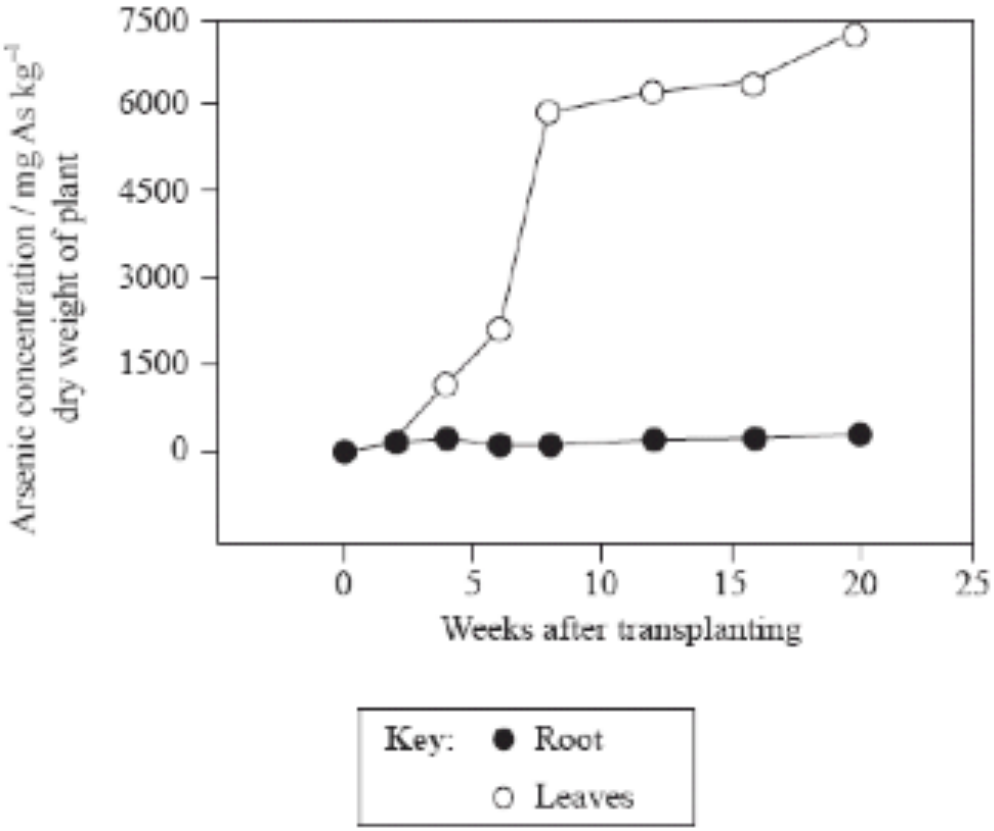
Arsenic Accumulation (7 marks)

The element arsenic (As) is not needed for plant growth and development. The accumulation of arsenic in the Chinese brake fern (*Pteris vittata*) was studied. Young ferns with five or six leaves were transplanted to soil contaminated with arsenic and were grown for 20 weeks in a greenhouse. The graph below shows the arsenic concentrations in leaves and roots of the Chinese brake fern during the 20 weeks after transplanting. Arsenic concentration is expressed as mg As kg^{-1} dry weight of plant.



a. Using the data in the graph, describe the accumulation of arsenic in the Chinese brake fern. *(3 marks)*

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The table below shows the total amount of arsenic accumulated by the Chinese brake fern, expressed as a concentration in the plant tissue and as a percentage of the arsenic originally in the soil.

Time / weeks	Arsenic concentration in fern / mg As kg–1	Percentage of original soil arsenic absorbed by fern
0	2	0.00
2	66	0.05
4	221	0.15
6	408	0.28
8	1300	0.88
12	5390	3.68
16	13800	9.43
20	37900	25.90

b. Assuming the mean rate of arsenic accumulation over the first 20 weeks continued, calculate how long it would take to remove all the arsenic from the soil. *(1 mark)*

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c. Using the data in the table, discuss the potential of using Chinese brake fern to remove arsenic from contaminated soil. *(2 marks)*

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d. Suggest **one** possible consequence of arsenic accumulation in plants for other organisms in the community. *(1 mark)*

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Air Pollution (12 marks)

The air in urban areas contains a variety of pollutants, including particles of solids and gases. The table below shows the pH of rain in urban areas of New York and rural areas nearby. The concentration of four air pollutants is also shown. The concentrations of gases are measured in parts per billion (ppb).

