

Name: _____

Date: _____

Class: _____

IB ESS

6.3 Photochemical Smog

Significant ideas:

The combustion of fossil fuels produces primary pollutants which may generate secondary pollutants and lead to photochemical smog, whose levels can vary by topography, population density and climate.

Photochemical smog has significant impacts on societies and living systems.

Photochemical smog can be reduced by decreasing human reliance on fossil fuels.



Urban Air Pollution

1. Define "pollution".

(Review chapter 1.5 - Humans and Pollution)

Addition of a substance or an agent to the environment by human activity at a rate greater than that at which it can be rendered harmless and which has an appreciable effect on the environment and the organisms within it.

2.

a) Outline what is meant by "primary pollutant" and "secondary pollutant".

Primary pollutant - emitted directly from a process. may be natural e.g. volcanic eruptions or anthropogenic e.g. industry

Secondary pollutant - formed when primary pollutants undergo a variety of reactions with other chemicals in the atmosphere

b) List 3 examples of primary pollutants.

carbon monoxide from incomplete combustion

nitrogen oxides - especially nitrogen dioxide

sulphur dioxide

c) List 3 examples of secondary pollutants.

tropospheric ozone

particulates produced from gaseous primary pollutants

peroxyacetyl nitrate (PAN)



Tropospheric Ozone

1. Outline how photochemical reactions can form secondary pollutants.

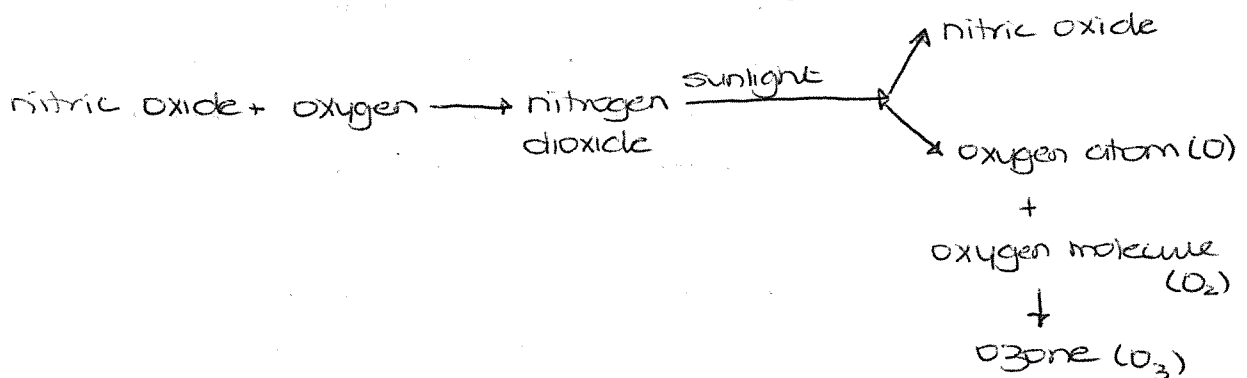
These are reactions in the presence of sunlight. Primary pollutants undergo chemical reactions with chemicals in the atmosphere e.g. Tropospheric ozone is formed when oxygen molecules react with oxygen atoms released from NO_2 .

2. With reference to fossil fuel use, describe what is meant by "incomplete combustion".

Poor mixing of fuel and air or due to low temperatures. Fossil fuels are only partially burned releasing carbon monoxide (CO) as a by-product.

3. Using a simple diagram (e.g. a flow diagram), summarize the formation of tropospheric ozone from nitric oxide.

(Nitric oxide is a product of incomplete combustion of fossil fuels.)



4. Distinguish between "stratospheric ozone" and "tropospheric ozone". Include reference to sources and depletion, as well as consequences, in your answer.

	stratospheric O_3	tropospheric O_3
Source	Natural when O_2 splits in the presence of sunlight	VOCs, CO , CO_2 , black carbon, unburned hydrocarbons, oxides of nitrogen and sulfur
Depletion	ODS e.g. CFCs, NO_x	
Effects	Filtering of harmful UV radiation	Pollutant - toxic gas and oxidising agent, reduces crop yields, irritates eyes, breathing difficulty



5. Complete the table to show the potential negative affects of tropospheric ozone.

Effect	Details
Oxidizing	Ozone is a toxic gas and a powerful oxidising agent. Capability to give away free oxygen atoms.
Damage to plants	<ul style="list-style-type: none"> • Interferes with the ability of sensitive plants to produce and store food. • Damages leaves, degrades chlorophyll with reduces photosynthesis and therefore productivity.
Damage to humans	can harm lung tissue, impair the body's defence mechanism, increase respiratory tract infections and aggravate asthma, bronchitis and pneumonia.
Damage to materials	<p>High levels of ozone can damage fabrics and rubber materials.</p> <p>bleaches reduces lifetime of tyres.</p> <p>Attacks natural rubber, cellulose and some plastics.</p>



Photochemical Smog

1. State the conditions in which photochemical smog is likely to form or become more pronounced

- associated with certain climates - in particular, high air pressure systems. Winds are low so pollutants are not dispersed.
- associated with low-lying areas due to thermal inversion
- associated with large populations due to greater number of vehicles.

2. Outline the formation of photochemical smog.

Hint: in your answer you should include the words/phrases:

tropospheric ozone, nitrogen oxides, gaseous hydrocarbons, vehicle exhausts, volatile organic compounds, peroxyacyl nitrates, sunlight

Photochemical smog is mainly nitrogen dioxide and ozone but is a complex mixture of about 100 different primary and secondary air pollutants.

It is formed when ozone, nitrogen oxides and gaseous hydrocarbons (mainly from motor vehicle exhausts in cities) interact with strong sunlight.

