

## ENVIRONMENTAL SCIENCE

## SECTION II

Time—90 minutes

4 Questions

**Directions:** Answer all four questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers on the pages following the questions in the pink booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

1. Read the article below from the *Fremont Free Press* and answer the questions that follow.

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## Fremont City Council Considers Nitrogen Ban to Fight Smog!

At Tuesday's council meeting, Susan Lanza, a local environmental scientist, spoke about the role that nitrogen compounds play in the photochemical smog episodes that have recently plagued Fremont. Noting how successful the ban on the sale of phosphate detergents had been in improving conditions in Lake Fremont, Councilman Peter Budd proposed a ban on the use of all nitrogen-containing

fertilizers in Fremont to solve the local photochemical-smog problem.

Councilwoman Nita Smith made a statement that "although nitrogen-based fertilizers can cause other environmental problems, the ban on nitrogen fertilizers won't solve the smog problem in Fremont." After a heated discussion, the council tabled the motion on the ban.

- (a) Support Councilwoman Smith's statement that nitrogen-based fertilizers cause other environmental problems by describing one such problem.
- (b) Identify a nitrogen-containing primary pollutant that contributes to the formation of photochemical smog. Describe how that primary pollutant forms and explain why Councilman Budd was wrong.
- (c) Identify one secondary pollutant that is a component of photochemical smog and describe the following.
  - (i) How the secondary pollutant forms
  - (ii) ONE human health effect of the pollutant
  - (iii) ONE environmental effect of the pollutant
- (d) Earth's natural nitrogen cycle occurs in several steps. Describe one chemical transformation that occurs in the natural nitrogen cycle and discuss the importance of that transformation to an ecosystem.

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### Question 1

- (a) **Support Councilwoman Smith's statement that nitrogen-based fertilizers cause other environmental problems by describing one such problem.**

Two points can be earned for describing the cause and effect of one environmental problem not related to photochemical smog that is associated with the use of nitrogen-based fertilizers. One point can be earned for a description of an effect without a description of a cause.

Cause (1 point)	Effect (1 point)
Fertilizer enters surface waters or groundwater	<ul style="list-style-type: none"> <li>Increases algal blooms in surface waters</li> <li>Decreases dissolved oxygen levels in surface waters</li> <li>Promotes eutrophication in surface waters</li> <li>Results in nitrate contamination of drinking water</li> <li>"Blue baby syndrome"</li> </ul>
Bacterial decomposition of fertilizer	<ul style="list-style-type: none"> <li>Produces nitrous oxide (<math>\text{N}_2\text{O}</math>), which increases global warming</li> <li>Produces <math>\text{N}_2\text{O}</math>, which depletes stratospheric ozone</li> </ul>
Production, transportation, and application of fertilizer	<ul style="list-style-type: none"> <li>Consumes fossil fuels, increasing habitat destruction during their extraction</li> <li>Consumes fossil fuels, which produces carbon dioxide (<math>\text{CO}_2</math>) and increases global warming</li> </ul>

- (b) **Identify a nitrogen-containing primary pollutant that contributes to the formation of photochemical smog. Describe how that primary pollutant forms and explain why Councilman Budd was wrong.**

Three points can be earned: 1 point for identifying a nitrogen-containing primary pollutant; 1 point for describing how the selected primary pollutant is formed; and 1 point for explaining why Councilman Budd was wrong.

Primary Pollutant (1 point)	Formation (1 point)
Nitric oxide (nitrogen monoxide), nitrogen dioxide, or nitrogen oxides  <u>OR</u>  $\text{NO}$ , $\text{NO}_2$ , or $\text{NO}_x$	Nitrogen reacts with oxygen ( $\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}$ ) or ( $\text{N}_2 + 2\text{O}_2 \rightarrow 2\text{NO}_2$ ) or nitric oxide reacts with oxygen ( $2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$ ) during: <ul style="list-style-type: none"> <li>High-temperature combustion</li> <li>Combustion in automobile engines</li> <li>Combustion in fuel-burning power plants</li> <li>Burning of fossil fuels</li> </ul>

One point can be earned for a statement explaining that nitrogen-based fertilizers do not release the air pollutants that cause photochemical smog.

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### Question 1 (continued)

(c) Identify one secondary pollutant that is a component of photochemical smog and describe the following.