Area	Lead / µg m–3	Nitrogen dioxide / ppb	Nitrous oxide / ppb	Sulfur dioxide / ppb	pH of rain
Urban	0.09	37.7	39.3	18.7	4.3
Rural	0.04	6.2	0.5	2.3	4.2

a. Compare the acidity of rain in urban and rural areas. *(1 mark)*

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b. Compare the levels of atmospheric pollution in urban and rural areas. *(2 marks)*

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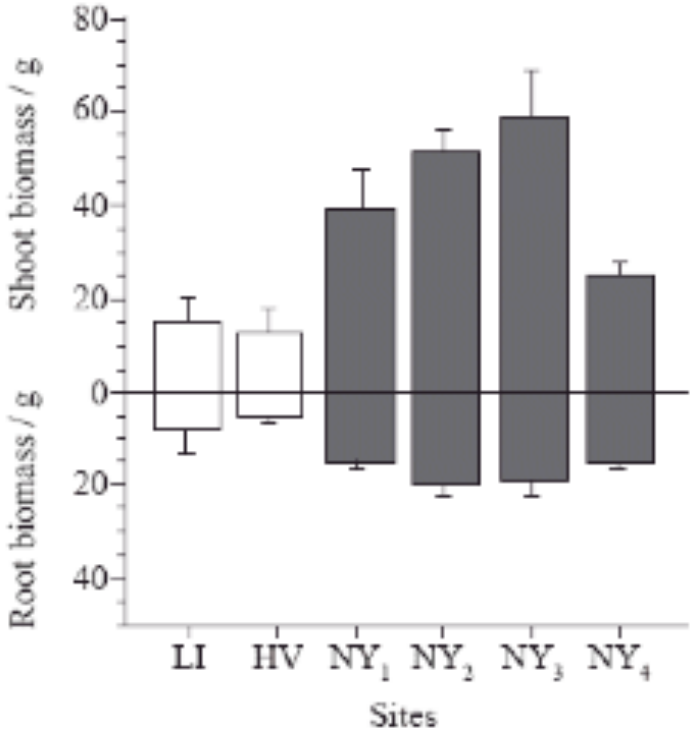
Tree planting has been suggested as a way of improving air quality in urban areas. The growth of *Populus deltoides* in urban and rural areas near New York was investigated. Trees were grown in pots containing the same type of soil in all areas. High levels of mineral nutrients in the soil ensured that lack of nutrients was not the limiting factor on growth rates. The growth of the trees above ground (shoot biomass) and below ground (root biomass) was measured after one year. The bar chart below shows the results for two rural areas (open bars) and four urban areas (filled bars).



c. Outline the conclusions that can be drawn about the growth of *Populus deltoides* from the data in the bar chart. *(2 marks)*

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d. Discuss factors that could cause differences in growth rates of *Populus deltoides* between urban and rural areas. *(2 marks)*

i. differences in the acidity of rain.

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ii. differences in the concentration of air pollutants.

