓ (increased temperature) moves (position of) equilibrium in the endothermic direction (ORA) ✓	**2**	Endothermic must be correctly spelled for the second mark to be awarded or 'exothermic' if reverse argument given **ALLOW** 'reaction moves in / favours the endothermic direction' / forward reaction is endothermic / shifts towards the endothermic reaction **ALLOW** endothermic for QWC if written on equation 2.1. Mark independently

PR10ii

AT9iii

Carrying out the reaction at a higher pressure.

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..... **[2]**

PR10ii

AT9iii

Amount of phenylethene / product decreases / lower yield ✓ (increased pressure) moves (position of) <u>equilibrium</u> to the side with fewer molecules / moles / particles ✓	**2**	**NOT** just 'equilibrium moves to the left'. **NOT** atoms. Mark independently

The catalyst used in the manufacture of phenylethene is in the form of a finely divided powder.

AT3iii

Explain why the use of a finely divided powder increases the reaction rate.

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..... **[2]**

AT3iii

Larger / greater / more surface area of catalyst **OR** Higher surface area to volume ratio ✓	**2**	**NOT** higher surface area
So more collisions per unit of time / more frequent collisions / collisions occur more often **OR** provides surface onto which reactants are adsorbed / can bond *(AW)* ✓		**NOT** just more collisions Mark independently

AT6

Explain how the use of a catalyst increases the reaction rate.

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..... **[2]**

AT6

(Catalyst) provides an alternative reaction path / route ✓ that has a lower activation enthalpy ✓	**2**	Answer must have the idea of a different path to gain the mark Mark independently

AT14

When CCl_4 vapour gets into Earth's stratosphere, a C–C*l* bond can be broken by UV radiation from the Sun.

Name the **type** of bond breaking that would occur.

..... **[1]**

AT14

Homolytic (fission) / homolysis ✓	1	IGNORE 'photodissociation' and 'photolysis'

AT22

The minimum frequency of radiation needed to break one C–C*l* bond is 8.67×10^{14} Hz. Calculate the minimum energy, in J, required to break one C–C*l* bond.

Planck constant, $h = 6.63 \times 10^{-34}$ J Hz^{-1}

minimum energy = ... J **[2]**

AT22

$8.67 \times 10^{14} \times 6.63 \times 10^{-34}$ ✓ $= 5.75 \times 10^{-19}$ (J) ✓	2	A completely correct answer on its own scores both marks. **ALLOW** ecf only if the sole error is a mis-copy of one of the number values. **ALLOW** 2sf or more but rounding must be correct

ES26iii

Calculate the bond enthalpy of the C–C*l* bond, in kJ mol^{-1}.

Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}

bond enthalpy = + ... kJ mol^{-1} **[2]**

ES26iii

= answer to (d) (ii) $\times 6.02 \times 10^{23}$ ✓ /1000 (= + 346 KJ mol^{-1}) ✓	2	One mark for multiplying answer to (d)(ii) by 6.02×10^{23} (Avogadro's constant) Other mark for converting the answer from J to KJ, i.e.: dividing by 1000 Can be scored in either order, but must be correctly evaluated to score both marks A completely correct answer on its own scores both marks (**ALLOW** 2 or more sf but rounding must be correct)

AT19

The production of $CBrCIF_2$ has been banned in most countries since 1994, because it contributes to ozone depletion.

Describe the theoretical work and research that led to the discovery of ozone depletion in the stratosphere and how the evidence was originally overlooked.

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..... **[3]**

AT19

Prediction / discovery (in the lab) that Cl can damage ozone layer ✓ Spectroscopic measurements showed ozone levels depleted/ lower than expected ✓ Results (initially) disregarded/ignored/overlooked/ thought to be an error/ thought to be anomalous as they were so low / depletion so high ✓	3	IGNORE 'hole in the ozone layer'. Must be lower, not different. Must mention 'spectroscopic' or one particular spectroscopic method (e.g.: ir) Must imply 'very low' and not just 'anomalous' or different. Both parts needed for the mark.

AT23ii
AT23iii

Some halogenoalkanes also contribute to global warming.

Explain how an increase in the concentration of a greenhouse gas leads to an enhanced greenhouse effect.

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..... **[2]**

AT23ii
AT23iii

(Greenhouse gas) absorbs IR from Earth ✓ More greenhouse gas means more IR absorbed ✓	2	Mark separately

AT24

Describe the evidence for the relationship between the increased concentration of greenhouse gases and global warming.

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..... **[1]**

AT24

There is a relationship/ correlation between models of gas and models of temperature OR models of gas and measured temperatures OR gas levels and measured temperatures	1	NOT 'global warming' for 'temperature'

3 In 2010, an Icelandic volcano erupted producing ash clouds that stopped plane flights across much of Europe. The volcano also emitted a mixture of gases.

The ash produced by the volcano contained silicon dioxide, SiO_2, whilst the gas mixture contained carbon dioxide.

AT2

Silicon dioxide is a solid but carbon dioxide is a gas at room temperature.

Explain this difference in terms of the bonding and structure in both compounds.

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..... **[3]**

AT2

SiO_2: giant covalent / giant structure / network solid / giant lattice / whole structure held together by covalent bonds, e.g.: every silicon atom is bonded to 4 oxygen atoms OR diagram showing at least 2 Si with all surrounding Os ✓ CO_2: simple molecular / molecules / O=C=O *AW* ✓ *One from:* a) weak intermolecular bonds in CO_2 b) little/less energy needed to separate molecules (of CO_2) c) bonds in SiO_2 are stronger than CO_2 intermolecular bonds ✓	3	**NOT** giant ionic structure **IGNORE** giant molecule. Reference to 'oxygen molecules' **CON**s this mark Statements that SiO_2 has any type of intermolecular bond **CON**s mp1. **IGNORE** 'covalent'. **IGNORE** 'intermolecular bonds' in SiO_2 in mp3. c) Needs to be a comparison.

AT10ii

Most scientists are concerned about the increasing amount of carbon dioxide in the Earth's atmosphere.

Give **two** different processes, other than volcanic activity, that are causing an increase in the amount of carbon dioxide in the atmosphere.

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..... **[2]**

AT10ii

2 from: Burning fossil fuels / named fossil fuel / hydrocarbons ✓ Production of cement ✓ Making iron/ making steel ✓ Deforestation *AW* ✓ Fermentation ✓ Oil refining ✓	2	**Must** refer to the process for the mark (e.g.: not just 'fossil fuels') **NOT** just burning fuels in vehicles

Most carbon dioxide from industrial processes is allowed to escape into the atmosphere.

Carrying out capture and storage of carbon dioxide is one way that a chemical manufacturing process could be changed to slow down the increase in carbon dioxide levels in the atmosphere.

AT25i

Suggest **TWO** other changes that a chemical company could make to its processes to achieve a reduction in the rate of increase of carbon dioxide levels.

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..... **[2]**

AT25i

2 from: Burn a fuel from a plant source OR an example, e.g.: wood, charcoal, (bio)ethanol, etc (which are carbon neutral) ✓ Use specified alternative energy source, choosing one from: solar energy / wind turbine / nuclear energy / hydroelectric / hydrothermal / wave / geothermal ✓ Improve the efficiency of the process OR use a catalyst (so that it needs less energy to run) ✓	2	**NOT** just 'alternative fuel that does not produce greenhouse gases' **ALLOW** 'burn fossil fuels more efficiently' **IGNORE** references to recycling / capturing CO_2

AT25iii

Suggest why capture and storage of carbon dioxide is expensive.

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..... **[1]**

AT25iii

(Capture and storage of the gas would need) lots of equipment / energy / compression OR costs would be incurred for: remedying environmental consequences / clearance of land / new or more infrastructure *AW* / specific equipment / larger workforce / space for storage *AW* ✓	1	**IGNORE** reference to CO_2 being gas.

The Earth absorbs visible radiation from the Sun and emits radiation from a different part of the electromagnetic spectrum. Carbon dioxide molecules absorb some of the emitted radiation.

AT23ii

(i) Name the type of electromagnetic radiation that is emitted from the Earth's surface.

..... [1]

AT23ii

Infrared (radiation) ✓	1	ALLOW 'IR'

AT21i

(ii) Explain what happens to carbon dioxide molecules when they absorb the radiation emitted from the Earth.

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..... [1]

AT21i

Makes their bonds vibrate (more) OR molecules gain or change in vibrational energy ✓	1

AT23iv

AT23v

(iii) Explain how the changes that happen after the process in **(ii)** result in the warming of the atmosphere.

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..... [2]

AT23iv

AT23v

Either: (Vibrational energy) becomes kinetic energy ✓ KE results in increased temp ✓ OR the molecules re–emit (some of the absorbed IR) ✓ in all directions ✓	2	Idea of transfer of energy is key here. Mark independently. **ALLOW** 'heat' or 'warmer' for increased temperature. **NOT** 'reflect' for re-emit. Second mark dependant on first in second set of marks

The amount of carbon dioxide in the troposphere is affected by the fact that it can dissolve in ocean water. The following equations describe the main reactions that occur.

$$CO_2(g) \rightleftharpoons CO_2(aq) \qquad \textbf{equation 3.1}$$

$$CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \qquad \textbf{equation 3.2}$$

AT9i

Using these equations, explain the effect that an increase in carbon dioxide concentration in the troposphere will have on the HCO_3^- concentration in the oceans.

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..... **[3]**

AT9i

Equation 3.1: Equilibrium moves so that more CO_2 aqueous will be formed OR equilibrium moves to the right ✓ Equation 3.2: (Increased CO_2 aqueous) moves equilibrium to the right ✓ HCO_3^- (concentration) increases ✓	3	If candidate implies that **both** equation 3.1 and equation 3.2 move to the right, but do not mention equilibrium, they score 1 of the first two marks. If they state this, and use the term equilibrium correctly at least once, they can score both mp1 and 2. One of mp 1 and 2 can be scored if the candidate states that 'the equilibrium moves to the right', but it is not clear which reaction they are referring to.

AT8

Suggest why the balance between gaseous CO_2 in the troposphere and $CO_2(aq)$ in the oceans cannot be regarded as a true dynamic equilibrium.

