Past-paper walk-through

Increases in the Greenhouse Gases ▪ 9.4

eXercise

Questions in this set

- 2024 Set 1 Q2
- 2024 Set 1 Q3
- 2023 Set 2 Q3
- 2019 Q3
- 2014 Q1
- 2014 Q4

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO_2-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m^2).

Global Warming Potential and Land Use from Animal Protein Production

[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg CO_2-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (10), Chicken (27), Pork (37), Beef (120).]

Question 2

(a) Based on the data in the graphs, **identify** the amount of land required to produce 1 kilogram of chicken protein.

Mealworms, the larvae of the darkling beetle, consume grains and decaying plant material. Darkling beetles are an *r*-selected species, and the entire mealworm can be consumed by humans for protein.

Question 2

Figure 1

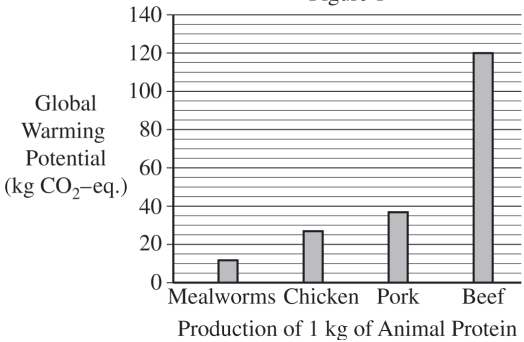
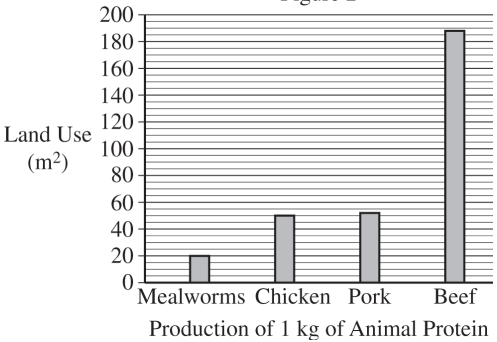


Figure 2



Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO_2-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m^2).
Global Warming Potential and Land Use from Animal Protein Production
[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg CO_2-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (10), Chicken (27), Pork (37), Beef (120).]

[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use (m^2)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (18), Chicken (50), Pork (53), Beef (188).]

Question 2

(b) Based on the information provided, **identify** the type of survivorship curve exhibited by the darkling beetle.

Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO_2-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m^2).
Global Warming Potential and Land Use from Animal Protein Production
[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg CO_2-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (10), Chicken (27), Pork (37), Beef (120).]

[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use (m^2)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (18), Chicken (50), Pork (53), Beef (188).]

Question 2

(c) Explain why the reproductive strategy of the darkling beetle is an advantage for using mealworms as an alternative protein source for the rapidly growing human population.
An individual's diet choices affect greenhouse gas emissions and land use.

Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO_2-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m^2).
Global Warming Potential and Land Use from Animal Protein Production
[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg CO_2-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (10), Chicken (27), Pork (37), Beef (120).]

[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use (m^2)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (18), Chicken (50), Pork (53), Beef (188).]

Question 2

(d) Based on the data in the graphs, **explain** whether producing 1 kilogram of chicken protein or 1 kilogram of pork protein would cause less environmental damage.
Cattle emit methane from fermentation in their digestive systems. The other animals do not emit methane.

Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO_2-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m^2).
Global Warming Potential and Land Use from Animal Protein Production
[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg CO_2-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (10), Chicken (27), Pork (37), Beef (120).]

[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use (m^2)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (18), Chicken (50), Pork (53), Beef (188).]

Question 2

(e) Based on the data in the graphs, **explain** why the production of 1 kilogram of beef protein has a different impact on global warming than the production of 1 kilogram of protein from any of the other animals studied would have.
Agricultural practices can have negative impacts on rivers and streams.

Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO_2-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m^2).
Global Warming Potential and Land Use from Animal Protein Production
[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg CO_2-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (10), Chicken (27), Pork (37), Beef (120).]