- (i) How the secondary pollutant forms
- (ii) ONE human health effect of the pollutant
- (iii) ONE environmental effect of the pollutant

Four points can be earned: 1 point for the identification of a correct secondary pollutant; 1 point for describing how the selected secondary pollutant is formed; 1 point for a correct human health effect; and 1 point for a correct environmental effect.

Pollutant (1 point)	Formation (1 point)	Human Health Effect (1 point)	Environmental Effect (1 point)
Ozone  <u>OR</u>  O <sub>3</sub>	<ul style="list-style-type: none"> <li>In the light-activated reactions of nitrogen oxides and volatile organic compounds (VOCs) or hydrocarbons</li> <li>In the reaction of O<sub>2</sub> with O</li> </ul>	<ul style="list-style-type: none"> <li>Respiratory problems</li> <li>Impairs immune system</li> <li>Eye irritation</li> <li>Reduces crop yields, which may lead to poor nutrition or lack of food</li> </ul>	<ul style="list-style-type: none"> <li>Damages plant tissues (cells, leaves, needles, stems, etc.)</li> <li>Inhibits photosynthesis in plants</li> <li>Suppresses plant growth</li> <li>Increases plant susceptibility to diseases and pests</li> <li>Causes respiratory problems in animals</li> <li>Damages materials (rubber, paint, fabric, etc.)</li> <li>Acts as a greenhouse gas and increases global warming</li> </ul>
Peroxyacyl nitrates  <u>OR</u>  PANs	In the light-activated reactions of nitrogen oxides and volatile organic compounds (VOCs) or hydrocarbons	<ul style="list-style-type: none"> <li>Respiratory problems</li> <li>Impairs immune system</li> <li>Eye irritation</li> <li>Reduces crop yields, which may lead to poor nutrition or lack of food</li> </ul>	<ul style="list-style-type: none"> <li>Damages plant tissues (cells, leaves, needles, stems, etc.)</li> <li>Inhibits photosynthesis in plants</li> <li>Suppresses plant growth</li> <li>Causes respiratory problems in animals</li> </ul>

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**Question 1 (continued)**

<b>Pollutant (1 point)</b>	<b>Formation (1 point)</b>	<b>Human Health Effect (1 point)</b>	<b>Environmental Effect (1 point)</b>
Nitrogen Dioxide  <u>OR</u>  $\text{NO}_2$	In the reaction of nitrogen oxide (NO) with oxygen	<ul style="list-style-type: none"> <li>• Respiratory problems</li> <li>• Impairs immune system</li> <li>• Eye irritation</li> <li>• Reduces crop yields, which may lead to poor nutrition or lack of food</li> </ul>	<ul style="list-style-type: none"> <li>• Reduces visibility, which also impairs photosynthesis</li> <li>• Increases plant susceptibility to diseases</li> <li>• Suppresses plant growth</li> <li>• Causes respiratory problems in animals</li> </ul>
Nitric Acid  <u>OR</u>  $\text{HNO}_3$	In the reaction of nitrogen oxides ( $\text{NO}_x$ ) with oxygen and water vapor	<ul style="list-style-type: none"> <li>• Irritates eyes, nose, or throat</li> <li>• Damages lungs when inhaled</li> <li>• Reduces crop yields, which may lead to poor nutrition or lack of food</li> </ul>	<ul style="list-style-type: none"> <li>• Causes loss of soil fertility</li> <li>• Leaches nutrients from soils</li> <li>• Releases toxic elements in soils</li> <li>• Causes plant damage or death</li> <li>• Increases susceptibility of plants to disease or drought</li> <li>• Causes loss of habitat</li> <li>• Causes injury or death of aquatic life</li> <li>• Causes loss of essential elements from aquatic ecosystems</li> <li>• Damages materials (limestone, marble, etc.)</li> </ul>
Sulfuric Acid  <u>OR</u>  $\text{H}_2\text{SO}_4$	In the reaction of sulfur dioxide ( $\text{SO}_2$ ) with oxygen and water vapor	<ul style="list-style-type: none"> <li>• Irritates eyes, nose, or throat</li> <li>• Damages lungs when inhaled</li> <li>• Reduces crop yields, which may lead to poor nutrition or lack of food</li> </ul>	<ul style="list-style-type: none"> <li>• Causes loss of soil fertility</li> <li>• Leaches nutrients from soils</li> <li>• Releases toxic elements in soils</li> <li>• Causes plant damage or death</li> <li>• Increases susceptibility of plants to disease or drought</li> <li>• Causes loss of habitat</li> <li>• Causes injury or death of aquatic life</li> <li>• Causes loss of essential elements from aquatic ecosystems</li> <li>• Damages materials (limestone, marble, etc.)</li> </ul>