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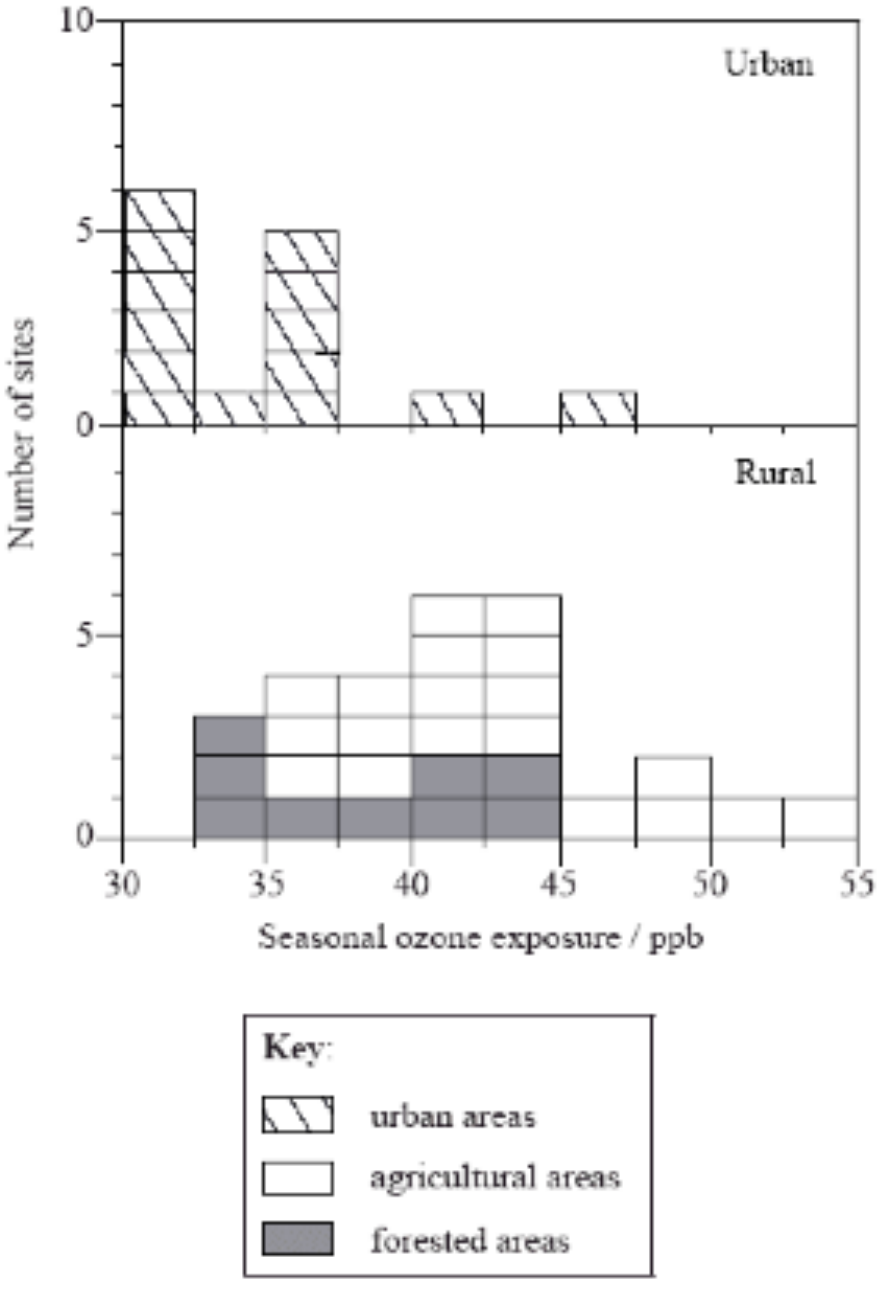
The histograms below show the range of ozone exposure between May and September in urban and rural areas near New York.



e. Compare the seasonal ozone exposures in urban, agricultural and forested areas. *(2 marks)*

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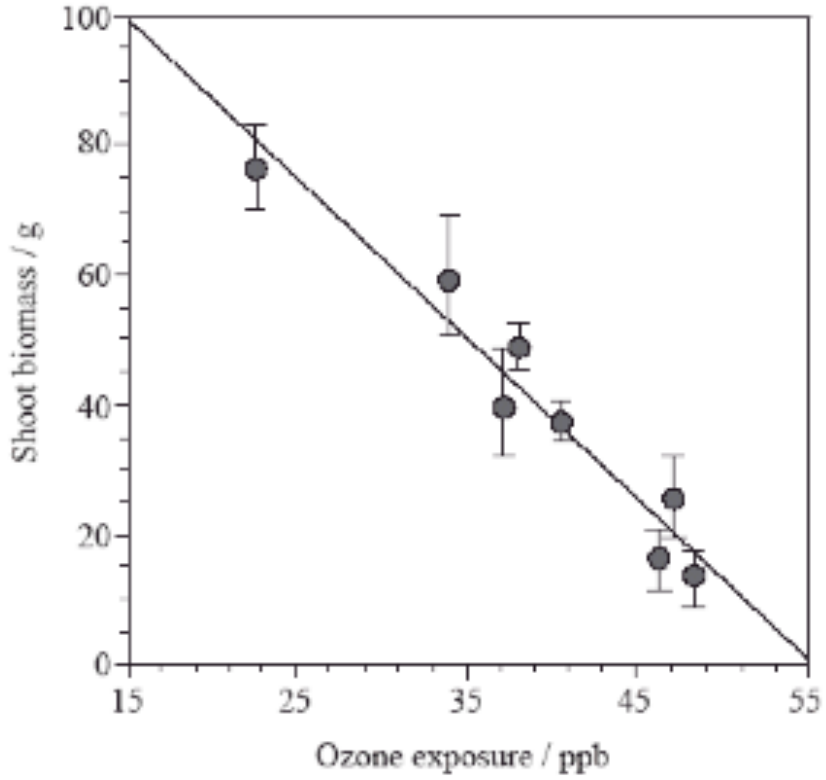
The concentrations of ozone and the shoot growth of *Populus deltoides* were measured at eight sites. The results are shown in the scattergraph below.



f. Using the data in the scattergraph and in previous parts of this question, suggest a hypothesis for differences in the growth of *Populus deltoides* between urban and rural areas. Give reasons for your hypothesis. *(3 marks)*

