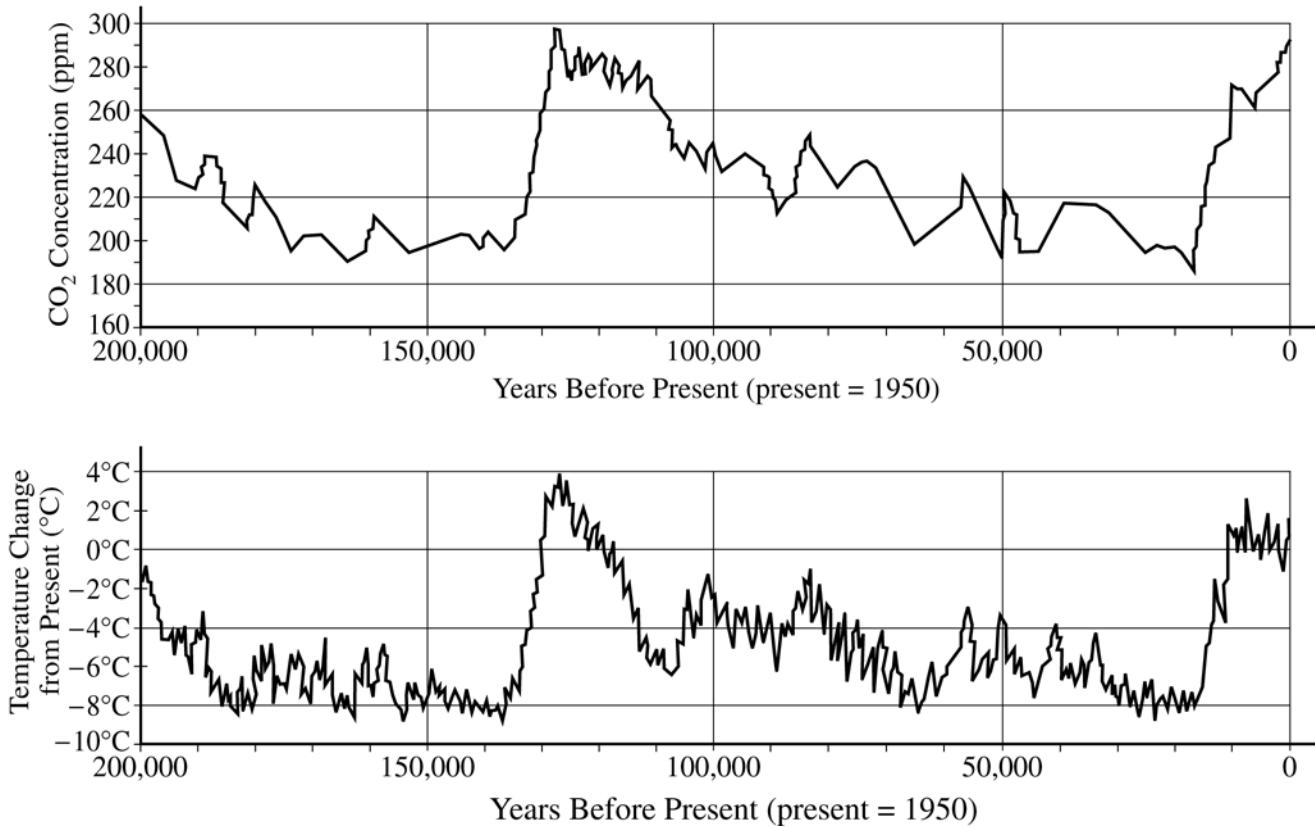


## 2006 AP<sup>®</sup> ENVIRONMENTAL SCIENCE FREE-RESPONSE QUESTIONS

2. According to atmospheric temperature and CO<sub>2</sub> concentration records derived from Antarctic ice cores, Earth's climate has undergone significant changes over the past 200,000 years. Two graphs are shown below. The upper graph shows the variation in atmospheric CO<sub>2</sub> concentration, and the lower graph shows the variation in air temperature. Both graphs cover the same time period from approximately 200,000 years ago up until the year 1950, which is represented as year 0 on the graphs.