[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use (m^2)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (18), Chicken (50), Pork (53), Beef (188).]

Question 2

(f) Describe how water quality can be altered by cattle grazing that occurs near a stream or river.

Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO_2-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m^2).
Global Warming Potential and Land Use from Animal Protein Production
[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg CO_2-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (10), Chicken (27), Pork (37), Beef (120).]

[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use (m^2)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (18), Chicken (50), Pork (53), Beef (188).]

Question 2

(g) Propose a solution to reduce the negative impacts on waterways that result from cattle grazing, while still allowing cattle to graze.

Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO_2-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m^2).
Global Warming Potential and Land Use from Animal Protein Production
[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg CO_2-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (10), Chicken (27), Pork (37), Beef (120).]

[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use (m^2)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (18), Chicken (50), Pork (53), Beef (188).]

Question 2

(h) Crop production can cause soil erosion. **Describe** a sustainable agricultural practice used to reduce soil erosion.

Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO_2-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m^2).
Global Warming Potential and Land Use from Animal Protein Production
[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg CO_2-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (10), Chicken (27), Pork (37), Beef (120).]

[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use (m^2)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (18), Chicken (50), Pork (53), Beef (188).]

Question 2

(i) Justify the use of the sustainable practice described in part (h) by describing an additional advantage, other than the reduction of soil erosion.

Question 2

2024 Set 1 ▪ Q2

As the human population continues to grow, the demand for animal protein is expected to double by 2050. Animal protein can be obtained from conventional livestock and other sources. The production of all animal protein has environmental costs, as shown in the following graphs. In Figure 1, global warming potential (GWP) is measured in kilograms of carbon dioxide equivalent (kg CO_2-eq). Carbon dioxide equivalent is a measure of the warming effect of a gas relative to that of carbon dioxide. In Figure 2, land use is measured in meters squared (m^2).
Global Warming Potential and Land Use from Animal Protein Production
[Figure 1: bar graph titled "Figure 1". Y-axis "Global Warming Potential (kg CO_2-eq.)" from 0 to 140 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (10), Chicken (27), Pork (37), Beef (120).]

[Figure 2: bar graph titled "Figure 2". Y-axis "Land Use (m^2)" from 0 to 200 in increments of 20. X-axis "Production of 1 kg of Animal Protein" with four bars: Mealworms (18), Chicken (50), Pork (53), Beef (188).]

Question 2

(j) Crop production around the world is affected by climate change. **Describe** how crop production could be negatively affected by climate change.

Solution 2

(a)

Mark scheme

- 50 m^2 of land is required to produce 1 kilogram of chicken protein (read from the graph).

Solution 2

(b)

Mark scheme

- The darkling beetle exhibits a Type III survivorship curve (high mortality early in life, few survivors reach old age — consistent with an r-selected species).

Solution 2

(c)

Mark scheme

- Darkling beetles are r-selected and reproduce quickly with many offspring, which allows a large amount of protein (mealworm biomass) to be produced in a short period of time — an advantage for feeding a rapidly growing human population.

Solution 2

(d)

Mark scheme

- Producing 1 kg of chicken protein causes less environmental damage than producing 1 kg of pork protein: chicken production has a lower global warming potential (releases less greenhouse gas) than pork, and/or chicken has lower land use than pork, so it causes less deforestation/habitat destruction/soil erosion/fossil fuel use.

Solution 2

(e)

Mark scheme

- Beef production has a larger impact on global warming than the other animals studied because cattle emit methane from digestive (enteric) fermentation, and methane is a greenhouse gas with a high global warming potential; beef also requires much more land use, which causes loss of forests/habitat/grasslands and releases stored CO2 (reducing carbon storage).

Solution 2

(f)

Mark scheme

- Cattle grazing near a stream or river can alter water quality by: causing erosion that increases sedimentation/turbidity in the water; adding nutrients (nitrogen/phosphorus) to waterways via feces; and/or contaminating waterways with bacteria from feces.