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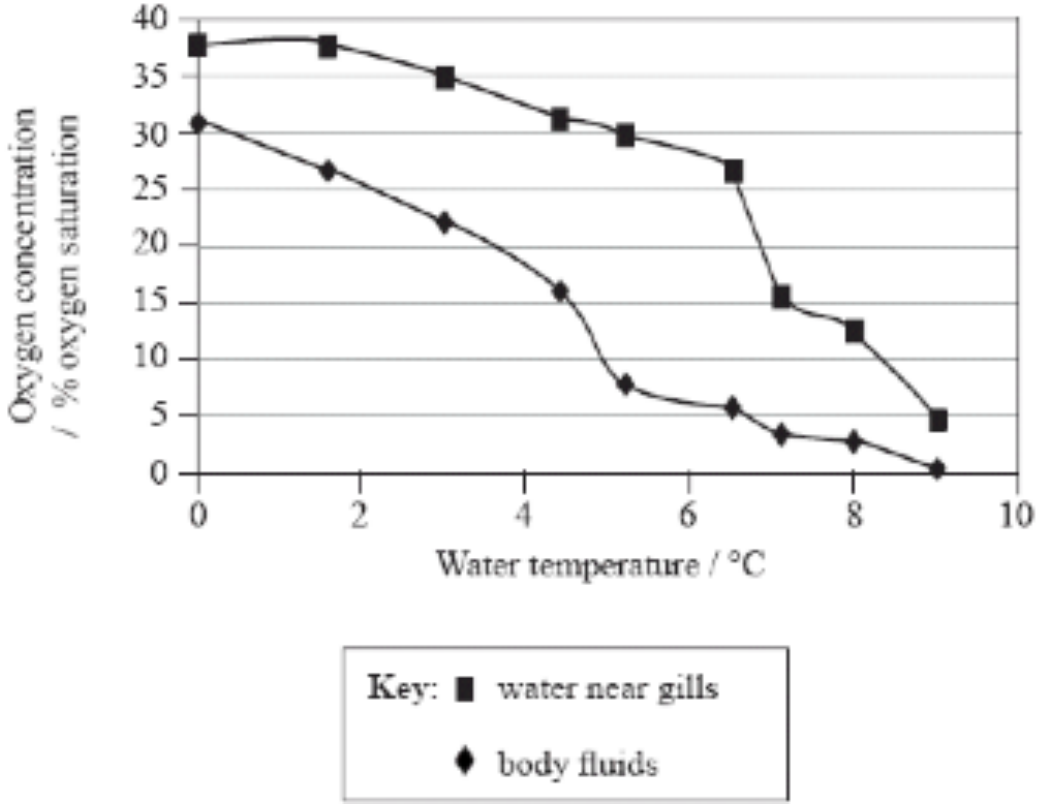
Greenhouse Effect (18 marks)

During aerobic cell respiration, oxygen is consumed and carbon dioxide is produced inside cells. This generates concentration gradients between respiring cells and the environment, which cause diffusion of oxygen and carbon dioxide. Both oxygen and carbon dioxide are soluble in water. As the temperature rises, water becomes saturated at a lower concentration of the gas. *Laternula elliptica* is a mollusc that lives on the sea bed in Antarctica. Its body temperature is always similar to that of the environment around it. To investigate the effect of temperature on *Laternula elliptica*, specimens were kept in temperature-controlled aquaria. The oxygen concentrations of water near the gills and in the body fluids were measured, at a range of temperatures from 0°C to 9°C. The graph below shows the mean results.



a. Outline the relationship between temperature and oxygen concentration in the body fluids in *Laternula elliptica*. *(2 marks)*

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b. Suggest **two** reasons for the relationship. *(2 marks)*

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c. In its natural environment, *Laternula elliptica* buries itself in the mud on the sea bed. In this investigation, it was found that above 6°C it is unable to bury itself. Suggest a reason for this. *(1 mark)*