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**Question 1 (continued)**

<b>Pollutant (1 point)</b>	<b>Formation (1 point)</b>	<b>Human Health Effect (1 point)</b>	<b>Environmental Effect (1 point)</b>
Nitrates, sulfates, or fine particulate matter  <u>OR</u>  PM 2.5	In the reaction of nitrogen oxides (NO <sub>x</sub> ) or sulfur dioxide (SO <sub>2</sub> ) with oxygen	<ul style="list-style-type: none"> <li>• Irritates eyes, nose, or throat</li> <li>• Damages lungs when inhaled</li> <li>• Reduces crop yields, which may lead to poor nutrition or lack of food</li> </ul>	<ul style="list-style-type: none"> <li>• Causes loss of soil fertility</li> <li>• Leaches nutrients from soils</li> <li>• Releases toxic elements in soils</li> <li>• Causes plant damage or death</li> <li>• Increases susceptibility of plants to disease or drought</li> <li>• Causes loss of habitat</li> <li>• Causes injury or death of aquatic life</li> <li>• Causes loss of essential elements from aquatic ecosystems</li> <li>• Damages materials (limestone, marble, etc.)</li> </ul>

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### Question 1 (continued)

**(d) Earth's natural nitrogen cycle occurs in several steps. Describe one chemical transformation that occurs in the natural nitrogen cycle and discuss the importance of that transformation to an ecosystem.**

Two points can be earned: 1 point for a correct natural nitrogen-cycle chemical transformation and 1 point for a corresponding discussion of its importance to an ecosystem. A discussion point can be earned without a description of the chemical transformation.

Chemical Transformation (1 point)	Discussion (1 point)
Nitrogen is converted to ammonia, ammonium, or nitrate  <u>OR</u>  $\text{N}_2 \rightarrow \text{NH}_3 \text{ or } \text{NH}_4^+ \text{ or } \text{NO}_3^-$	<ul style="list-style-type: none"> <li>Converts atmospheric nitrogen into terrestrial nitrogen</li> <li>Converts nitrogen to a biologically usable form</li> <li>Provides plants with biologically available (fixed) nitrogen</li> </ul>
Ammonia or ammonium is converted to nitrite, which is converted to nitrate (a description of only one of the steps is acceptable)  <u>OR</u>  $\text{NH}_3 \text{ or } \text{NH}_4^+ \rightarrow \text{NO}_2^- \rightarrow \text{NO}_3^-$ $\text{NH}_3 \text{ or } \text{NH}_4^+ \rightarrow \text{NO}_3^-$ $\text{NO}_2^- \rightarrow \text{NO}_3^-$ (a description of only one of the steps is acceptable)	<ul style="list-style-type: none"> <li>Provides plants with nitrates that can be taken up and used</li> <li>Nitrates, along with ammonia and ammonium, are the most useful forms of nitrogen to plants</li> </ul>
Nitrate, ammonia, or ammonium is converted to nitrogen-containing molecules (e.g., proteins, nucleic acids)  <u>OR</u>  $\text{NH}_3 \text{ or } \text{NH}_4^+ \text{ or } \text{NO}_3^- \rightarrow \text{proteins or nucleic acids}$	<ul style="list-style-type: none"> <li>Converts nitrogen to proteins, nucleic acids, and other molecules essential to life</li> </ul>
Nitrate is converted to nitrogen gas  <u>OR</u>  $\text{NO}_3^- \rightarrow \text{N}_2$	<ul style="list-style-type: none"> <li>Converts terrestrial nitrogen into atmospheric nitrogen to continue the cycle</li> </ul>
Nitrogen-containing molecules (e.g., nitrates, urea, uric acid, proteins, nucleic acids) are converted to ammonia or ammonium  <u>OR</u>  $\text{NO}_3^-, \text{urea, uric acid, proteins or nucleic acids} \rightarrow \text{NH}_3 \text{ or } \text{NH}_4^+$	<ul style="list-style-type: none"> <li>Converts the nitrogen in nitrogen-containing wastes and dead organisms back into biologically useful forms</li> <li>Provides plants with nitrogen in a biologically usable form</li> </ul>