Solution 2

(g)

Mark scheme

- A solution that reduces waterway damage while still allowing grazing: practice rotational grazing (alternate grazing parcels so land can recover); reduce dietary reliance on meat/beef; fence/barricade the riparian zone to keep cattle out of the waterway; or provide alternative water sources for the cattle away from the stream.

Solution 2

(h)

Mark scheme

- A sustainable agricultural practice to reduce soil erosion: switch crops to perennial plants; plant crops on terraces; implement contour plowing/farming; or use no-till farming/cover crops.

Solution 2

(i)

Mark scheme

- Justify the practice named in part (h) with an advantage beyond reduced erosion. Matching the scoring table: perennial crops or no-till/cover crops → reduce fossil fuel use, reduce farming costs, increase/maintain soil carbon storage, and preserve soil habitat for organisms (cover crops can also serve as green manure); terracing or contour plowing → allows otherwise-too-steep areas to be farmed and increases groundwater absorption (terracing also lets sediment/contaminants settle out behind the ridge, further reducing runoff).

Solution 2

(j)

Mark scheme

- Climate change could negatively affect crop production/yields through: increased drought; increased flooding; increased insect infestation due to warmer temperatures; increased temperature generally; changes in seasonal rain patterns; expansion of the geographic range of invasive pests/species; or climate conditions moving outside crops' range of tolerance.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(a) Identify a fuel used in a nuclear power plant.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(b) Describe a negative environmental impact on nearby bodies of water that is caused by using water for cooling in nuclear power plants.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(c) In 2021, 4.1×10^{12} kilowatt hours (kWh) of commercial electricity was generated in the United States. Nuclear power accounted for 18.9

Another approach to reduce greenhouse gas emissions is to switch from coal-burning power plants to natural gas power plants.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(d) In addition to reducing greenhouse gas emissions, **describe** how switching from coal-burning power plants to natural gas power plants will improve air quality.

Researchers have proposed large-scale tree planting as a solution to reduce the effects of fossil fuel combustion on global climate change.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(e) Justify the proposed solution by explaining an additional advantage, other than the reduction of atmospheric greenhouse gases.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(f) 7.4×10^7 cubic meters of natural gas were extracted from a large deposit in 2020. An average of 4.76 kWh of electricity can be generated from each cubic meter of natural gas combusted. In 2020, an average home consumed 10,715 kWh of electricity. **Calculate** how many homes could have been provided with electricity by natural gas extracted from the large deposit in 2020. **Show** your work.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(g) In 2021, 8.99×10^{11} kWh of electricity was generated through the combustion of coal. One kilogram of carbon dioxide is produced per kWh of electricity generated by combusting coal, while 0.42 kilograms of carbon dioxide is produced by combusting natural gas. **Calculate** how much less carbon dioxide would have been produced in 2021 if all coal-burning power plants were replaced with natural gas-burning power plants. **Show** your work.

Solution 3

(a)

Mark scheme

- A fuel used in a nuclear power plant: Uranium (U-235) or Plutonium.

Solution 3

(b)

Mark scheme

- Using water for cooling in nuclear power plants causes thermal pollution: discharged water raises the temperature of nearby bodies of water outside organisms' range of tolerance and/or decreases dissolved oxygen; organisms can also be wounded or killed at the water intake; and water loss through evaporation can decrease stream flow/volume.

Solution 3

(c)

Mark scheme

- Calculate electricity generated by nuclear power in the US in 2021 (2 points: 1 for setup, 1 for the answer). Setup: (4.1×10^12 kWh) × 18.9% = (4.1×10^12) × 0.189. Calculation: 4.1×10^12 × 0.189 = 7.749×10^11 kWh 774,900,000,000 kWh (accept 7.75×10^11 or 7.7×10^11 kWh).

Solution 3

(d)

Mark scheme

- Switching from coal-burning to natural gas power plants improves air quality because burning natural gas produces less NOx, SOx, ash, particulates, toxic metals, and smog compared to burning coal.