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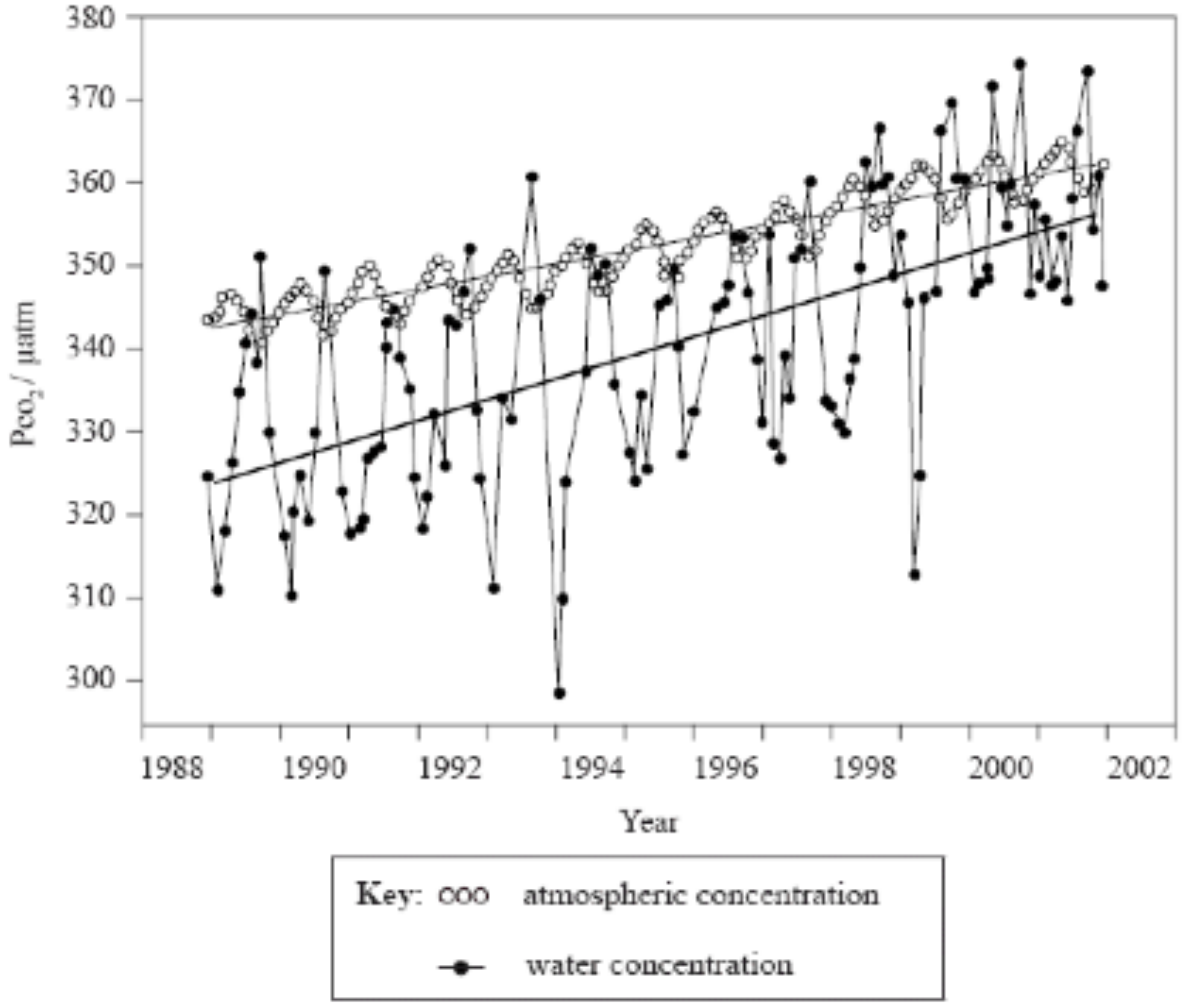
The world's oceans can absorb large amounts of carbon dioxide. This process has been studied in the Pacific Ocean near Hawaii, by measuring carbon dioxide concentrations in the atmosphere and in surface water every month, from October 1988 onwards. The graph below shows the carbon dioxide concentration expressed as partial pressures (PCO_2).



d. Describe the trends in atmospheric carbon dioxide concentration, shown in the graph. *(2 marks)*

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e. Suggest **two** reasons for the trends that you have described. *(2 marks)*

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f. Diffusion of carbon dioxide only occurs when there is a concentration gradient. Deduce the pattern of carbon dioxide diffusion, between water and atmosphere, from 1988 to 2002. *(2 marks)*

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g. The graph provides evidence for the hypothesis that there will be no net diffusion of carbon dioxide between water and atmosphere by 2020. Explain this evidence. *(1 mark)*