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..... **[1]**

AT8

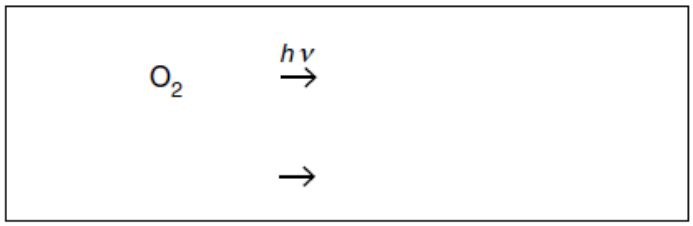
System is not closed OR CO_2 moves away from the surface OR specific example of input or output of CO_2 ✓	1	ALLOW '<u>not</u> a sealed system' or 'it is an open system'.

There has also been concern about the amount of ozone in the atmosphere. The overall equation for the formation of ozone in the Earth's atmosphere is shown below.

$$3O_2 \rightarrow 2O_3$$

ES1vi
AT18i

(i) Complete and balance **two** equations to show how oxygen is converted into ozone in the stratosphere.



[2]

ES1vi
AT18i

$O_2 \rightarrow 2O$ OR $O_2 \rightarrow O + O$ ✓ $O + O_2 \rightarrow O_3$ ✓	2	**IGNORE** dots **ALLOW** multiples

AT18i

(ii) Explain why the formation of ozone you have described in **(i)** takes place in the stratosphere but **not** usually in the troposphere.

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..... **[2]**

AT18i

High frequency radiation OR high energy radiation OR uv only present in the stratosphere / not in troposphere *AW* ✓	2	**ALLOW** a specific frequency is needed
(energy is needed for) bonds in O_2 to be broken OR O radicals are formed OR (photo)dissociation / photolysis / breakdown of O_2 OR homolytic fission / homolysis of O_2 ✓		Mark separately

Ozone can be broken down by nitrogen monoxide. The mechanism for this process is shown below.

step 1 $NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$ **equation 3.3**

step 2 $NO_2(g) + O(g) \longrightarrow NO(g) + O_2(g)$ **equation 3.4**

AT18i

Combine **equations 3.3** and **3.4** to produce the overall equation for the reaction.

[1]

AT18i

$O_3 + O \rightarrow 2O_2$ OR $O_3 + O \rightarrow O_2 + O_2$ ✓	1	IGNORE state symbols

In the mechanism shown above for the breakdown of ozone, NO is acting as a homogeneous catalyst.

AT7i

Explain what is meant by the term *homogeneous* in the context of catalysis.

How can you tell from **equation 3.3** and **equation 3.4** that NO is a catalyst?

homogeneous: .....

.....

NO is a catalyst because: .....

.....

..... **[2]**

AT7i

(Catalyst) is in the same phase/state(gases) as the reactants ✓ NO is not used up in the reaction / NO is reformed / NO is regenerated / NO is recycled / NO is (chemically) unchanged ✓	2	ALLOW 'it' for NO. ALLOW 'does not appear in the overall equation' AW.

4 Chlorofluorocarbons, CFCs, were originally regarded as very useful compounds. Their physical and chemical properties meant that they could be used for a wide range of applications, including as refrigerants and cleaning solvents.

Unfortunately, we now know that CFCs break down in the stratosphere, starting a sequence of reactions that lead to ozone depletion.

$$CCl_2F_2 \xrightarrow{h\nu} CClF_2 + Cl \qquad \textbf{equation 4.1}$$

$$Cl + O_3 \rightarrow ClO + O_2 \qquad \textbf{equation 4.2}$$

$$ClO + O \rightarrow Cl + O_2 \qquad \textbf{equation 4.3}$$

AT15ii

Underline the term from the list below that describes the type of process shown in **equation 4.3**.

initiation **propagation** **termination** **[1]**

AT15ii

Propagation ✓	1

AT18ii

Explain why it is important that there is a certain minimum amount of ozone in the stratosphere.

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..... **[3]**

AT18ii

It filters / screens / absorbs / removes / prevents / shields / blocks (AW) uv ✓ (uv) of high energy OR high frequency / short wavelength ✓ which could otherwise cause skin cancer / damage to DNA / damage to eyes / damage to immune system / cell mutation / affects crops / premature ageing of the skin ✓	3	**IGNORE** protects us from uv **IGNORE** high intensity radiation **ALLOW** UVC/ UVB/ 10^{16} Hz/ 200–320nm **IGNORE** skin damage.

Scientists have decided that hydrofluorocarbons, or HFCs, like F_3CCFH_2, will make good long-term replacements for CFCs.

AT17ii

Explain, in terms of the reactivity of HFCs in the **stratosphere**, why scientists think HFCs are a good long-term solution as replacements for CFCs.

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..... **[2]**

AT17ii

F radicals not formed (in stratosphere) OR <u>HFCs</u> not broken down (in stratosphere) ✓	2	**ALLOW** HFCs were already broken down in the troposphere. **IGNORE** references to being unreactive.
because of the stronger C–F bond OR C–F needs more energy to break OR uv not high enough frequency to break C-F OR uv not high enough energy to break C–F ✓		**IGNORE** 'C-F bond is unreactive'.

AT17ii

Give **one** advantage and **one** disadvantage, not linked to their ozone depleting potential, which scientists would take into account when considering the use of HFCs in place of CFCs.

Advantage: .....

.....

Disadvantage:.....

..... **[2]**

AT17ii

Advantage: Same essential properties to the CFC they are to replace OR they are broken down in the troposphere ✓	2s	
*Disadvantage – **one** of:* (they are also) greenhouse / global warming gases OR expensive (to make) OR form HF (as a breakdown product) ✓		**IGNORE** less effective

ES24iii

The hydrofluorocarbon, F_3CCFH_2, can be prepared industrially by reacting hydrogen fluoride with $Cl_2C{=}CClH$.

$$Cl_2C{=}CClH + 4HF \longrightarrow F_3CCFH_2 + 3HCl \qquad \textbf{equation 4.4}$$

In the reaction shown in **equation 4.4**, some of the hydrogen fluoride takes part in a nucleophilic substitution reaction with the $Cl_2C{=}CClH$.

Explain how HF can act as a *nucleophile* in this reaction.

.....

.....

..... **[2]**

ES24iii

The F in the molecule has a lone pair of electrons ✓ that it can donate (to the δ+ charged carbon atom) **AND** forms a (covalent) bond ✓	2	**ALLOW** 'HF' or 'it' for 'F in the molecule' Second mpt must be in the context of an electron pair donated. Mark independently

AT6

The reaction shown in **equation 4.4** can be catalysed by chromium(III) fluoride.

Explain why the use of a catalyst speeds up the reaction rate.

.....

.....

..... **[2]**

AT6

Catalyst provides an alternative pathway ✓ with a lower activation enthalpy ✓	2

AT10ii

Many seashells contain calcium carbonate. The carbonate ions, CO_3^{2-}, come from atmospheric carbon dioxide that dissolves in the sea water.

Name **two** industrial processes that are major sources of atmospheric carbon dioxide.

.....

..... **[2]**

AT10ii

Two from: Refining oil ✓ Generating electricity ✓ Processes in a petrochemical plant ✓ Producing steel / iron ✓ Heating limestone / making cement ✓ Fermentation ✓	2	**ALLOW** burning a fossil fuel provided it is the context of another industrial activity (e.g. in a factory) **IGNORE** deforestation

AT25iii

Companies use various methods for the disposal of the carbon dioxide they produce to prevent its release straight into the atmosphere.

Suggest **two** methods that they could use for disposal of carbon dioxide.

.....

.....

..... **[2]**

AT25iii

Any <u>two</u> from: React the CO_2 with lime / other suitable named solid ✓ Disposal in an old mine / old oil or gas well / other suitable disposal site ✓ Pump it / bury it under the ocean ✓	2	**ALLOW** removal of CO_2 via reactions at source. (e.g. 'react the CO_2 before it is released') **IGNORE** 'Pump into rocks' and 'in a container' **DO NOT ALLOW** 'pump it <u>into</u> the ocean' in place of under **DO NOT ALLOW** just 'pump it underground'

AT2

Carbon dioxide is a gas at room temperature. Silicon dioxide, another Group 4 oxide, is a solid with a high melting point.

Explain this difference in melting point in terms of bonding and structure.

.....

.....

.....

.....

.....

.....

..... **[3]**

AT2

SiO_2: giant covalent / network / lattice / whole structure held together by covalent bonds / diagram ✓ CO_2: simple molecular / molecules / O=C=O AW ✓ *Comparison of forces – one from:* weaker intermolecular bonds (or forces) in CO_2 less energy needed to separate molecules of CO_2 bonds in SiO_2 are stronger than CO_2 intermolecular bonds (or forces) ✓	3	**IGNORE** 'intermolecular bonds' in SiO_2 / giant molecule / giant structure / just 'covalent'. Marks can be given for a labelled/annotated diagram Any type of intermolecular bonds can be named and can be abbreviated. It must be clear that the intermolecular bonds in CO_2 are being discussed, not the covalent bonds **IGNORE** intermolecular bonds in SiO_2

(c) Carbon dioxide acts as a greenhouse gas because it can absorb infrared radiation.

AT23iv

(i) Describe what happens to carbon dioxide molecules when they absorb the infrared radiation.

.....

..... **[1]**

AT23iv

Makes their <u>bonds</u> vibrate OR Molecules change in <u>vibrational</u> energy ✓	1

AT23iv

AT23v

(ii) The changes that happen after the process in **(c)(i)** result in the warming of the troposphere.

Describe these changes and explain how they warm the troposphere.

.....

.....

.....

..... **[2]**

AT23iv

AT23v

Either: (vibrational energy) becomes kinetic energy ✓ KE results in increased temperature ✓ *OR* the molecules re-emit (some of the absorbed IR), ✓ in all directions ✓	2	Idea of transfer of energy is key here. In the *Either option*, mark independently **ALLOW** 'heat' or 'warmer' for increased temperature **NOT** reflect for re-emit In the *OR* option 2nd mark depends on 1st

AT11

In an air sample that was analysed, carbon dioxide was found to be present at a concentration by volume of 395 parts per million.