Solution 3

(e)

Mark scheme

- An additional advantage of large-scale tree planting beyond reducing atmospheric greenhouse gases: provides forest habitat/increases biodiversity/diversifies niches; creates jobs (planting, recreation, wood harvesting); creates a more aesthetically pleasing environment/enhances cultural ecosystem services; decreases soil loss/erosion/sedimentation in waterways; provides shade/decreases ambient temperature; or slows water runoff/reduces flooding.

Solution 3

(f)

Mark scheme

- Calculate how many homes could be powered by the natural gas extracted (2 points: 1 for setup, 1 for the answer). Setup: (7.4×10^7 m^3) × (4.76 kWh / 1 m^3) × (1 home / 10,715 kWh). Calculation: 7.4×10^7 × 4.76 / 10,715 32,874 homes (accept 32,873 or 33,000).

Solution 3

(g)

Mark scheme

- Calculate how much less CO2 would be produced if all coal plants were replaced by natural gas plants in 2021 (2 points: 1 for setup, 1 for the answer). Setup: difference in emission rate $\times$ total kWh from coal = (1.0 kg CO2/kWh $-$ 0.42 kg CO2/kWh) $\times$ (8.99$\times$10^11 kWh); equivalently compute CO2 from coal (8.99$\times$10^11 kWh $\times$ 1.0 kg/kWh = 8.99$\times$10^11 kg) minus CO2 if that electricity were from natural gas (8.99$\times$10^11 kWh $\times$ 0.42 kg/kWh = 3.776$\times$10^11 kg). Calculation: 0.58 $\times$ 8.99$\times$10^11 = 5.2142$\times$10^11 kg 521 billion kg (accept 521,420,000,000 kg, 5.21$\times$10^11 kg, or 5.2$\times$10^11 kg).

Question 3

2023 Set 2 ▪ Q3

Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

(a) Describe one environmental problem associated with the release of methane into the atmosphere.

Question 3

2023 Set 2 ▪ Q3

Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

(b) Describe one factor that could affect the decomposition of the solid waste in a landfill.

Question 3

2023 Set 2 ▪ Q3

Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

(c) Propose a solution to decrease the amount of methane released from landfills into the atmosphere.

Question 3

2023 Set 2 ▪ Q3

Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

(d) Justify the solution proposed in part (c) by describing an additional advantage, other than decreasing the amount of methane released from landfills.

Question 3

2023 Set 2 ▪ Q3

Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

(e) The average cow releases 150 liters of methane per day. **Calculate** the amount of methane that was released by all beef cattle raised in the United States in 2021. **Show** your work.

Question 3

2023 Set 2 ▪ Q3

Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

(f) A typical beef cow needs 11.8 kilograms of food per day, and each hectare of cattle pasture produces 26.2 kilograms of grasses. **Calculate** the number of hectares of

Question 3

pasture that would be needed to support all beef cattle raised in the United States for one day. **Show** your work.

Question 3

2023 Set 2 ▪ Q3

Human activities generate large amounts of solid waste, including organic waste. The decomposition of organic waste in landfills can result in the release of methane into the atmosphere.

There are biological and physical factors that can affect the decomposition of the solid waste in a landfill and the release of methane in the atmosphere.

Another anthropogenic activity that releases methane is raising beef cattle. In 2021, 31.2 million beef cattle were raised in the United States.

Another environmental concern with raising beef cattle for food is that it is not as efficient as growing crops for food.

(g) The average American consumes 2,250 kilocalories of food per day. Beef cattle can produce 2.7 million kilocalories per hectare of land. Corn can produce 30.4 million kilocalories per hectare of land. **Calculate** how many more American people could be

Question 3

fed if 150 hectares of land was used to grow corn instead of raising beef cattle. **Show** your work.

Solution 3

(a)

Mark scheme

- One environmental problem, e.g.: methane traps heat effectively, enhancing the greenhouse effect and leading to climate change/global warming — which can in turn cause melting ice and rising sea levels.

