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 CO₂ 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: CO₂ ~ 200 ppm (accepted range ~195-205 ppm)
125,000 years before present: CO₂ ~ 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 CO₂ 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 CO₂ 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 CO₂ 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)
(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.

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Validity of Assumption</th>
</tr>
</thead>
</table>
| Direct relationship exists between CO\(_2\) and temperature.              | Invalid due to anthropogenic increase of other GHGs and/or precursors.  
  - CH\(_4\), O\(_3\), N\(_2\)O, CFCs, HCFCs, HFCs, halons, NO\(_x\), NO, NO\(_2\), CO, VOCs, HCs  
  Invalid due to negative feedbacks.  
  - Aerosol increase offsets warming  
  - Clouds can offset warming  
  Invalid due to positive feedbacks.  
  - Clouds can enhance warming  
  Invalid because temperature change leads CO\(_2\) concentration change.  
  Invalid because correlation does not remain constant over time series period.  
  Valid because this has been the case for past 200K years (must refer to time series).  
  - Correlation remains constant over time |
| CO\(_2\) is the only GHG that impacts temperature.                         | Invalid due to anthropogenic increase of other GHGs and/or precursors.  
  - CH\(_4\), O\(_3\), N\(_2\)O, CFCs, HCFCs, HFCs, halons, NO\(_x\), NO, NO\(_2\), CO, VOCs, HCs  
  Valid because this has been the case for past 200K years.  
  - Correlation remains constant over time |
| Change expected to occur over a very short time period.                   | Invalid because uncharacteristically large changes relative to time series scale:  
  - nonlinear fluctuations  
  - correlation changes over time |
(b) Identify and describe TWO major causes for the predicted 200 ppm increase in atmospheric CO₂ concentration between 1950 and 2050.

(2 points possible)

One point is possible for each major cause of CO₂ 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 CO₂
- Land-clearing and burning for increasing food production
- Deforestation (even though this involves the cycling of existing carbon, deforestation is indicated as a CO₂ sink in the texts and is accepted)
- Lack of development of alternative energy solutions

(c) Identify TWO gases other than CO₂ 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 (H₂O) vapor is not a direct result of human activity.
### Question 2 (continued)

<table>
<thead>
<tr>
<th>Greenhouse Gas Precursor</th>
<th>Human Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO, NO₂, (NOₓ)</td>
<td>Coal burning, internal combustion engines (fossil fuels too generic)</td>
</tr>
<tr>
<td>CO</td>
<td>Incomplete combustion of fossil fuels</td>
</tr>
<tr>
<td>VOCs</td>
<td>Gasoline/petroleum evaporation</td>
</tr>
<tr>
<td></td>
<td>Paints and solvents</td>
</tr>
<tr>
<td></td>
<td>Aerosols</td>
</tr>
<tr>
<td>HCs</td>
<td>Gasoline/petroleum</td>
</tr>
<tr>
<td></td>
<td>• incomplete combustion</td>
</tr>
<tr>
<td></td>
<td>• evaporation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Greenhouse Gas</th>
<th>Human Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane (CH₄)</td>
<td>Production of rice</td>
</tr>
<tr>
<td></td>
<td>Landfill use</td>
</tr>
<tr>
<td></td>
<td>Cattle/sheep ranching</td>
</tr>
<tr>
<td></td>
<td>Creation of wetlands/bogs</td>
</tr>
<tr>
<td></td>
<td>Leaks from pipelines, refineries, and coal mines</td>
</tr>
<tr>
<td></td>
<td><em>No credit earned for CH₄ escapes from melting permafrost because melting is not a direct result of human activity.</em></td>
</tr>
<tr>
<td>Ozone (O₃)</td>
<td>Photochemical smog resulting from internal combustion engines, vehicle exhaust</td>
</tr>
<tr>
<td>Nitrous oxide (N₂O)</td>
<td>Burning of petroleum products, biomass, nitrogen-rich fuels (particularly coal)</td>
</tr>
<tr>
<td></td>
<td>Fertilizers</td>
</tr>
<tr>
<td></td>
<td>Feedlots (CAFO and/or CAFL) and dairy farms</td>
</tr>
<tr>
<td>CFCs (freons), HFCs, and HCFCs</td>
<td>Used in refrigerators and air conditioners, in foam production, to clean electronics, and formerly as propellants</td>
</tr>
<tr>
<td>Halons</td>
<td>Used in fire extinguishers</td>
</tr>
</tbody>
</table>
2. According to atmospheric temperature and CO₂ 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 CO₂ 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 CO₂ 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.

(i) Determine the net change in atmospheric CO₂ concentration between 140,000 years ago and 125,000 years ago.

(ii) Calculate the ratio of the change in mean global temperature to the change in atmospheric CO₂ concentration between 140,000 years ago and 125,000 years ago.