Calculate the percentage of carbon dioxide in the sample.

% carbon dioxide = ... **[1]**

AT11

(395 / 1,000,000) x 100 = 3.95×10^{-2} / 0.0395 ✓	1	**ALLOW** any number of sf.

When carbon dioxide dissolves in water, the following reactions occur.

ES11iv

$$CO_2(g) \rightleftharpoons CO_2(aq) \quad \textbf{equation 1.1}$$

$$CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \quad \textbf{equation 1.2}$$

$$HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq) \quad \textbf{equation 1.3}$$

Give the systematic name of the HCO_3^- ion.

..... **[1]**

ES11iv

Hydrogencarbonate ✓	1	**ALLOW** hydrogen carbonate **IGNORE** incorrect oxidation states

AT8

The reaction in **equation 1.3** can reach a state of dynamic equilibrium.

Explain what is meant by the term *dynamic equilibrium*.

.....

.....

.....

..... **[2]**

AT8

Rate of forward reaction = rate of back reaction OR reactants and products are formed at the same rate ✓ Concentrations of reactants and products remain constant OR closed system ✓	2	Mark independently **DO NOT ALLOW** concentrations of reactants and products are the same/equal

AT8

Suggest why the balance of $CO_2(g)$ in the atmosphere and $CO_2(aq)$ in the oceans cannot be regarded as a dynamic equilibrium.

.....

.....

..... **[1]**

AT8

System is not closed OR CO_2 moves away from the surface OR specific example of input or output of CO_2 ✓	1	**ALLOW** 'not a sealed system'

$$CO_2(g) \rightleftharpoons CO_2(aq) \quad \textbf{equation 1.1}$$

$$CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \quad \textbf{equation 1.2}$$

$$HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq) \quad \textbf{equation 1.3}$$

AT9i

The concentration of hydrogen ions in a sample of sea water is increased.

Using **equation 1.3**, describe and explain what would happen, if anything, to the concentration of carbonate ions.

.....

.....

.....

..... **[2]**

AT9i

CO_3^{2-} (concentration) decreases ✓ Equilibrium (position) moves to left / towards reactants / towards hydrogencarbonate ✓	2	**MUST** mention **equilibrium** for the second mark Mark independently

2

Leafcutter ants are responsible for producing some of the halogenoalkanes that are released into the Earth's atmosphere. The ants have been found to be responsible for producing large quantities of chloromethane and bromomethane.

AT12ii

Halogenoalkane	Estimated global emissions / tonnes per year	Atmospheric lifetime / years
Chloromethane, CH_3Cl	800	1.3
Bromomethane, CH_3Br	500	0.7

Why does chloromethane not photodissociate in the troposphere?

.....

.....

..... **[1]**

AT12ii

UV / radiation (in troposphere) does not have enough energy OR UV / radiation / energy (in troposphere) is not high enough frequency OR Bonds are too strong to be broken by the UV / radiation / energy ✓	1	**ALLOW** 'photon density in the troposphere is insufficient'

If a bromomethane molecule reaches the stratosphere, UV radiation breaks the C–Br bond in the molecule, forming bromine atoms.

ES26iii

(i) The C–Br bond has an enthalpy of +290 kJ mol^{-1}.

Calculate the minimum energy (in Joules) needed to break a **single** C–Br bond.

Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}

minimum energy = ... J **[2]**

ES26iii

(290 / 6.02 x 10^{23}) x 1000 **AND** evaluate = 4.817 / 4.82 / 4.8 x 10^{-19} J ✓✓ 290 x 1000 ✓ **OR** 290 / 6.02 x 10^{23} ✓	2	A completely correct answer on its own scores both marks One mark is for converting 290 from kJ to J, i.e. multiply by 1000, the other mark is for dividing by 6.02x10^{23} (the Avogadro constant) – in either order

AT22

(ii) Calculate the frequency of radiation that is needed to break a **single** C–Br bond.

Planck constant, $h = 6.63 \times 10^{-34}$ J Hz^{-1}

frequency = ... Hz **[2]**

AT22

Answer to (b)(i) (rounded or not rounded) / 6.63 x 10^{-34} ✓ = 7.266 / 7.27 / 7.3 x 10^{14} ✓	2	**DO NOT ALLOW** second mark for evaluating any other expression e.g. Answer to (b)(i) x 6.63 x 10^{-34} A completely correct answer on its own scores both marks

The following table gives values for the boiling points of bromomethane, chloromethane and water:

	Boiling point/K
Bromomethane	277
Chloromethane	249
Water	373

PR2

Use ideas about intermolecular bonds to explain:

why chloromethane has a lower boiling point than water;

.....

..... **[1]**

PR2

Intermolecular bonds in chloromethane are weaker ORA OR Less energy needed to break intermolecular bonds in chloromethane ORA ✓	1	Answer must be a comparison **ALLOW** 'it' for chloromethane' **IGNORE** less / fewer IMB **IGNORE** references to specific types of intermolecular bond

ES23ii

why bromomethane has a higher boiling point than chloromethane.

.....

.....

.....

.....

..... **[2]**

ES23ii

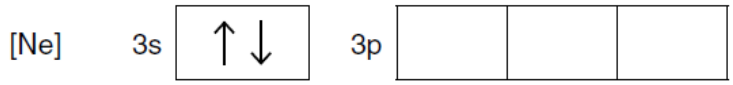
IMB in bromomethane are stronger ORA OR More energy needed to break intermolecular bonds in bromomethane ✓ because (bromomethane or Br) has more electrons / bromomethane molecules bigger / bromine atoms bigger / higher A_r for Br / higher M_r for CH_3Br ✓	2	**ALLOW** 'it' for bromomethane' **DO NOT ALLOW** if bond polarity is included in the reason (i.e. it must be id-id being described) **IGNORE** more IMB Mark independently

3 Wine labels often show that the wine contains sulfites, because sulfur dioxide gas has been added as a preservative. Strict legal limits have been placed on the amount of SO_2 that can be added to wine, because above a certain value the sulfur dioxide affects the taste of the wine.

Sulfur dioxide can be made industrially by burning sulfur in air.

ES4

Complete this diagram to show the arrangement of electrons in a sulfur atom.



[1]

ES4

[Ne] 3s ↑↓ 3p ↑↓ ↑ ↑ ✓	1	**ALLOW** single arrows in any 3p atomic orbitals pointing up or down **ALLOW** use of other arrow symbols (such as 1, as long as – in each box that contains a pair– one points up and one down)

AT10ii

Industries producing sulfur dioxide have to make sure they do **not** allow the sulfur dioxide to escape into the atmosphere.

Name a type of pollution caused by sulfur dioxide in the atmosphere.

..... **[1]**

AT10ii

Acid rain ✓		**ALLOW** particulate formation **ALLOW** 'industrial smog' **DO NOT ALLOW** just 'smog'

3 In the 1980s, two incidents occurred in Africa as a result of rock slides that disturbed the water in the bottom of a lake. In both cases, large volumes of carbon dioxide gas, originally released by volcanic activity on the lake floor, erupted from the water and suffocated people.

Some gases, including carbon dioxide, enter the Earth's atmosphere as a result of human activities, such as the combustion of fuel in vehicle engines.

AT10ii

Give another industrial activity that acts as a source of atmospheric carbon dioxide.

..... **[1]**

AT10ii

refining oil / generating electricity / processes in a petrochemical plant / producing steel / heating limestone / fermentation (1) ;	1	**allow** burning a fossil fuel provided it is the context of another industrial activity eg in a factory **allow** making cement **ignore** deforestation

Name another gas, that is present in vehicle exhaust fumes, which is a pollutant.

AT10ii

Explain why it is considered to have a polluting effect.

.....

.....

..... **[2]**

AT10ii

any one pair from: NO/ NO_2 / NO_x / SO_2 / SO_3 / SO_x (1) ; causes acid rain / causes breathing problems (1) ; **or** unburnt hydrocarbons / Carbon monoxide / NO_x (1) ; causes smog (1) ; **or** CO_2 / NO_x / C_xH_y (1) ; causes greenhouse effect / global warming (1) ; **or** NO_x / SO_x / CO / aromatics (1) ; causes toxic effects on humans (1) ;	2	A correct pollutant gas scores the first mark. The second mark depends on the first. **do not allow** harmful instead of toxic

Carbon dioxide is described as a 'Greenhouse gas'. Explain how increased concentrations of carbon dioxide in the troposphere could be linked to global warming, saying where the energy comes from originally.

AT23i
AT23ii
AT23iii
AT23iv
AT23v

In your answer, you should make it clear how the steps you describe are linked to one another.

.....

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..... **[6]**

AT23i
AT23ii
AT23iii
AT23iv
AT23v

*any **five** from*:	5	
(a) UV / visible from the Sun is absorbed by the Earth / heats the Earth(1) ;		(a) **do not allow** light or sunlight instead of UV / visible
(b) Earth radiates/emits IR (1) ;		(b) & (c) allow long-wave or low frequency radiation, **do not allow** reflects IR.
(c) CO_2 absorbs IR (1) ;		(c) **allow** answers suggesting other radiations are absorbed by the CO_2
(d) which causes bonds to vibrate (more) (1) ;		(c) and (e) **allow** 'greenhouse gases' for CO_2
(e) more CO_2 means more radiation is absorbed (1) ;		
(f) this energy is transferred to KE that increases atmospheric temperature / molecules radiate IR that warms Earth / atmosphere (1) ;		
QWC for connection of ideas:	1	
Earth absorbing radiation or being warmed then Earth emitting radiation *or* *CO_2 absorbs IR then bonds vibrate* *or* *CO_2 absorbs IR then energy is transferred to the atmosphere.*		

One of the methods being considered for reducing the amount of atmospheric carbon dioxide is to capture it. Carbon dioxide can then be stored by pumping it, under pressure, onto the ocean floor.

AT25iii

Suggest why is it unlikely that carbon dioxide stored under the ocean would escape in the way that occurred in the African lakes.

.....