TEMPERATURE AND CO<sub>2</sub> CONCENTRATION IN THE ATMOSPHERE  
OVER THE PAST 200,000 YEARS



- (a) Answer the following questions that relate to the graphs above. Remember that for any calculations you must clearly indicate how you arrived at your answer. Answers must also include appropriate units.
- Determine the net change in atmospheric CO<sub>2</sub> concentration between 140,000 years ago and 125,000 years ago.
  - Calculate the ratio of the change in mean global temperature to the change in atmospheric CO<sub>2</sub> concentration between 140,000 years ago and 125,000 years ago.
  - Scientists predict that between 1950 and 2050, the atmospheric CO<sub>2</sub> concentration will increase by 200 ppm. Predict the change in mean global temperature between 1950 and 2050 using the ratio that you calculated in part (ii).
  - Describe one major assumption that was necessary to make the prediction in part (iii) above. Discuss the validity of the assumption.

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**Question 2**

**(a) Answer the following questions that relate to the graphs above. Remember that for any calculations you must clearly indicate how you arrived at your answer. Answers must also include appropriate units.**

**(i) Determine the net change in atmospheric CO<sub>2</sub> concentration between 140,000 years ago and 125,000 years ago.**

**(1 point possible)**

*Point is earned for the correct set-up and answer, with numbers shown, and units included.*

Note: Lines drawn to x and y-axes were accepted in place of explicit calculation set-up.

140,000 years before present: CO<sub>2</sub> ~ 200 ppm (accepted range ~195–205 ppm)

125,000 years before present: CO<sub>2</sub> ~ 280 ppm (accepted range ~270–290 ppm)

280 ppm – 200 ppm = an increase of 80 ppm (accepted range 65–95 ppm).

**(ii) Calculate the ratio of the change in mean global temperature to the change in atmospheric CO<sub>2</sub> concentration between 140,000 years ago and 125,000 years ago.**

**(2 points possible)**

*One point is earned for the correct temperature change calculation showing numbers and including units.*

Note: Lines drawn to x and y-axes were accepted in place of explicit calculation.

Temperature 140,000 years ago ~ –8°C (below present)

Temperature 125,000 years ago ~ +2°C (above present)

2°C - (-8°C) = an increase of 10°C (range 8.5°C–11.5°C).

*1 point is earned for the correct calculation of ratio of temperature to CO<sub>2</sub> concentration change.*

Note: No penalty for ratio calculation based on incorrect answer(s) from above. Range must be consistent with previous values. Percentages not accepted.

Acceptable answers include 10:80 or 10/80 or 10 to 80; 1:8 or 1/8 or 1 to 8.

**(iii) Scientists predict that between 1950 and 2050, the atmospheric CO<sub>2</sub> concentration will increase by 200 ppm. Predict the change in mean global temperature between 1950 and 2050 using the ratio that you calculated in part (ii).**

**(1 point possible)**

*Point is earned for the correct set-up and answer with correct units.*

Note: No penalty if student uses incorrect calculation(s) from above, as long as values are applied correctly. Range must be consistent with previous values.

200 ppm × 1°C/8 ppm = 25°C increase in global temperature (accepted range 18°C–34°C)

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**Question 2 (continued)**

- (iv) Describe one major assumption that was necessary to make the prediction in part (iii) above. Discuss the validity of the assumption.**

***(2 points possible)***

*One point is earned for a correct assumption and 1 point is earned for an appropriate discussion of the validity of the assumption.*

<b>Assumption</b>	<b>Validity of Assumption</b>
Direct relationship exists between CO <sub>2</sub> and temperature.	<p>Invalid due to anthropogenic increase of other GHGs and/or precursors.</p> <ul style="list-style-type: none"> <li>• CH<sub>4</sub>, O<sub>3</sub>, N<sub>2</sub>O, CFCs, HCFCs, HFCs, halons, NO<sub>x</sub>, NO, NO<sub>2</sub>, CO, VOCs, HCs</li> </ul> <p>Invalid due to negative feedbacks.</p> <ul style="list-style-type: none"> <li>• Aerosol increase offsets warming</li> <li>• Clouds can offset warming</li> </ul> <p>Invalid due to positive feedbacks.</p> <ul style="list-style-type: none"> <li>• Clouds can enhance warming</li> </ul> <p>Invalid because temperature change leads CO<sub>2</sub> concentration change.</p> <p>Invalid because correlation does not remain constant over time series period.</p> <p>Valid because this has been the case for past 200K years (must refer to time series).</p> <ul style="list-style-type: none"> <li>• Correlation remains constant over time</li> </ul>
CO <sub>2</sub> is the only GHG that impacts temperature.	<p>Invalid due to anthropogenic increase of other GHGs and/or precursors.</p> <ul style="list-style-type: none"> <li>• CH<sub>4</sub>, O<sub>3</sub>, N<sub>2</sub>O, CFCs, HCFCs, HFCs, halons, NO<sub>x</sub>, NO, NO<sub>2</sub>, CO, VOCs, HCs</li> </ul> <p>Valid because this has been the case for past 200K years.</p> <ul style="list-style-type: none"> <li>• Correlation remains constant over time</li> </ul>
Change expected to occur over a very short time period.	<p>Invalid because uncharacteristically large changes relative to time series scale:</p> <ul style="list-style-type: none"> <li>• nonlinear fluctuations</li> <li>• correlation changes over time</li> </ul>