(iii) Scientists predict that between 1950 and 2050, the atmospheric CO₂ 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).

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

GO ON TO THE NEXT PAGE.
(b) Identify and describe TWO major causes for the predicted 200 ppm increase in atmospheric CO₂ concentration between 1950 and 2050.

(c) Identify TWO gases other than CO₂ that contribute to the anthropogenic increase in mean global temperature. For each gas, describe a major human activity that leads to its release.

\[ \text{a) i. CO₂ concentration at 140,000 years ago} = 200 \text{ ppm} \]
\[ \text{125,000 years ago} = 280 \text{ ppm} \]
\[ \frac{80 \text{ ppm}}{200 \text{ ppm}} = 0.4 = \text{40% increase in CO₂ concentration} \]
\[ 280 \text{ ppm} - 200 \text{ ppm} = 80 \text{ ppm net change in atmospheric CO₂ concentration between 140,000 years ago and 125,000 years ago.} \]

ii. Mean global temperature at 140,000 years ago = -8°C
\[ \text{125,000 years ago} = 2°C \]
\[ 2°C - (-8°C) = 10°C \text{ net change} \]
\[ \frac{10°C}{80 \text{ ppm}} = \frac{1°C}{8 \text{ ppm}} \text{ is the ratio of the change in mean global temperature to the change in atmospheric CO₂ concentration between 140,000 years ago and 125,000 years ago.} \]

iii. \[ \frac{1°C}{8 \text{ ppm}} = \frac{x°C}{200 \text{ ppm}} \]
\[ 8x = 200 \text{ ppm} \]
\[ x = 25°C \text{ increase in mean global temperature} \]

iv. A major assumption that was necessary to make
the prediction in part ii was that the concentration of atmospheric CO₂ and mean global temperature have a perfect linear correlation. By looking at the data for the 200,000 years before 1850 this assumption seems to be true. From this observation we can assume with some certainty that the prediction in part iii is approximately correct.

b. Two major cause for the predicted 200 ppm increase in atmospheric CO₂ are:

1) Exponential growth of population meaning greater need for electricity which means more coal burning power plants in operation, which means greater release of CO₂ from coal burning.

2) Increasing population means more need for timber and more need for agricultural land, thus greater deforestation especially of tropical rainforests. Reduction of forests means less reduction of a major carbon sink (trees take in CO₂). Thus more atmospheric CO₂.
c. Two gases other than CO₂ that contribute to the anthropogenic increase in mean global temperature are:

1) Methane gas which is heavily released from ruminants especially in cattle ranches. Humans breed cattle for food so large cattle ranches and dairy farms are high releasers of methane.

2) Nitrous Oxide is another greenhouse gas. It is released from coal burning power plants. The burning of the coal releases many air pollutants including NOₓs.
2. According to atmospheric temperature and CO₂ 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 CO₂ 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 CO₂ CONCENTRATION IN THE ATMOSPHERE**

**OVER THE PAST 200,000 YEARS**

![Graph showing temperature and CO₂ concentration over 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.

(i) Determine the net change in atmospheric CO₂ concentration between 140,000 years ago and 125,000 years ago.

(ii) Calculate the ratio of the change in mean global temperature to the change in atmospheric CO₂ concentration between 140,000 years ago and 125,000 years ago.

(iii) Scientists predict that between 1950 and 2050, the atmospheric CO₂ 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).

(iv) 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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(b) Identify and describe TWO major causes for the predicted 200 ppm increase in atmospheric \( \text{CO}_2 \) concentration between 1950 and 2050.

(c) Identify TWO gases other than \( \text{CO}_2 \) that contribute to the anthropogenic increase in mean global temperature. For each gas, describe a major human activity that leads to its release.

\[
\begin{align*}
\text{(i)} & \quad 290 \text{ ppm} - 200 \text{ ppm} = 80 \text{ ppm} \\
\text{(ii)} & \quad \frac{\text{1.1°C}}{\text{80 ppm}} \quad \text{=} \quad \frac{\text{1°C}}{\text{8 ppm}} \\
\text{(iii)} & \quad \frac{1°C}{8 \text{ ppm}} \times 8 \text{ ppm} = 8 \text{ ppm} \\
\end{align*}
\]

\[
\begin{align*}
\Rightarrow 1°C : 8 \text{ ppm} \\
\Rightarrow 8 \times 200 \\
\Rightarrow x = 25°C \\
\end{align*}
\]

(iv) The major assumption I had to make was that the ratio between 140,000 years ago and 125,000 years ago was the same as the ratio between 1950 and 2050. In order for the scientist to come up with their prediction of \( \text{CO}_2 \) concentration, they also had to assume that the ratio was the same as 140,000 years ago and 125,000 years ago. Therefore, it is only logical to assume the same and have only one variable in the equation.