..... **[1]**

AT25iii

the ocean water is too deep to be disturbed by a rock-slide / pressure under the ocean keeps the CO_2 in place(1) ;	1	**allow** rock slides (of this type) don't occur in the ocean.

AT25i

AT25ii

Name **two** ways of reducing the amount of carbon dioxide in the atmosphere, other than storing it under the ocean.

.....

.....

.....

..... **[2]**

AT25i

AT25ii

any **two** from: burn less fossil fuel (1) ; named alternative power source (1) ; less deforestation / plant more trees (AW) / more photosynthesis (1) ; reacting the CO_2 with lime/other suitable named solid (1) ; disposing of it in an old mine / well / other suitable disposal site (1) ;	2	**do not allow** just fewer cars

3 A lightning strike provides energy to start reactions between chemicals present in the atmosphere. One possible reaction sequence involving gaseous substances is shown below.

$$N_2 + 4O_2 \rightarrow 2NO + 2O_3 \quad \textbf{equation 3.1}$$

$$NO + O_3 \rightarrow NO_2 + O_2 \quad \textbf{equation 3.2}$$

$$NO_2 + O \rightarrow NO + O_2 \quad \textbf{equation 3.3}$$

$$NO_2 + OH \rightarrow HNO_3 \quad \textbf{equation 3.4}$$

AT10ii

The reactions represented by **equations 3.1** and **3.2** involve the formation of oxides of nitrogen.

Give an example of a human activity that gives rise to oxides of nitrogen.

.....

..... **[1]**

AT10ii

Burning fuel in vehicle engines / putting fertilisers onto soil ✓	1	Answer must be an activity (e.g. driving a vehicle) DO NOT ACCEPT 'burning a fuel' without a context ACCEPT nitrogen and oxygen reacting in a vehicle engine

Some of the species involved in the reactions shown in the equations above are radicals.

AT15i

(i) Circle **one** substance in the list below that represents the formula of a radical.

HNO_3 **N_2** **NO** **[1]**

AT15i

NO ✓	1	Any clear indication scores the marks (e.g. ringed) More than one indicated: the additional incorrect answer indicated CONs a correct answer

AT15i

(ii) Explain your answer to **(i)**.

.....

..... **[1]**

AT15i

Unpaired electron ✓	1	IGNORE 'lone electron', 'free electron', 'spare electron' or 'single electron' and references to which atom has the unpaired electron ALLOW have odd number of electrons

AT15ii

(iii) NO_2 and OH are also radicals. Give the name that is used to describe the type of radical reaction illustrated by **equation 3.4**.

..... **[1]**

AT15ii

Termination ✓	1

AT4ii

The reaction represented by **equation 3.4** has a low activation enthalpy.

Suggest why this reaction has a low activation enthalpy.

.....

..... **[1]**

AT4ii

No bond breaking ✓	1	**ALLOW** 'only formation of bonds'

AT3i
AT3ii

Suggest why, even though this reaction has a low activation enthalpy, it still occurs slowly in the atmosphere.

.....

..... **[1]**

AT3i
AT3ii

The concentrations of the reacting particles are low / low abundance / few particles / few collisions / low pressure ✓	1	**ALLOW** temperature is low / very low / cold **ALLOW** high temperature needed for reaction to occur **ALLOW** the particles are far apart

Describe and explain how the rate of a reaction varies under different temperature conditions.

In your answer, you should make clear how the points you make are linked to one another.

AT3iv
AT5

.....

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.....

..... **[5]**

AT3iv
AT5

	Any ***four*** from: 1. Rate is greater when temperature is higher *ORA* ✓ 2. (At higher temperatures) particles have more energy/move faster ✓ 3. More particle collisions ✓ 4. per unit of time ✓ 5. More collisions have (total) energy of at least the activation energy / more successful collisions ✓ QWC – for linking: Link made between greater energy/move faster and increased rate (mp 2 & 1) ✓	5 **Please use annotations on answer in appropriate places** Reverse argument allowed throughout MP3: Must be clear that collisions are between particles, not reactants or similar wording MP3: **DO NOT ACCEPT** more chance of / likelihood of collisions More frequent collisions scores mp 3 **and** 4 MP5: **DO NOT ALLOW** more particles have energy greater than E_a Please indicate QWC mark using red cross or green tick on the right of the pencil icon on the answer screen. **DO NOT ACCEPT** links between temperature and rate for the QWC mark

Equations 3.2 and **3.3** represent the process in which NO reacts with ozone in the stratosphere.

$$NO + O_3 \rightarrow NO_2 + O_2 \qquad \textbf{equation 3.2}$$

$$NO_2 + O \rightarrow NO + O_2 \qquad \textbf{equation 3.3}$$

AT18i

Combine **equations 3.2** and **3.3** to produce the overall equation for the process.

[1]

AT18i

$O_3 + O \rightarrow 2O_2$ / $O_2 + O_2$ ✓	1	**DO NOT ALLOW** with extra chemicals not cancelled

AT7i

Explain how **equations 3.2** and **3.3** show that NO could be a catalyst for the breakdown of ozone.

.....

..... **[1]**

AT7i

NO is not used up in the reaction / NO is reformed / chemically unchanged *AW* ✓	1

AT7i

In this process NO is a homogeneous catalyst.

Explain what is meant by the term *homogeneous*.

.....

.....

..... **[1]**

AT7i

Catalyst is in the same (physical) state as the reactants ✓	1	ALLOW phase ALLOW NO or 'it' for catalyst

AT7ii

Explain why a reaction is faster in the presence of a catalyst.

.....

.....

..... **[2]**

AT7ii

(Catalysts) provide an alternative (AW): route / pathway / path / intermediate ✓ with lower activation energy / enthalpy ✓	2	Mark separately

AT18ii

Ozone is present in both the stratosphere and the troposphere.

Explain how the presence of ozone in the **stratosphere** benefits us.

.....

.....

.....

.....

..... **[3]**

AT18ii

(Ozone) stops UV ✓ (UV) of high energy / high frequency / short wavelength ✓ which could otherwise cause skin cancer / damage to DNA / damage to eyes / damage to immune system / cell mutation / affects crops ✓	3	DO NOT ALLOW 'protects us from UV' or 'reflects UV' DO NOT ALLOW high intensity radiation ALLOW UVC / UVB / 10^{15} Hz / 200–320 nm ✓

AT18iii

Give **one** disadvantage of a build-up of **tropospheric** ozone.

.....

..... **[1]**

AT18iii

(Causes) photochemical smog / breathing problems / respiratory problems / lung damage / toxic ✓	1	ALLOW deterioration of rubber

4 Chlorofluorocarbons, CFCs, have been used for a variety of applications, including as blowing agents for plastics. Since the discovery that CFCs cause environmental damage, alternative compounds have been used.

The table below gives data for some compounds that could be used in place of CFCs. ODP is the Ozone Depletion Potential.

compound	formula	boiling point /K	flammable	ODP	price
A	$CFCl_3$	297	no	1.0	medium
B	CF_2Cl_2	243	no	1.0	medium
C	CF_3CCl_2H	302	no	0.02	high
D	CF_3CH_2F	247	no	0.0	very high
E	$CH_3CH_2CH_3$	231	yes	0.0	low

ES20i

Give the systematic name of **compound D**.

..... **[2]**

ES20i

1,1,1,2-Tetrafluoroethane ✓✓

Tetrafluoroethane ✓

1,1,1,2 ✓

2 Mark independently

IGNORE commas and dashes
ALLOW minor spelling errors

ALLOW 1 mark for numbers if given in two parts: such as 1,1,1-trifluoro-2-fluoroethane
DO NOT ALLOW other numbers, such as 2,2,2,1 or the reverse

CFCs were used as blowing agents for plastics like expanded polystyrene. The CFC was incorporated into the plastic as it was being produced. The CFC vaporised during the polymerisation reaction, so it 'blew' tiny bubbles in the plastic.

AT17i

Use data from the table to suggest **one** advantage and **one** disadvantage of **compound C** as a replacement for **compound A** as a blowing agent.

advantage: .....

.....

disadvantage: .....

..... **[2]**

AT17i

Advantage: lower / low ODP (*AW*) ✓ **Disadvantage:** (more) expensive ✓	2	In both parts, each additional answer CONs the mark

AT17i

Chemicals used as refrigerants need to be volatile. **Compound B** has been used as a refrigerant because it has a suitable volatility.

Suggest from the list in the table, **one** substance of similar volatility to be a suitable replacement for **compound B** as a refrigerant.

..... **[1]**

AT17i

Compound D ✓	1

2 Many gases can pollute our troposphere, including ozone and oxides of nitrogen.

Oxides of nitrogen are involved in the production of ozone, as shown in the equations below.

$NO(g) + ½ O_2(g) \rightarrow NO_2(g)$ **equation 2.1**
$NO_2(g) \rightarrow NO(g) + O(g)$ **equation 2.2**
$O_2(g) + O(g) \rightarrow O_3(g)$ **equation 2.3**

AT18i

Write the overall equation for the reaction sequence shown in **equations 2.1** to **2.3**.

→ **[1]**

AT18i

$1½ O_2 \rightarrow O_3$ ✓	1	**IGNORE** state symbols. All other species must be absent from the equation for the mark to be given. **ALLOW** $O_2 + ½ O_2 \rightarrow O_3$ **ALLOW** multiples.

AT12i

Identify the catalyst involved in this series of reactions. Explain your choice.

.....

..... **[2]**

AT12i

Catalyst is NO / nitrogen monoxide / nitrogen (II) oxide **OR** NO_2 / nitrogen dioxide / nitrogen (IV) oxide **OR** O / oxygen atom / oxygen radical ✓ It is regenerated / recycled / reformed ✓	2	**ALLOW** 'nitrogen oxide'. **ALLOW** 'remains unchanged **at the end**', 'not used up'. **DO NOT ALLOW** 'not involved in reaction'. Second mark depends on first.

AT15i

The chemicals taking part in these reactions are radicals. Explain what is meant by the term *radical*.

.....