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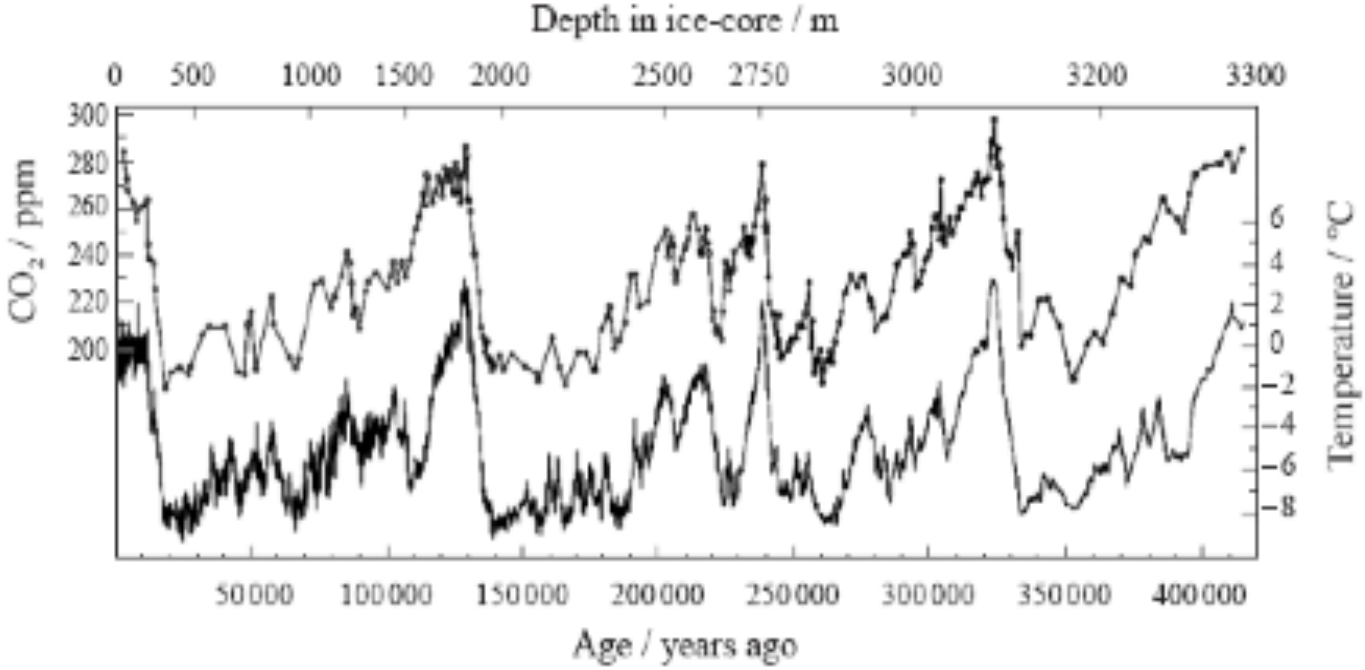
The concentration of carbon dioxide in the atmosphere is currently 385 ppm (parts per million). Variations in the concentration of carbon dioxide in the atmosphere can be studied using ice-cores. An ice-core record covering the last 400 000 years has been obtained from Vostok in the Antarctic. The graph below shows the carbon dioxide concentrations that were measured at different depths in the ice. Atmospheric temperatures are also shown on the graph. These were deduced from ratios of oxygen isotopes. The upper line on the graph shows CO_2 concentrations and the lower line shows temperature.



h. State the highest carbon dioxide concentration shown on the graph. *(1 mark)*

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i. State the highest temperature shown on the graph. *(1 mark)*

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j. Using the data in the graph, deduce the relationship between atmospheric carbon dioxide concentration and temperature. *(1 mark)*

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k. Using the data in this question, explain reasons for concern about the long-term survival of Antarctic species, such as *Laternula elliptica*. *(3 marks)*