Solution 3

(b)

Mark scheme

- One factor, e.g.: the amount/percentage of organic material in the solid waste; the amount/percentage of non-degradable material in the waste; landfill conditions such as oxygen concentration, population of microbes/decomposers, temperature, or moisture; or environmental conditions of the area such as temperature, rainfall, climate, or weather.

Solution 3

(c)

Mark scheme

- A solution such as: incinerating waste; composting waste; recycling/reusing non-synthetic organic waste (paper, textiles); installing/using methane collection systems; or burning off/combusting the methane coming from the landfill.

Solution 3

(d) Mark scheme

- An additional advantage matching the solution proposed in (c). Incinerating waste: extends the landfill's lifetime, reduces the amount of waste going to the landfill, can be used to generate electricity/heat or income, or reduces land area needed for landfills. Composting waste: extends the landfill's lifetime, produces effective inexpensive fertilizer, or reduces land area needed for landfills. Recycling/reusing organic waste: reduces land needed for landfills, reduces energy/resources needed for new products, or reduces trees cut for new paper. Installing methane collection / burning off methane: can be used to generate electricity, can be used to heat buildings, can generate income, can be used as fuel, or reduces the need for other energy sources.

Solution 3

(e)

Mark scheme

- Setup (1 pt): 150 L methane/day/cow $\times$ 31,200,000 cows (cattle) $\times$ 365 days/year. Calculation (1 pt): 150 $\times$ 31,200,000 $\times$ 365 = 1,708,200,000,000 L (1.7 $\times$ 10^12 L) of methane released by all beef cattle raised in the United States in one year.

Solution 3

(f)

Mark scheme

- Setup (1 pt): (11.8 kg food/day/cow ÷ 26.2 kg grass produced/ha) × 31,200,000 cows (cattle). Calculation (1 pt): (11.8/26.2) × 31,200,000 14,051,908 hectares (1.4 × 10^7 ha, or 14.1 million hectares) of pasture needed to support all beef cattle raised in the United States for one day.

Solution 3

(g)

Mark scheme

- Setup (1 pt): [(30,400,000 kcal/ha − 2,700,000 kcal/ha) ÷ 2,250 kcal/person] × 150 ha — the extra kcal/ha produced by growing corn instead of raising beef cattle, converted to people fed, for 150 hectares. Calculation (1 pt): (27,700,000/2,250) × 150 = 1,846,667 additional people (1.8 × 10^6) could be fed if 150 hectares were used to grow corn instead of raising beef cattle.

Question 3

2019 ▪ Q3

The graph shows measurements of atmospheric levels of carbon dioxide (CO_2) at Mauna Loa Observatory, Hawaii, and the measurements of pH levels in the ocean nearby at Station ALOHA. Measurements of pH began in 1992.

ATMOSPHERIC CARBON DIOXIDE AT MAUNA LOA AND OCEANIC pH AT STATION ALOHA, HAWAII

[Dual-axis line graph, x-axis "Year" from 1965 to 2015. Left y-axis "CO_2 (ppm)" from 275 to 400 in steps of 25 (275, 300, 325, 350, 375, 400). Right y-axis "pH" from 8.00 to 8.37 in steps of 0.07 (8.00, 8.08, 8.16, 8.23, 8.30, 8.37). Solid line = Mauna Loa Atmospheric CO_2 (ppm): a steadily rising, seasonally oscillating (sawtooth) curve starting at about 315 ppm in the early 1960s and rising to about 400 ppm by 2015. Dashed line = Station ALOHA Ocean pH: begins around 1992 near pH 8.11, oscillates with high-frequency noise, and shows an overall gradual downward trend to about pH

Question 3

8.07 by 2015 (with a fitted trend line sloping downward from left to right over that span).]