..... **[1]**

AT15i

(A particle) with one (or more) unpaired electron(s) ✓	1	**IGNORE** 'free' or 'lone' or single electron. **ALLOW** 'an electron not in a pair'. **DO NOT ALLOW** 'is an unpaired electron' **OR** 'an element or compound or substance with …'. **IGNORE** wrong method of formation e.g.: heterolytically.

PR5i
ES27i

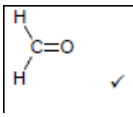
Ozone reacts with hydrocarbons in the troposphere to form smog. One example is the reaction of ozone with ethene to form methanal, HCHO, which is found in smog.

$$O_3(g) + C_2H_4(g) \rightarrow 2HCHO(g) + \tfrac{1}{2} O_2(g) \qquad \textbf{equation 2.4}$$

Draw the full structural formula for a molecule of methanal.

[1]

PR5i
ES27i

 ✓	1	Must show all atoms and all bonds for the mark.

PR11i

Methanal can be made from methanol in a laboratory. Give the reagents and conditions required for this reaction.

.....

.....

..... **[3]**

PR11i

(Potassium / sodium) dichromate / correct formula ✓	3	**IGNORE** dichromate oxidation state if dichromate written in words (**ALLOW** minor spelling error). **IGNORE** formula if correct name is given.
Acidified / (sulfuric) acid / H_2SO_4 / H^+ ✓		**ALLOW** hydrochloric acid / HCl / nitric acid / HNO_3 for second mark. **DO NOT ALLOW** the solution acidified with organic acids **IGNORE** 'concentrated'. **ALLOW** concentrated sulphuric acid with water, but **DO NOT** give credit for **conc.** sulphuric acid as the **only** reagent.
Distil ✓		Only allow distil mark if dichromate given as reagent. Reflux **CON**s distil mark. **IGNORE** heat. Any additional reagent, other than water, negates the dichromate mark, but candidate can still score the acid mark.

The reaction represented by **equation 2.4** occurs at different rates in winter and summer, because of the seasonal temperature differences.

Describe and explain how the rate of a reaction varies with temperature.

In your answer, you should make it clear how the steps you describe are linked to one another.

AT13iv

.....

.....

.....

.....

.....

.....

..... **[3]**

	2	**Please use annotations on answer in appropriate place.**
1. The reaction will be faster at higher temp OR rate increases with temperature ORA ✓		
2. Greater proportion of collisions OR more frequent collisions OR more collisions per unit time: **AND** (a) have (total energy of at least) the activation enthalpy OR (b) are effective OR (c) are successful ✓		**DO NOT ALLOW** 'better chance of', 'are more likely' or 'particles have energy greater than activation energy' (must be collisions). MP2 must have one of the first 3 statements and one of (a), (b) or (c).
3. QWC Particles / molecules / O_3 and C_2H_4 have more energy ORA ✓	**1**	**DO NOT ALLOW** atoms OR reagents OR reactants. **ALLOW** 'higher energy' for 'more energy'. **IGNORE** vibrational or rotational energy and references to speed.

AT18iii

The presence of ozone in the troposphere can cause other problems, apart from smog formation. Give **one** other problem associated with tropospheric ozone.

.....

..... **[1]**

Respiratory problems / breathing difficulties / asthma attacks / weakens immune system / attacks lung tissue / greenhouse gas / degrades rubber ✓	**1**	**IGNORE** toxic and global warming. **ALLOW** '(adds to) greenhouse effect'.

The presence of ozone in the stratosphere is important to humans.

Describe and explain:

- why the presence of ozone in the stratosphere is important to humans and
- the natural processes by which ozone is formed in the stratosphere.

In your answer, you should make it clear how the steps you describe are linked to one another.

AT18ii
AT18i

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..... **[7]**

AT18ii
AT18i

		Please use annotations on answer in appropriate place.
1. It filters / removes / screens / absorbs / prevents / blocks / shields / stops (AW) any type of uv ✓	6	**IGNORE** 'protects us from UV'. **DO NOT ALLOW** 'reflects UV'.
Plus two from mp 2 – 6 : 2. (radiation) of high energy / frequency / UVC / UVB / 10^{16} Hz / 200-320 nm ✓ 3. (radiation) causes skin cancer / damages skin / damages DNA / cell mutations ✓ 4. (radiation) damages eyes ✓ 5. (radiation) damages immune system ✓ 6. (radiation) affects crops ✓		**ALLOW** mp2 – 6 if the wrong type of radiation has been given in mp1. **DO NOT ALLOW** high intensity radiation. **DO NOT ALLOW** just 'cancer'.
and:		
7. Oxygen **OR** water molecules are split **OR** dissociate to form (oxygen) atoms / radicals		Mark can be awarded for the correct equation: $O_2 \rightarrow 2O$ **OR** $H_2O \rightarrow 2H + O$ Answer for oxygen must say 'oxygen molecules', O_2 or dioxygen. **ALLOW** splitting up of nitrogen oxides or any named oxide of nitrogen or correct formula.
OR the bond in the O_2 **OR** H_2O molecule is broken ✓		
8. uv radiation causes formation of oxygen radicals ✓		MP 8 can be awarded for uv written on reaction arrow, but not hν.
9. The O atoms / radicals react with O_2 forming ozone ✓		Mark can be awarded for the correct equation: $O + O_2 \rightarrow O_3$
QWC: Mark awarded for correct sequence of processes in the last part of the answer (mp 7 & 9) ✓	1	**Please indicate QWC using green tick or red cross on the right of the pencil icon on the answer screen.**

Methanol can be made from the carbon monoxide and hydrogen.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -91\,kJ\,mol^{-1} \qquad \textbf{equation 4.2}$$

The reaction represented by **equation 4.2** is an example of a dynamic equilibrium.

AT8

Explain what is meant by the term *dynamic equilibrium*.

.....

.....

..... **[2]**

AT8

Rate of forward reaction = rate of back reaction ✓ Concentrations of reactants and products remain constant (AW) OR closed system ✓	2	ALLOW 'reactants and products produced at same rate' and 'products change to reactants and back again at same rate'. DO NOT ALLOW concentrations of reactants and products are the same / equal.

AT9ii

AT9iii

Describe and explain the effect of the following changes on the **yield** of methanol produced in the reaction represented by **equation 4.2**.

Carrying out the reaction at a higher temperature: .....

.....

.....

.....

Increasing the total pressure of the reaction system: .....

.....

.....

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..... **[4]**

AT9ii

AT9iii

Higher temperature: Amount of methanol produced / yield decreases ✓ (increased temperature) pushes (position of) equilibrium in the endothermic direction OR equilibrium moves to the left as this it is endothermic OR equilibrium moves towards the reactants as it is endothermic ✓ *Higher pressure:* Amount of methanol produced / yield increases ✓ (increased pressure) pushes (position of) equilibrium to the side with fewer (gaseous) molecules / moles / particles ✓	4	IGNORE references to 'favour'. ALLOW reverse argument. Must mention endothermic (or exothermic, if reverse argument is used). Mark independently. ALLOW reverse argument. Mark independently.

Describe **and** explain the effect that the use of a catalyst would have on the rate at which methanol is produced.

In your answer, you should use appropriate technical terms, spelled correctly.

.....

.....

..... **[2]**

AT6

Methanol produced more quickly / rate of reaction increased ✓ Reaction proceeds by a route with lower <u>activation enthalpy</u> / <u>energy</u> ✓	**2**	MP 2 requires both 'route' and 'lower E_a' for the mark. **QWC:** Term 'activation enthalpy / energy' must be correctly spelled for the mark to be awarded. **IGNORE** references to intermediates.

AT22

Calculate the frequency of radiation that is needed to break one C–C*l* bond.

Planck constant, $h = 6.63 \times 10^{-34}\,J\,Hz^{-1}$

frequency = ... Hz **[2]**

AT22

Answer to (d) (ii) / 6.63 x 10^{-34} ✓ = 8.67 x 10^{14} Hz ✓	2	One mark is for dividing the answer to (d)(ii) by the value of 6.63 x 10^{-34} (Planck's constant). The second mark is for evaluating that expression and no other. **ALLOW** 2 or more s.f. correctly rounded A completely correct answer on its own scores both marks. If answer to (d)(ii) is rounded to 2 s.f., answer will be 8.60/ 8.6 x 10^{14}.

AT12i

It has been found that halogenoalkanes have been responsible for some of the ozone depletion in the stratosphere.

Describe how halogenoalkanes deplete ozone and give the evidence for the ozone depletion.

.....

.....

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.....

.....

..... **[3]**

AT12i

1. (Halogenoalkanes) break down in the presence of uv (or high-frequency radiation) **AND** give chlorine / bromine / halogen radicals ✓ 2. The radicals catalyse the breakdown / removal of ozone ✓ 3. Low ozone concentrations were found above the Antarctic ✓	3	In mp1, **ALLOW** photodissociation / photolysis for 'break down in the presence of uv'. In mp 2, **ALLOW** a description of a catalytic process, in words or equations. In mp3, **ALLOW** 'ozone hole' for 'low ozone concentrations'. Answer must mention both low concentration of ozone and Antarctic / Antarctica / South Pole / Arctic / North Pole / Poles.

Explain why CFCs like compound **C**, $CFCl_3$, are not broken down in the troposphere and how CFCs contribute to the breakdown of ozone in the stratosphere.

AT21ii
AT12i

In your answer, you should make it clear how the steps you describe are linked to one another.

.....