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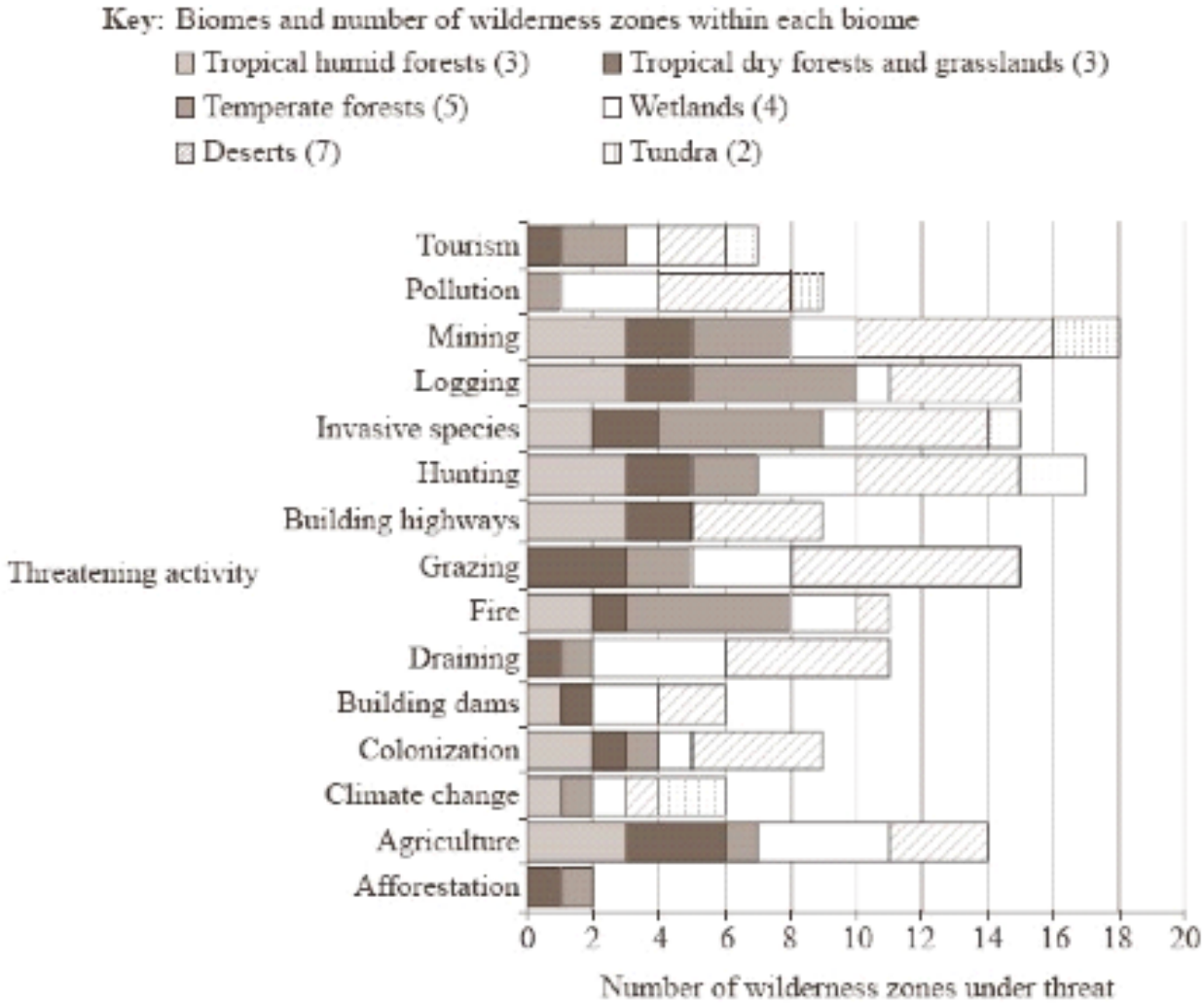
Human Activities (6 marks)

Conservationists identified twenty-four wilderness zones in the world. A wilderness is defined as an area greater than 10 000 km2, with a human population of less than five inhabitants per km2 and is mostly unspoiled, therefore, retaining its natural condition. Various activities threaten the biodiversity of these wilderness zones. Each wilderness zone was identified as belonging to one of six major biomes. The chart below shows the number of wilderness zones belonging to each biome and the number under threat.



a. State how many of the activities threaten all of the biomes. *(1 mark)*

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b. Identify one activity that threatens all desert wilderness zones. *(1 mark)*

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c. Compare the effects of pollution and climate change on the biomes. *(3 marks)*

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d. Suggest how fire affects biodiversity. *(1 mark)*

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Answers

1a *(3 marks)*

a. arsenic accumulates in leaves

arsenic concentration (in leaves) increases rapidly in the first 7 weeks *(Accept range of 7–10 weeks in all points)*

b. arsenic (in leaves) increases from 0 to approximately 6000 mg kg^{-1} at 7 weeks

c. maximum arsenic level (in leaves) is about 7500 mg kg^{-1} at end of experiment / valid numerical example

d. after week 7 arsenic concentration in plant increases more slowly/ begins to plateau

e. arsenic concentration in roots remains relatively unchanged throughout the experiment

1b *(1 mark)*

77 weeks *(Allow answers in range 70 – 80 weeks)*

1c *(2 marks)*

a. Chinese brake fern could be used to remove arsenic from soil

b. after 20 weeks about 25% of soil arsenic removed by fern

c. arsenic concentration increases (rapidly) in fern (tissue) in 20 weeks

d. eventually/longer periods may reach toxic levels for plant

1d *(1 mark)*

a. plants may become toxic for consumers

b. arsenic may accumulate in the food chain / biomagnification

2a *(1 mark)*

both (moderately) acidic / similar acidity / rural (slightly) more acidic / lower pH / *converse*

2b *(2 marks)*

a. urban areas have overall more (atmospheric) pollution / *converse*

b. levels of each pollutant are much higher concentrations in urban areas

c. qualified by correct example *e.g.* more solid pollution/more lead *e.g.* nitrous oxide is almost eighty times higher in urban areas

Comparative terms are required to award the mark.