Complex reactions create many chemicals in photochemical smog including VOCs (volatile organic compounds), PANs (peroxyacyl nitrates) ozone, aldehydes, carbon monoxide and nitrogen oxides.

Highly reactive VOCs oxidise nitrogen oxides into nitrogen dioxide without breaking down ozone which leads to a build up of ozone near ground level and smog formation.

3. Photochemical smog often peaks in the early afternoon, despite the fact that the amount of primary pollution release is at a maximum during rush hour (early morning and late afternoon). Explain why this is.

Even though the main primary pollutants reach a maximum concentration during the morning and evening rush hours, the important smog-causing reaction is a photochemical one so it reaches its peak in the afternoon sun.



4. Outline the way the following factors can influence the extent of photochemical smog.

Local Topography:

Urban areas located within valleys with surrounding upland areas tend to experience low air circulation and so high levels of accumulation of pollutants

Climate

Stable high pressure reduces winds which would disperse the pollutants
In monsoonal areas smog only occurs in the dry season.

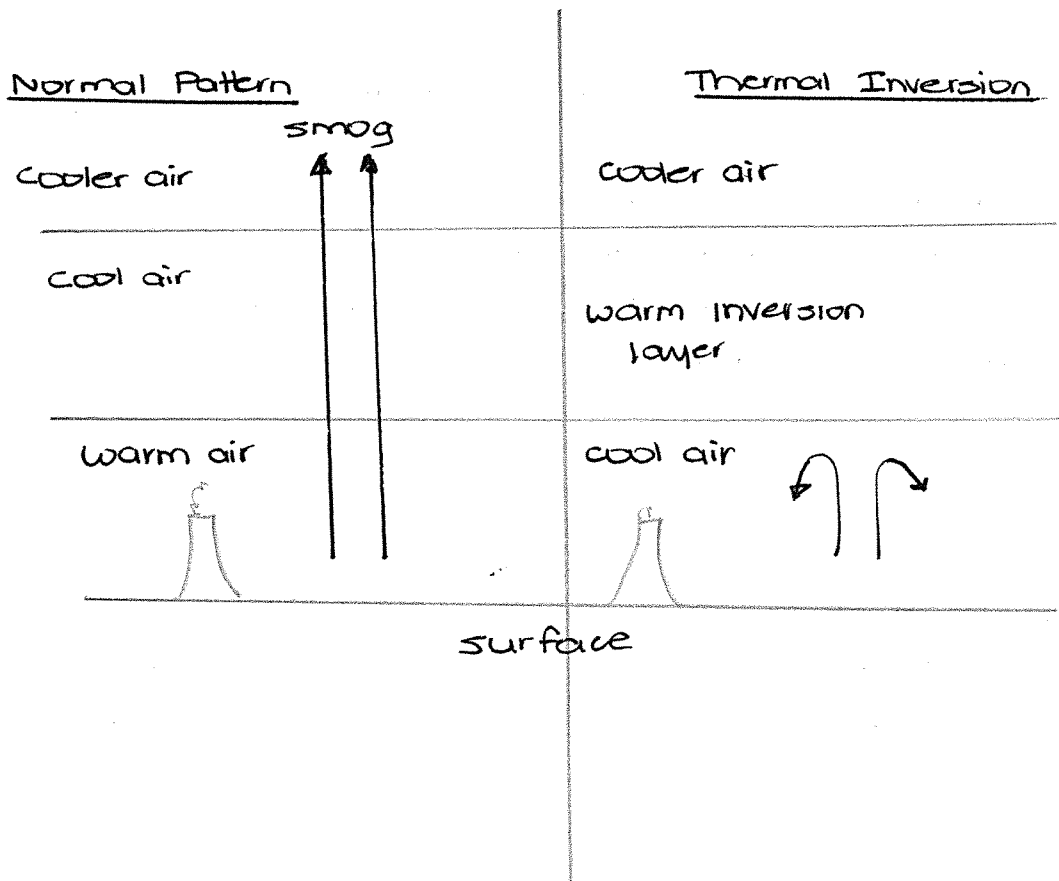
Population density

The larger the population the greater the number of vehicles

Fossil fuel use

Increased fossil fuel use increase the chances of tropospheric ozone being produced

5. Draw a diagram to explain how a thermal inversion can amplify the effect of photochemical smog.



Pollution Management Strategies for Photochemical Smog

1. Briefly summarize the three categories of the pollution management strategy model

Replace

link [Booklet 1.5](#)

Find alternatives to the materials that are causing the pollution
usually involves altering human activity.

Regulate

legislating and regulating standards of emissions
developing / applying technologies for extracting pollutants from emissions

Restore

extracting and removing pollutants from ecosystem
replanting / restocking lost or depleted populations and communities



2. Complete the table to list some suggestions for pollution management strategies to tackle photochemical smog.

Once you have your chosen list of strategies, **evaluate** each of them. Give one "for" and one "against" comment for each if possible.

Strategy	Action	Evaluation
Altering human activities causing the pollution	Consume less, burn less fossil fuel - especially in the internal combustion engine	can be effective with clear education. Demand for power is increasing worldwide
	Lobby governments to increase renewable energy.	Allows citizens to have a voice. Government response will vary greatly
Regulate and reduce at point of emission	Government regulation / taxation	Effective Requires careful monitoring
	Catalytic converters to clean exhaust of primary pollutants from car exhaust	Although initially expensive can be cost effective if well maintained
Clean-up and restore	Afforestation to increase carbon sinks and filter air.	Long term strategy Does not reduce emissions
	Re-greening of cities - more trees, more parks which absorb carbon dioxide	Aesthetically pleasing Difficult to continue as more urbanization + world population