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..... **[5]**

AT21ii
AT12i

1. Bonds too strong to be broken in the troposphere **OR** (there is) too little energy / frequency of radiation too low in the troposphere to: break bonds / cause photodissociation / cause homolytic fission **OR** high energy / frequency radiation needed to break bonds not present in troposphere ✓ 2. in the stratosphere uv breaks bonds **OR** in the stratosphere uv causes photodissociation / homolytic fission ✓ 3. (to form) chlorine atoms / chlorine radicals / Cl ✓ 4. radicals catalyse the breakdown of ozone *AW* ✓ **QWC**: *for connection of ideas: Link made between breaking down of molecule and either production of Cl radicals or radicals catalysing ozone breakdown* ✓	4 1	**Please use annotations on answer in appropriate place** 1. **DO NOT ALLOW** just 'the molecule is not broken down' **OR** 'the molecule does not react' **DO NOT ALLOW** 'the right amount of energy is not present in the troposphere' 2. **DO NOT ALLOW** 'high energy' for uv. **ALLOW** 'In the stratosphere uv breaks down the molecule' 3. **DO NOT ALLOW** mark if chlorine radicals **and** fluorine radicals are formed. Can be scored from equation: $CFCl_3 \rightarrow CF_3 + Cl$ 4. Answer **MUST** have the idea of recycling or regenerating the radical. Can be shown in equations. Award mark even if radicals other than Cl given. Please indicate qwc mark using red cross or green tick on to the right of the pencil icon on the answer screen. If mp2 and either 3 or 4 are gained, award QWC

AT18ii

Explain why the presence of ozone in the stratosphere is important for humans.

.....

.....

.....

.....

..... **[3]**

AT18ii

It filters / screens / absorbs / removes / prevents / shields / blocks / stops (*AW*) any type of uv ✓ (radiation) of high energy / high frequency / UVB / UVC / value in range 10^{14} - 10^{16} Hz / short wavelength / value in range 200 – 320 nm ✓ (which could otherwise cause) skin cancer / damage to DNA / damage to skin / damage to eyes / damage to immune system / cell mutation / affects crops ✓	3	**IGNORE** 'protects us from uv' **IGNORE** high intensity radiation **ALLOW** sunburn

Compound **E**, CF_3CCl_2H, is broken down in the troposphere. The first step in the breakdown of compound **E** involves a reaction with OH radicals.

$$CF_3CCl_2H + OH \longrightarrow CF_3CCl_2 + H_2O \qquad \textbf{equation 2.1}$$

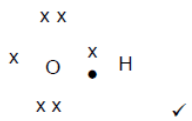
ES5i

Draw a '*dot-and-cross*' diagram for an OH radical.

Show outer shell electrons only.

[1]

ES5i



✓

1	Any two different symbols can be used to represent the electrons Candidate can draw circles for electron shells It **MUST** be clear that a pair of electrons is being shared between the H and the O **IGNORE** inner shell electrons **DO NOT ALLOW** diagram showing a charge

ES26iii

OH radicals are formed from water molecules in the stratosphere.

(i) The bond enthalpy of the O–H bond in water is +463 kJ mol^{-1}.

Calculate the minimum energy, **in J**, required to break a single O–H bond.

Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}

energy = ... J **[2]**

ES26iii

(463/ 6.02 x 10^{23}) x 1000 and evaluate (= 7.691/ 7.69 / 7.7 x 10^{-19} J) ✓✓ **OR** one mark for **EITHER**: 463 x 1000 (=463000) **OR** 463/ 6.02 x 10^{23} and evaluate (=7.691/ 7.69 / 7.7 x 10^{-22})	2	One mark is for converting 463 from kJ to J i.e.: multiply by 1000 Other mark is for dividing by 6.02x10^{23} (the Avogadro constant) To get second mark, there must be a correct evaluation **IGNORE** sig figs A completely correct answer on its own scores both marks

AT22

Calculate the minimum frequency of radiation needed to break the O–H bond.

Give the appropriate units.

Planck constant, $h = 6.63 \times 10^{-34}\,\text{J Hz}^{-1}$

frequency = ... units ..... [3]

AT22

Answer to (h)(i) / 6.63 x 10^{-34} ✓ = 1.16 x 10^{15} ✓ Units Hz **OR** s^{-1} ✓	3	**DO NOT ALLOW** second mark for evaluating any other expression e.g.: Answer to (e) (i) x 6.63 x 10^{-34} unless: the sole error is a mis-copy of one of the number values (e.g.: answer to (h)(i) / 6.36 x 10^{-34} doesn't score 1st mark, but gets 2nd) **ALLOW** hz A completely correct answer on its own scores both marks

AT14

What **type** of bond breaking occurs when OH radicals are produced from water molecules?

..... [1]

AT14

Homolytic (fission) / homolysis ✓	1	Ignore 'photochemical dissociation'

AT21ii

Suggest why OH radicals are not produced in the **troposphere** by the action of sunlight on water molecules.

.....

..... [1]

AT21ii

The frequency (of radiation / uv) is not high enough (to break the bond) *AW* **OR** The energy of (radiation / uv) is not enough (to break the bond) *AW* ✓	1	Ignore 'intensity' and 'light' **ALLOW** 'uv / high energy / high frequency radiation needed is not present (in troposphere)' **OR** has been absorbed (in stratosphere)

The student titrates a 25.0 cm^3 sample of the solution of bromide ions, Br^-, with 0.0200 mol dm^{-3} silver nitrate solution, $AgNO_3$. The reaction requires 32.60 cm^3 of silver nitrate solution to reach the end-point.

ES1ix

(i) Calculate the number of moles of $AgNO_3$ the student uses in the titration.

answer = ... mol **[1]**

ES1iii

(ii) Use your answer to **(i)** and **equation 3.2** to give the number of moles of Br^- ions that react.

answer = ... mol **[1]**

ES1v

iii) Calculate the concentration of Br^- ions in the sample.

Give your answer to **three** significant figures.

concentration = ... mol dm^{-3} **[3]**

ES1ix

(32.6 x 0.0200 /1000 =) 6.52 x 10^{-4} ✓	1	Working not needed and does not score on its own
Answer to (i) (6.52 x 10^{-4}) ✓	1	

ES1iii

ES1v

Answer to (ii) / 25.0 ✓ x 1000 and correct evaluation (= 2.608 x 10^{-2}) ✓ **OR** Answer to (ii) x1000 ✓ divide by 25 and evaluate ✓ 0.0261 / 2.61 x 10^{-2} to 3s.f. ✓	3	The answer on the line must come from the answer to (ii). Hence 0.0261 / 2.61 x 10^{-2} is not necessarily the correct response **ALLOW** sf mark for any 3 sig fig answer that follows from any correctly evaluated calculation

Carbon monoxide and hydrogen are produced industrially by reacting methane with steam in the presence of a powdered solid catalyst. Chemists are now investigating the use of *nanoparticles* of the catalyst coated onto an inert wire mesh. Nanoparticles are particles the size of a few thousand atoms.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\,kJ\,mol^{-1} \qquad \textbf{equation 4.1}$$

AT8

The reaction shown in **equation 4.1** is in a state of dynamic equilibrium.

Explain what is meant by *dynamic equilibrium*.

.....

.....

..... **[2]**

AT8

Rate of forward reaction = rate of back reaction **OR** reactants and products are formed at the same rate ✓ Concentrations of (reactants and products) remain constant / stay the same **OR** closed system ✓	2	**DO NOT ALLOW** 'concentrations of reactants and products **are** the same/equal'. If this has been stated, only 1 mark can be scored, even if the answer also states 'closed system'

AT3iii

Explain why the use of nanoparticles of catalyst, rather than the powdered solid, could further increase the rate of the reaction.

.....

.....

..... **[2]**

AT3iii

Nanoparticles will provide a larger / greater / more / surface area of catalyst (in contact with the reactants) *AW* ✓ (Allowing) more collisions per unit time (*AW*) / more frequent collisions **OR** more particles can bond to the surface per unit of time ✓	2	Must be comparative. Not just 'large' **ALLOW** 'higher' **DO NOT ALLOW** just 'more collisions' or 'more chance of collisions' Mark independently

AT4ii

Using a catalyst has an effect on the activation enthalpy for the reaction.

Explain what is meant by the term *activation enthalpy*.

.....

.....

.....

..... **[2]**

AT4ii

Minimum energy *AW* ✓ (Energy) for colliding particles to react / for a collision to cause a reaction **OR** (Energy) for a successful / effective collision *AW* ✓	2	**DO NOT ALLOW** references to reactants colliding

AT3ii

In addition to looking at different catalysts, chemists have also studied how changing pressure and temperature affect the rate and equilibrium yield of the reaction shown in **equation 4.1**.

Describe and explain the effect, if any, of an increase in **pressure** on the **rate** of reaction.

.....

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.....

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..... **[3]**

AT3ii

Reaction rate increases ✓ Particles are closer together (*AW*) **OR** concentration increases / more particles per unit volume ✓ so collide more frequently / more collisions per unit time ✓	3	**IGNORE** references to equilibrium **ALLOW** 'more particles in the same area' **DO NOT ALLOW** particles are more compressed **DO NOT ALLOW** just 'more collisions' or 'more chance of collisions' **IGNORE** comments on particle speed and energy or yield

AT9iii

Describe and explain the effect, if any, of an increase in **pressure** on the equilibrium **yield** of the reaction.

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..... **[3]**

AT9iii

(equilibrium yield) decreases **OR** less products / CO / H_2 **OR** yield of reactants increases **OR** more CH_4 / H_2O forms ✓ equilibrium (position) moves: to oppose the change / to the left / in backwards direction / towards reactants ✓ because fewer moles/molecules/particles on left-hand-side/ reactants side (ora) ✓	3	**IGNORE** references to rate. **ALLOW** 'yield of reactants increases' / 'more reactants' / 'more CH_4 **OR** H_2O' Mark independently **DO NOT ALLOW** atoms instead of 'molecules

AT9ii

Describe and explain the effect, if any, of an increase in **temperature** on the equilibrium **yield** of the reaction.

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..... **[3]**

AT9ii

(Yield would) increase **OR** more products / CO / H_2 **OR** yield of reactants decreases **OR** less CH_4 / H_2O forms ✓ equilibrium (position) moves: to oppose the change / to the right / in forwards direction / towards products ✓ in the endothermic direction / forward reaction is endothermic ✓	3	**IGNORE** references to rate. **ALLOW** 'yield of reactants decreases' / 'less reactants' / 'less CH_4 **OR** H_2O'

AT10ii

Methane contributes to the greenhouse effect. There is a low concentration of methane in our atmosphere.

Give an agricultural activity that acts as a source of methane.