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**Question 2 (continued)**

<b>Assumption</b>	<b>Validity of Assumption</b>
200 ppm CO <sub>2</sub> concentration change (prediction used as assumption).	Invalid because the change may be greater or less than this value.
Increasing CO <sub>2</sub> concentrations cause atmospheric temperature to rise.	Invalid because time series shows periods when change in temperature leads the change in CO <sub>2</sub> concentration. Valid because time series shows periods when change in CO <sub>2</sub> concentration leads the change in temperature.
Antarctic data can be applied to assume global temperature changes.	Invalid because there are regional variations in the magnitude of temperature fluctuations over time.
Measurement techniques are precise.	Valid because of scientific consensus of data. Invalid because of measurement uncertainty.

**(b) Identify and describe TWO major causes for the predicted 200 ppm increase in atmospheric CO<sub>2</sub> concentration between 1950 and 2050.**

**(2 points possible)**

*One point is possible for each major cause of CO<sub>2</sub> increase identified if linked with an appropriate description.*

- Continuing burning of fossils fuels by a growing population
- Increased per capita usage of fossil fuels
- Increased fossil fuel use for energy production
- Increased fossil fuel use for transportation
- Increased fossil fuel use for industry
- Increased ocean temperature results in release of dissolved CO<sub>2</sub>
- Land-clearing and burning for increasing food production
- Deforestation (even though this involves the cycling of existing carbon, deforestation is indicated as a CO<sub>2</sub> sink in the texts and is accepted)
- Lack of development of alternative energy solutions

**(c) Identify TWO gases other than CO<sub>2</sub> that contribute to the anthropogenic increase in mean global temperature. For each gas, describe a major human activity that leads to its release.**

**(2 points possible)**

*One point is possible for each gas that contributes to an anthropogenic increase in mean global temperature IF linked to an appropriate description of a major human activity that leads to the release of that gas.*

Note: Increased atmospheric water (H<sub>2</sub>O) vapor is not a direct result of human activity.

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**Question 2 (continued)**

<b>Greenhouse Gas</b>	<b>Human Activity</b>
Methane ( $\text{CH}_4$ )	Production of rice Landfill use Cattle/sheep ranching Creation of wetlands/bogs Leaks from pipelines, refineries, and coal mines <i>No credit earned for <math>\text{CH}_4</math> escapes from melting permafrost because melting is not a direct result of human activity.</i>
Ozone ( $\text{O}_3$ )	Photochemical smog resulting from internal combustion engines, vehicle exhaust
Nitrous oxide ( $\text{N}_2\text{O}$ )	Burning of petroleum products, biomass, nitrogen-rich fuels (particularly coal)  Fertilizers  Feedlots (CAFO and/or CAFL) and dairy farms
CFCs (freons), HFCs, and HCFCs	Used in refrigerators and air conditioners, in foam production, to clean electronics, and formerly as propellants
Halons	Used in fire extinguishers

<b>Greenhouse Gas Precursor</b>	<b>Human Activity</b>
NO, NO <sub>2</sub> , (NO <sub>x</sub> )	Coal burning, internal combustion engines (fossil fuels too generic)
CO	Incomplete combustion of fossil fuels
VOCs	Gasoline/petroleum evaporation  Paints and solvents  Aerosols
HCs	Gasoline/petroleum <ul style="list-style-type: none"> <li>• incomplete combustion</li> <li>• evaporation</li> </ul>