(b) One cause for the predicted 200 ppm increase in atmospheric concentration is the increased use of fossil fuels to create energy, and at the same time, emitting large amounts of \( \text{CO}_2 \) into the air. Another cause for the predicted 200 ppm increase in atmospheric concentration could be attributed to mass amounts of tree harvesting and deforestation in areas like the rainforest. The loss of those lands would cause a loss of anaerobic respiration, the trees would not eat enough trees to handle the \( \text{CO}_2 \) and convert it into oxygen, therefore causing an abundance of \( \text{CO}_2 \) in the atmosphere.
C.) CFC and CO both contribute to the anthropogenic increase in mean global temperature. CFC are released through hairsprays and other things like cleaners that need propellants. CO is released when water heaters are broken.
2. According to atmospheric temperature and CO$_2$ 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$_2$ 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.

![Graphs showing temperature and CO$_2$ concentration 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.

(i) Determine the net change in atmospheric CO$_2$ concentration between 140,000 years ago and 125,000 years ago.

(ii) Calculate the ratio of the change in mean global temperature to the change in atmospheric CO$_2$ concentration between 140,000 years ago and 125,000 years ago.

(iii) Scientists predict that between 1950 and 2050, the atmospheric CO$_2$ 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).

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

GO ON TO THE NEXT PAGE.
(b) Identify and describe TWO major causes for the predicted 200 ppm increase in atmospheric CO₂ concentration between 1950 and 2050.

(c) Identify TWO gases other than CO₂ that contribute to the anthropogenic increase in mean global temperature. For each gas, describe a major human activity that leads to its release.

a) (i) The net change in atmospheric CO₂ between 140,000 ya (years ago) 125,000 ya is about 10 ppm.

(ii) The ratio of change is about 70%.

(iii) The ratio is 130%.

(iv) My assumption was that has the CO₂ concentration increases so does the temperature. That is a valid assumption because in the past years it has been true according to tree graph.

b) Two major causes for the increase in atmospheric CO₂ are increasing number of people on the planet. People require energy. At the moment energy requires coal fossil to be burned which puts CO₂ into the atmosphere. Another cause is people drive cars and cars pollute.

c) CFC's, people release CFC's through aerosol cans.
Question 2

Overview

This question was designed to assess students’ ability to analyze data, make a prediction based on calculations using these data, and apply critical thinking skills to determine the validity of this prediction. Analysis, manipulation, and interpretation of these data provide a framework for students to view science as a process.

Sample: 2A
Score: 10

Part (a): One point was earned in (ai) for giving the correct CO₂ concentration change calculation, including units. Two points were earned in (aii): 1 point for the correct temperature change calculation, including units, and 1 point for the correct ratio calculation. One point was earned in (aiii) for the correct temperature change calculation using the ratio from above. Two points were earned in (aiv): 1 point for the assumption that there is a near-perfect correlation between temperature and CO₂ concentration, and 1 point for relating this relationship to that indicated by the graphs.

Part (b): Two points were earned: 1 point for linking growth in coal-burning power plants to an exponentially growing population, and 1 point for linking deforestation to the loss of a CO₂ sink.

Part (c): Two points were earned: 1 point for mentioning methane (linked to cattle ranches), and 1 point for saying that N₂O is emitted by coal-burning power plants.

Sample: 2B
Score: 6

Part (a): One point was earned in (ai) for giving the correct CO₂ concentration change calculation, including units. The first point in (aii) was not earned because the temperature change calculation is incorrect (-10°C). The second point in (aii) was earned for the correct ratio calculation, even though it is based on an incorrect temperature change value. One point was earned in (aiii) for the temperature change calculation. One point was earned in (aiv) for the assumption that the ratio between 140,000–125,000 years ago will be the same between 1950 and 2050. The second point was not earned because the description is only a repetition of the assumption.

Part (b): One point was earned for linking increased fossil fuel use and energy creation. The second point was not earned because the loss of the CO₂ sink caused by deforestation is incorrectly attributed to anaerobic respiration.

Part (c): One point was earned for citing CFCs, used in hairsprays and propellants. The second point was not earned because the student erroneously states that CO is released by broken water heaters.
Sample: 2C
Score: 4

Part (a): No point was earned in (ai) because the CO₂ concentration change is not calculated. Neither point was earned in (aii) because the temperature change and ratio are not calculated. No point was earned in (aiii) because the temperature change is not calculated. Two points were earned in (aiv): 1 point for the assumption that CO₂ and temperature changes are related, and 1 point for relating this relationship to that shown on the graphs.

Part (b): One point was earned for linking increased population and coal burning for energy production. The second point was not earned because the link between cars and pollution is too vague.

Part (c): One point was earned for stating that CFCs are released by aerosol cans. The second point was not earned because a second gas is not identified.