..... **[1]**

AT10ii

Growing rice / livestock farming / making silage *AW* ✓	1	Must be an agricultural activity (e.g.: cows belching does not score)

AT23iii
AT23iv
AT23v
AT23vi

Methane acts as a greenhouse gas because it can absorb infrared radiation.

Explain how increased concentrations of methane in the troposphere could be linked to global warming.

.....

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..... **[2]**

AT23iii
AT23iv
AT23v
AT23vi

(More methane means) more radiation is absorbed **OR** (More methane means) more bonds vibrate ✓ This energy is transferred to KE **and** that increases atmospheric temperature / warms atmosphere **OR** molecules radiate/emit ir **and** that warms Earth/atmosphere ✓	2	**DO NOT ALLOW** mark if answer refers to absorbing radiation other than ir **DO NOT ALLOW** bonds vibrate more Both points needed for mark here Idea of transfer needed

AT11

A sample of air is analysed and found to contain 1.8 ppm of methane and 21% oxygen by volume.

How much more abundant is oxygen than methane in this sample of air?

answer = ... times more abundant **[2]**

AT11

21% = 210000 ppm ✓ $210000/1.8 = 1.2 \times 10^5$ times more ✓ **OR** 1.8ppm = 1.8×10^{-4}% ✓ $21/1.8 \times 10^{-4} = 1.2 \times 10^5 / 1.167 \times 10^5 / 116667$ times more ✓	2	**ALLOW** 2 or more sf **ALLOW** ecf from incorrect conversion of units for second mark **ALLOW** 1 mark for 21/1.8 correctly evaluated

1

Chlorine, Cl_2, can be used as a disinfectant for water. Chlorine is transported in pressurised containers.

ES23ii

Explain, in terms of intermolecular bonds, why chlorine is a gas at room temperature and pressure.

In your answer, you should use appropriate technical terms, spelled correctly.

.....

.....

..... **[2]**

ES23ii

Instantaneous dipole – induced dipole forces (must be correctly spelled) between molecules (1);
these are weak, so need little energy to overcome them and produce chlorine gas (1) **[2]**

ES17

In the event of an accident when chlorine is being transported, people living near the accident site are evacuated. Give **two** properties of chlorine that makes this necessary.

1.....

.....

2.....

..... **[2]**

ES17

Volatile/gas (1);
toxic to humans/causes respiratory diseases/choking gas (1) **[2]**

A student bubbled some chlorine through water. The chlorine reacted with the water as shown below.

$Cl_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + Cl^-(aq) + HClO(aq)$ **equation 1.1**

AT19i

The student added some solid sodium chloride to the solution of chlorine in water. Use le Chatelier's principle to describe and predict what would happen to the concentration of $Cl_2(aq)$.

.....

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..... **[3]**

AT19i

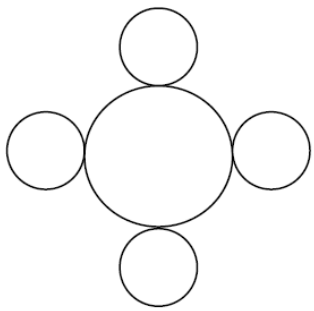
increase in (chloride ion) concentration (1);
will cause equilibrium (position) to move to the left AW (1);
(molecular) chlorine/Cl_2 (concentration) increases (1)

[3]

ES8ii

The diagram below shows part of a layer of a sodium chloride lattice.

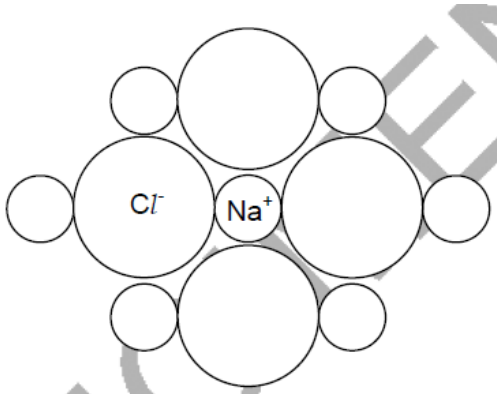
Label each type of particle and complete the diagram with enough particles to show the structure of the layer clearly.



[2]

ES8ii

For example:



correct sized ions for Cl^- and Na^+ (1);
4 oppositely charged ions or atoms around each type of ion/atom (1) **[2]**

ES12i

Sodium, like other elements in Group I, readily forms 1+ ions. Explain, in terms of ionisation enthalpies, why this is so and why sodium is unlikely to form compounds containing Na^{2+} ions.

.....

.....

.....

..... [2]

ES12i

1st IE is low (1), 2nd IE is very (AW) high (1). [2]

ES9i

(i) Give the oxidation states of chlorine in Cl_2 and HC*l*O.

Cl_2 .....

HC*l*O ..... [2]

ES9i

Cl_2 = 0 (1)
HOC*l* = +1 (1) [2]

ES9ii

(ii) Give the name of the process in which Cl_2 is changed into HC*l*O.

..... [1]

ES9ii

Oxidation/redox (1) [1]

ES9ii

(iii) Explain your choice of answer in **(ii)**.

..... [1]

ES9ii

Oxidation state of C*l* has increased/ C*l* has lost electrons (1) [1]

ES15iii

Write a **half-equation** that shows what happens to the chlorine molecules in **equation 1.1** that are converted into chloride ions.

→

[1]

ES15iii

$Cl_2 + 2e^- \rightarrow 2\,Cl^-$

[1]

When a solution of chlorine in water behaves as a disinfectant, the active chemical is HC*l*O.

ES1vi

The disinfecting power decreases when the solution is exposed to sunlight because HC*l*O decomposes to form oxygen and a solution of hydrochloric acid.

Complete the balanced chemical equation for this reaction below. **[2]**

HC*l*O →

ES1vi

$2\,HClO \rightarrow 2\,HCl + O_2$

Correct formulae for products (1)

Balancing (1)

[2]

2 There is considerable concern over rising carbon dioxide levels that most scientists think are causing global warming. This concern has prompted the British Government to charge less in road fund tax for cars that produce less carbon dioxide.

AT25i

Cars are now more fuel efficient than they used to be and so they produce less carbon dioxide. Suggest **one** design feature that has made cars more fuel efficient.

.....

..... **[1]**

AT25i

Lean burn engines/ oxygen sensors/ reduced drag/ more complete combustion/ more oxygenates (1)

[1]

AT23i

AT23ii

AT23iv

Greenhouse gases like carbon dioxide absorb infrared radiation in the troposphere. Explain the source of this infrared radiation and suggest what happens to a molecule of carbon dioxide when it absorbs this radiation.

In your answer you should make clear how your explanation links with the chemical theory.

.....

.....

.....

.....

..... **[5]**

AT23i

AT23ii

AT23iv

Four from:
UV/ visible (1);
(warms) Earth (1);
which radiates IR (1);
makes bonds vibrate (1) more (1)
warm Earth must be related to IR and IR related to vibration (1)

[5]

The Earth's oceans act in a way that regulates the increase in carbon dioxide levels in the troposphere. An equilibrium is set up between gaseous and aqueous carbon dioxide.

AT8

(i) Suggest and explain why the balance between gaseous and aqueous carbon dioxide is not a true equilibrium.

.....

..... **[1]**

AT8

System not closed/ as CO_2 (g) moves away from surface/ CO_2 is ionised (1)

[1]

AT25iii

(ii) Suggest **two** possible methods that could be used for the capture and storage of carbon dioxide, to prevent its build-up in the atmosphere.

1 .....

.....

2 .....

..... **[2]**

AT25iii

1. Pump it under pressure onto the ocean floor (1);
2. Pump it underground into spent oil or gas wells (1)

[2]

AT25iii

(iii) For **one** of your methods in **(ii)**, suggest an environmental impact that could arise from its use.

..... **[1]**

AT25iii

The CO_2 combines with any minerals in the surrounding rocks to convert them to carbonates/
pH of Oceans might be affected (1)

[1]

3

The polymer commonly known as PVC exists in two forms. Plasticised PVC is used where flexibility is required. Unplasticised PVC, uPVC, is rigid at room temperature and is used to make things such as guttering for houses.

PR14

Suggest **one** other use for uPVC in the construction of a house.

.....[1]

PR14

(drain)pipes/window frames/doors/roofing (1) **[1]**

PR12ii

PR12i

PVC is manufactured by polymerising chloroethene. Chloroethene is produced in a two stage synthesis as outlined below.

stage 1 $CH_2 = CH_2 + Cl_2 \xrightarrow{FeCl_3} ClCH_2CH_2Cl$

stage 2 $ClCH_2CH_2Cl \xrightarrow{heat} CH_2{=}CHCl + HCl$

Underline **two** of the following words to describe the reaction in **stage 1**.

addition electrophilic elimination nucleophilic radical substitution

[2]

PR12ii

PR12i

electrophilic (1)
addition (1) **[2]**

PR8

Select **one** word from the list to describe the reaction in **stage 2**.

.....[1]

PR8

elimination (1) **[1]**

PVC owes many of its properties to the intermolecular bonds between the polymer chains.

ES7ii

Name the strongest type of intermolecular bond that is present in PVC.

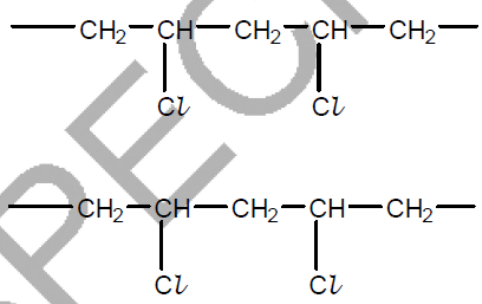
..... **[1]**

ES7ii

permanent dipole–permanent dipole (1) **[1]**

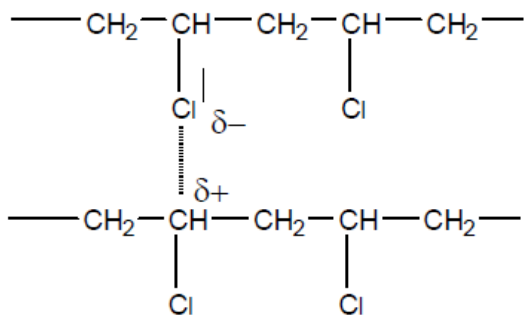
ES7ii

Use the diagram below to show how these intermolecular bonds hold the PVC chains together.