2c *(2 marks)*

a. (overall) growth/biomass was greater in urban areas

b. greater growth/biomass in urban areas for roots / below ground

c. greater growth/biomass for shoots / above ground

d. growth/biomass was (more) variable in urban areas

e. shoot/above ground growth/biomass always greater than root biomass

2d *(2 marks)*

Differences in acidity:

a. unlikely to be the cause because differences in pH are small

Differences in pollutants:

b. higher growth in areas where there is higher pollution

c. might not be cause / correlation rather than cause and effect

d. pollutant might have stimulated growth / acted as fertilizer in urban areas

e. pollutant did not negatively affect growth (as more pollution in urban areas/area with higher growth)

2e *(2 marks)*

a. lowest ozone exposures in urban areas / highest ozone exposure in rural/agricultural areas

b. lower ozone exposure in forested than agricultural areas

c. highest range in agricultural areas / lowest range in forested areas

d. wide range of ozone exposures in each area

[1 max] *if candidates are referring to months/x axis as time.*

2f *(3 marks)*

a. (strong) negative correlation/lower shoot biomass/less growth with higher ozone exposure
b. ozone exposure is lower in urban areas/other reference to graph
c. ozone is toxic/damages plants impacts photosynthesis
d. (hypothesis is) higher growth rates (in urban areas) are due to lower ozone exposure
e. (hypothesis is) both factors/ozone and air pollution may have played a role in growth differences

Do not accept hypotheses involving pH. Accept converse of above points.

3a *(2 marks)*

a. oxygen concentration falls as temperature rises / negative correlation/ inverse relationship
b. steady decline below 4.2/4.3/4.4°C / *vice versa*
c. rapid decrease between 4.2/4.3/4.4°C and 5°C
d. zero oxygen concentration at/above 9 °C

3b *(2 marks)*

a. warmer water can hold less oxygen / lower oxygen solubility as temperature rises
b. lower oxygen concentration of water reaching gills / less oxygen available from the water to diffuse into the gills
c. higher metabolic rate / faster rates of respiration / more oxygen consumption as temperature rises

3c *(1 mark)*

not enough energy/ATP/aerobic respiration (for muscle contraction/movement)

3d *(2 marks)*

a. rising trend overall
b. annual rise and fall / fluctuations

3e *(2 marks)*

a. (CO_2 emissions from) increased burning of fossil fuels / deforestation / other anthropogenic factor
b. variation in photosynthesis rates during the year / variations in CO_2 uptake in the oceans

3f *(2 marks)*

a. diffusion in both directions during each year
b. diffusion from atmosphere to water during most of the year
c. diffusion from water to atmosphere for part of year/autumn/fall/seasonal
d. increasing diffusion from water to atmosphere in later years

3g *(1 mark)*

a. (no net diffusion because) concentrations will become equal / there will be no gradient
b. water concentration higher than atmospheric concentration as often as atmospheric concentration higher than water concentration

3h *(1 mark)*

300 ppm *(Allow answers in the range 295–305 ppm) unit must be included to earn mark.*

3i *(1 mark)*

3.3°C *(Allow answers in the range 3.0–3.3°C) unit must be included to earn mark.*

3j *(1 mark)*

positive correlation / higher temperature with higher CO_2 concentration

3k *(3 marks)*

a. oceans may cease to act as sink / store for CO_2
b. atmospheric CO_2 concentration may then rise more rapidly
c. atmospheric CO_2 concentration is higher than for at least 400 000 years/ any time in recent (geological) time
d. Antarctic temperatures will (probably) rise higher than at any time in 400 000 years/any time in recent (geological) time
e. rising (sea water) temperature would reduce oxygen availability in water
f. significant changes in habitat/abiotic factors
g. populations may not be able to adapt

4a *(1 mark)*

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4b *(1 mark)*

grazing

4c *(3 marks)*

a. pollution affects more wilderness zones than climate change
b. climate change affects more biomes (5) than pollution
c. tropical humid forests / affected by climate change but not pollution
d. both affect temperate forests / wetlands / deserts / tundra
e. pollution effect on deserts / wetlands greater than climate change
f. climate change effect on tundra greater than pollution

4d *(1 mark)*

biodiversity is reduced due to destruction of habitats / food / breeding grounds / killing species