SL Paper 3

Stratospheric ozone is in dynamic equilibrium with oxygen. Give the equations that describe the formation of ozone from oxygen and its depletion in the stratosphere in the presence of ultraviolet light.

Formation:

Depletion:

Markscheme

Formation

$\mathrm{O_2} \rightarrow 2\mathrm{O}\bullet$ **and** $\mathrm{O_2} + \mathrm{O}\bullet \rightarrow \mathrm{O_3}$;

Depletion

$\mathrm{O_3} \rightarrow \mathrm{O_2} + \mathrm{O}\bullet$ **and** $\mathrm{O_3} + \mathrm{O}\bullet \rightarrow 2\mathrm{O_2}$;

Examiners report

Part (a) produced mixed responses with some candidates writing appropriate equations, and some writing only one equation for the formation and depletion of ozone when two equations were needed for each process. A few candidates seemed to have no idea of the formula of ozone.

Ozone prevents UV radiation emitted from the Sun reaching the surface of the Earth.

Describe, using chemical equations, the two-step mechanism of photochemical decomposition of ozone in the Earth's stratosphere.

Step 1:

Step 2:

Markscheme

Step 1:

$\mathrm{O_3(g)} \xrightarrow{\mathrm{UV}/hf/h\upsilon} \mathrm{O_2(g)} + \mathrm{O}\bullet\mathrm{(g)}$;

UV not needed for mark (since given in question).

Step 2:

$\mathrm{O_3(g)} + \mathrm{O}\bullet\mathrm{(g)} \rightarrow 2\mathrm{O_2(g)}$;

Ignore state symbols.

Allow O instead of $O\bullet$ if consistent throughout.

Examiners report

Most of the candidates were able to score part marks for (a); marks were not gained either due to incorrectly balanced equations or incorrect Step 2 equation. In part (b) comparing $\mathrm{C_2F_6}$ with CFCs was challenging with many not really knowing why $\mathrm{C_2F_6}$ is used. Candidates demonstrated a poor understanding of reactivity and the strength of the fluorine to carbon bond. Many referred to CFCs as having longer lifetime and being more stable. Most candidates were able to score only one mark for this question.

The ozone layer protects living organisms from dangerous UV radiation. In the Earth's stratosphere, ozone is photochemically formed from oxygen by the following two-step process.

$$\mathrm{O_2} \xrightarrow{\text{UV light}} 2\mathrm{O}\bullet$$
$$\mathrm{O_2} + \mathrm{O}\bullet \rightarrow \mathrm{O_3}$$

(a) Ozone decomposition can proceed photochemically. Describe, using chemical equations, the two-step mechanism of photochemical decomposition of ozone in the Earth's stratosphere.

Step 1:

Step 2:

(b) Ozone decomposition can also be catalysed by ozone-depleting substances such as chlorofluorocarbons, CFCs. State **two** alternatives to CFCs.

Markscheme

(a) *Step 1:*

$\mathrm{O_3} + h\nu \rightarrow \mathrm{O_2} + \mathrm{O}\bullet$;

Step 2:

$\mathrm{O}\bullet + \mathrm{O_3} \rightarrow 2\mathrm{O_2}$;

Dots and radicals are not required for the mark.

Accept more detailed mechanisms ($O\bullet + O_2 + M \rightarrow O_3 + M*$, etc.).

(b) hydrocarbons

(per)fluorocarbons

hydrofluorocarbons / HFCs

hydrochlorofluorocarbons / HCFCs

ammonia/ $\mathrm{NH_3}$ / sulfur dioxide/ $\mathrm{SO_2}$

nitrogen/ $\mathrm{N_2}$ / argon/Ar

*Any two correct answers scores **[1]**.*

Examiners report

Only a small proportion of candidates could correctly quote the two equations for the photochemical decomposition of ozone, though many could correctly identify alternatives to CFCs.

Emissions of ozone-depleting substances such as CFCs have decreased extensively as a result of the Montreal Protocol. In the most recent assessment of ozone depletion by the United Nations Environmental Programme, scientists predict a substantial recovery of the ozone layer by 2050.

b.i. Although the use of harmful CFCs is being phased out, suggest why these compounds are expected to remain in the atmosphere for the next 80–100 years. [1]

b.ii. Discuss **one** advantage and **two** disadvantages of using hydrocarbons as alternatives to CFCs. [3]

Advantage:

Disadvantages:

Markscheme

b.i. CFCs have a low reactivity/strong bonds/are highly stable;

CFCs/radicals they produce/ Cl□ have high residual time in atmosphere;

some (developing) countries still producing/consuming CFCs / slower phase-out of CFCs;

harmful CFCs are still present in expanded polystyrene and old refrigerators and have yet to leak into the atmosphere;

slow mixing between lower atmosphere/troposphere and upper atmosphere/stratosphere;

b.ii *Advantage*:

do not damage the ozone layer;

decompose less readily (than CFCs);

cheaper than CFCs;

Disadvantages:

flammable;

both contribute to global warming/greenhouse gases/absorb IR radiation;

Examiners report

b.i. The equations required in the first part of this question were amongst the best known in the examination; the result of memorisation? A number of candidates incorrectly gave the reaction between two oxygen atoms as a significant process in ozone depletion and some discussed the way CFCs accelerate the depletion, rather than giving the natural processes asked for. Relatively few could give correct reasons for the persistence of CFCs in the atmosphere, but advantages and disadvantages of were relatively widely known.

b.ii. The equations required in the first part of this question were amongst the best known in the examination; the result of memorisation? A number of candidates incorrectly gave the reaction between two oxygen atoms as a significant process in ozone depletion and some discussed the way CFCs accelerate the depletion, rather than giving the natural processes asked for. Relatively few could give correct reasons for the persistence of CFCs in the atmosphere, but advantages and disadvantages of were relatively widely known.

Increasing concentrations of greenhouse gases are considered to cause global warming. Ozone depletion is another environmental concern.

Identify a gas that is both a greenhouse gas and a cause of ozone depletion.

Markscheme

specific CFC compound;

Accept CFC/chlorofluorocarbon.

Allow water vapour.

Examiners report

Few candidates gave a CFC compound in part (a). Candidates were more familiar with the impact of global warming than they were with the impact of ozone depletion.

The ozone layer protects us by absorbing ultraviolet (UV) radiation from the Sun during its natural formation and depletion.

Describe, using equations, the formation and depletion of ozone in the stratosphere by natural processes.

Formation:

Depletion:

Markscheme

Formation:

$\mathrm{O_2(g)} \xrightarrow{\mathrm{UV(light)}/h\nu/hf} \mathrm{2O\bullet(g)};$

$\mathrm{O_2(g) + O\bullet(g) \rightarrow O_3(g)};$

Depletion:

$\mathrm{O_3(g)} \xrightarrow{\mathrm{UV(light)}/h\nu/hf} \mathrm{O_2(g) + O\bullet(g)};$

$\mathrm{O_3(g) + O\bullet(g) \rightarrow 2O_2(g)};$

Allow representation of radical without ● if consistent throughout mechanism.

UV(light)/hv/hf can be represented above arrow or mentioned in accompanying description in words.

Penalize omission of UV (light)/hv/hf once only.

Ignore state symbols.

Examiners report

This question related to the formation and depletion of ozone in the stratosphere by natural processes. The most common errors in (a) were failure to mention the necessity for UV light to form the oxygen radicals and inconsistent use of the dot in equations to represent radicals.