[2]

ES7ii



δ+, δ- correct (1);
indication of attraction (1) **[2]**

PR10ii

Chloroethene will also undergo the following sequence of reactions.

$CH_2 = CHCl \longrightarrow CH_3CH_2Cl \longrightarrow CH_3CH_2OH \longrightarrow CH_3CHO$

chloroethene **chloroethane** **ethanol** **compound A**

Name the reagent and conditions needed to turn **chloroethene** into **chloroethane**.

.....

..... **[2]**

PR10ii

Hydrogen (1);
Ni, hot **or** Pt (room temperature and pressure) (1)

[2]

PR6

Classify **ethanol** as primary, secondary or tertiary, giving a reason.

.....

..... **[2]**

PR6

Primary (1);
as OH is attached to CH_2/ C with OH attached to one other C (1)

[2]

PR5i

Name the functional group in **compound A**.

..... **[1]**

PR5i

Aldehyde (1)

[1]

PR11i

Give the reagents and conditions for the conversion of **ethanol** to **compound A** in the laboratory.

.....

.....

..... **[3]**

PR11i

(potassium/sodium) dichromate/ correct formula (1);
(sulfuric) acid (1);
distil (1) *NOT heat*

[3]

ES1ii

In a laboratory experiment, 10 g of chloroethene, CH_2CHCl, produced 1.5 g of ethanol, CH_3CH_2OH.

Work out the percentage yield of the conversion of chloroethene to ethanol.

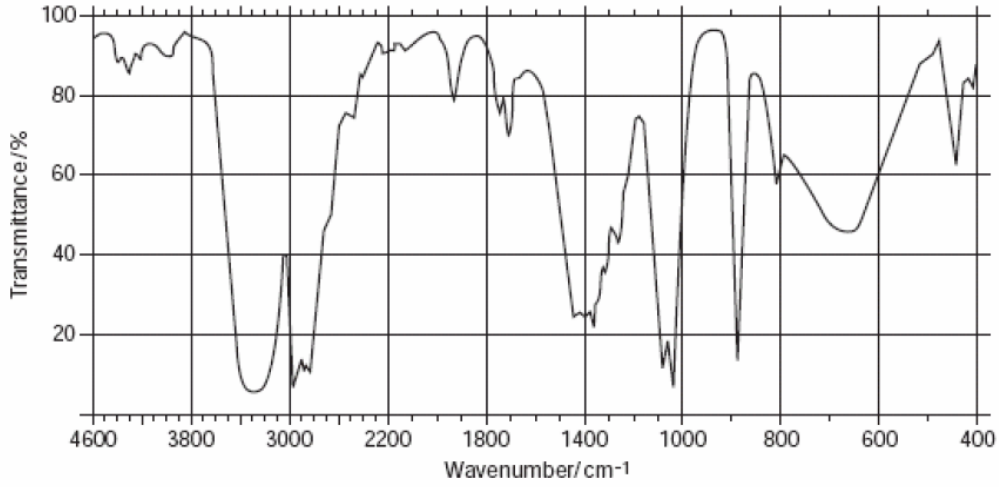
Give your answer to **two** significant figures.

yield = ... % **[5]**

ES1ii

M_r chloroethene = 62.5 ethanol = 46 (1);
Moles chloroethene = 10/62.5 (=0.16) moles ethanol = 1.5/46 (=0.0326/0.033) (1);
= moles ethanol (0.16) (1);
% = 0.0326 x 100/0.16 = 20% (1)
2 s.f. (1) Mark separately provided some working shown. ecf from figures above (allow 21% if 0.033 moles ethanol used) **[5]**

Infrared spectroscopy was carried out on the product formed in the reaction of chloroethene to give ethanol. The spectrum that was produced is shown below.



PR16

Use information from this spectrum to explain how it confirms that an alcohol had been produced.

..... **[1]**

PR16

Peak at ~3200 cm^{-1} *(or indicated on spectrum)* shows (alcoholic) OH bond (1)

[1]

PR17

Suggest how you would be able to confirm, using infrared spectroscopy, that the product was ethanol.

.....

.....

..... **[2]**

PR17

Run IR spectrum for known sample of ethanol (1);
compare spectra – they have identical fingerprint/peak pattern (1)

[2]

Much of the ethanol is made industrially from ethene.

PR10iii

Give the reagents and conditions by which ethanol is made from ethene in industry.

.....

..... **[2]**

PR10iii

Water (1);
Catalyst with high temp & pressure/ catalyst of sulfuric or phosphoric acid *(second mark dependant on first)* **[2]**

PR12ii

The reaction in which ethanol is produced from ethene involves attack by an electrophile. Explain what is meant by the term *electrophile*.

.....

..... **[2]**

PR12ii

(Partially) positively charged/electron deficient reagent/attracted to areas of high electron density (1);
Bonds by accepting a pair of electrons (can be shown via mechanism) (1); **[2]**

PR10iii

Suggest a reason, other than cost, why ethanol is **not** manufactured from chloroethene.

.....

..... **[1]**

PR10iii

Low yield (1) **[1]**

4 Hydrofluorocarbons, HFCs, have replaced CFCs for many of their uses. They are broken down in the troposphere before they have time to reach the stratosphere.

AT17ii

Give the formula of a CFC.

.....[1]

AT17ii

Any carbon compound with chlorine and fluorine only (1) **[1]**

CFCs were used as the refrigerant in domestic fridges. The presence of CFCs makes disposing of old fridges difficult. Give **one** property of CFCs that made them suitable as refrigerants.

AT17i

.....

.....[1]

AT17i

High heat of vaporisation/volatile/non-toxic/unreactive (1) **[1]**

AT12i

CFCs cause depletion of the ozone layer. Describe how they do this.

.....

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.....

..... **[4]**

AT12i

In the stratosphere/ upper atmosphere (1);
they break down under the influence of high-energy/ high frequency UV/radiation(1);
to form chlorine atoms/ *radicals*/ C*l* (1);
that *catalyse* the breakdown of ozone (1)
QWC: *link between first and second marking points or first and third [1]* **[4]**

AT19

Initially, studies of changes in the Earth's atmosphere did not reveal the problem of ozone depletion. Explain why the information about ozone depletion was overlooked.

.....

.....

..... **[2]**

AT19

So much data was being collected that any outside expected ranges was discarded (1);
values for ozone concentration were significantly below expected values (1) **[2]**

Other atmospheric pollutants can contribute to a build-up in tropospheric ozone. For example, hydrocarbons can interfere with the normal reactions for the formation and breakdown of ozone. The reaction for the breakdown of ozone involves naturally occurring NO_2 and NO.

$$NO_2 \xrightarrow{h\nu} NO + O \qquad \textbf{equation 4.1}$$

$$NO + O_3 \rightarrow NO_2 + O_2 \qquad \textbf{equation 4.2}$$

$$O + O_2 \rightarrow O_3 \qquad \textbf{equation 4.3}$$

AT18i

Combine **two** of these equations to show how ozone is broken down.

[ ] → [ ]

[1]

AT18i

$O_3 \rightarrow O_2 + O$ **[1]**

AT12i

Hydrocarbons lead to reactions in which NO is converted into NO_2. Explain how this leads to a build-up of ozone.

.....

.....

..... **[2]**

AT12i

Hydrocarbons provide an alternative to equation 4.2 (1);
so less ozone is broken down/ more ozone is made because of increased O (1) **[2]**

AT18iii

Suggest **one** disadvantage of a build-up of tropospheric ozone.

.....

..... **[1]**

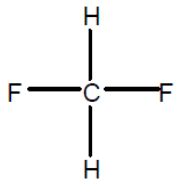
AT18iii

Photochemical smog/ an effect like breathing difficulties (1) **[1]**

One example of an HFC is CH_2F_2. The C–F bond is polar.

Mark partial charges on the C and F atoms in the structure below.

ES7ii



[1]

ES7ii

δ+ on carbon, δ- on fluorines (1)

ES6

Explain what determines where the partial charges are placed on this molecule.

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..... **[2]**

ES6

Mention of electronegativity (1);
Fluorine more electronegative than carbon (1)

[2]

ES7ii

Does the whole molecule have a dipole? Explain your answer.

.....

..... **[2]**

ES7ii

Yes, the charges do not balance (1);
Shape is tetrahedral (1)

[2]

AT12ii

AT21ii

If molecules of CH_2F_2 reach the stratosphere, they do not break down to produce F radicals.

Suggest why C–F bonds are not broken in the stratosphere.

.....

..... **[2]**

AT12ii

AT21ii

UV/radiation (1);
does not have enough energy/ does not have high enough frequency (1)
REJECT for second mark answers that imply intensity of radiation
"C–F is strong/ stronger than C–C*l*" scores (1) **[3]**

ES26iii

The bond enthalpy of the C–F bond is +467 kJ mol^{-1}.

Calculate the minimum energy (in joules) needed to break a single C–F bond.

Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}

minimum energy = ... **[2]**

ES26iii

467/6.02 x 10^{23} (1) x 1000 = 7.75(7)/ 7.76 x 10^{-19} J (1) **[2]**

AT22

Calculate the minimum frequency of radiation needed to break a C–F bond.

Give the appropriate units for your answer.

Planck constant, $h = 6.63 \times 10^{-34}$ J Hz^{-1}.

minimum frequency = ...

units..... **[3]**

AT22

7.757 x 10^{-19} *ecf*/ 6.63 x 10^{-34} (1) = 1.17 x 10^{15} (1) Hz (1) **[3]**

PR14
AT6

Vulcanisation improves the properties of rubber and accelerator molecules catalyse the process.

Use information from the article about polymer structures and your knowledge of catalysts to explain this.

In your answer you should make clear how your explanation links with the chemical theory.

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..... **[6]**

PR14
AT6

strong S–S bonds (1);
stop chains sliding over each other (1)
relation between strong bonds and stopping sliding (1)
path of lower E_a (1);
molecules contain sulfur (1);
form intermediates (1) **[6]**