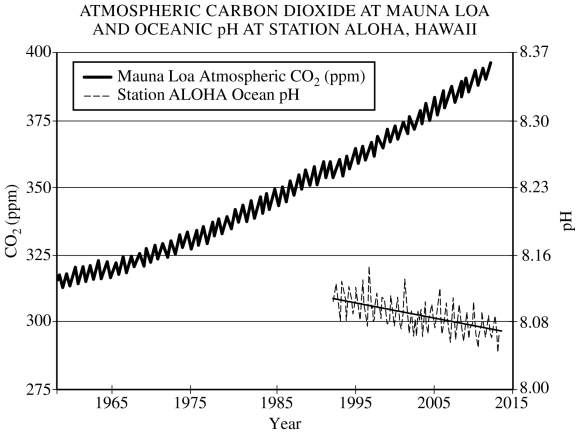
(a)(i) Use the graph above to answer the following questions.

Determine the concentration of CO_2 (in ppm) recorded at Mauna Loa in 2005.

(a)(ii) Determine the pH recorded at Station ALOHA in 2005.

Question 3

began in 1992.



Question 3

2019 ▪ Q3

The graph shows measurements of atmospheric levels of carbon dioxide (CO_2) at Mauna Loa Observatory, Hawaii, and the measurements of pH levels in the ocean nearby at Station ALOHA. Measurements of pH began in 1992.

ATMOSPHERIC CARBON DIOXIDE AT MAUNA LOA AND OCEANIC pH AT STATION ALOHA, HAWAII

[Dual-axis line graph, x-axis "Year" from 1965 to 2015. Left y-axis "CO_2 (ppm)" from 275 to 400 in steps of 25 (275, 300, 325, 350, 375, 400). Right y-axis "pH" from 8.00 to 8.37 in steps of 0.07 (8.00, 8.08, 8.16, 8.23, 8.30, 8.37). Solid line = Mauna Loa Atmospheric CO_2 (ppm): a steadily rising, seasonally oscillating (sawtooth) curve starting at about 315 ppm in the early 1960s and rising to about 400 ppm by 2015. Dashed line = Station ALOHA Ocean pH: begins around 1992 near pH 8.11, oscillates with high-frequency noise, and shows an overall gradual

Question 3

downward trend to about pH 8.07 by 2015 (with a fitted trend line sloping downward from left to right over that span).]

(b)(i) Changes in atmospheric carbon dioxide affect Earth's oceans.
Predict the effect of increased concentration of atmospheric CO_2 on the concentration of CO_2 in the ocean.

(b)(ii) Based on the data, identify the relationship between the concentration of atmospheric CO_2 and the pH of ocean water.

(b)(iii) Provide the complete chemical equation that represents the reaction between oceanic carbon dioxide (CO_2) and water (H_2O).

(b)(iv) Identify the specific environmental problem that directly results from the decrease in pH of Earth's oceans.

Question 3

2019 ▪ Q3

The graph shows measurements of atmospheric levels of carbon dioxide (CO_2) at Mauna Loa Observatory, Hawaii, and the measurements of pH levels in the ocean nearby at Station ALOHA. Measurements of pH began in 1992.

ATMOSPHERIC CARBON DIOXIDE AT MAUNA LOA AND OCEANIC pH AT STATION ALOHA, HAWAII

[Dual-axis line graph, x-axis "Year" from 1965 to 2015. Left y-axis "CO_2 (ppm)" from 275 to 400 in steps of 25 (275, 300, 325, 350, 375, 400). Right y-axis "pH" from 8.00 to 8.37 in steps of 0.07 (8.00, 8.08, 8.16, 8.23, 8.30, 8.37). Solid line = Mauna Loa Atmospheric CO_2 (ppm): a steadily rising, seasonally oscillating (sawtooth) curve starting at about 315 ppm in the early 1960s and rising to about 400 ppm by 2015. Dashed line = Station ALOHA Ocean pH: begins around 1992 near pH 8.11, oscillates with high-frequency noise, and shows an overall gradual

Question 3

downward trend to about pH 8.07 by 2015 (with a fitted trend line sloping downward from left to right over that span).]

(c)(i) Changes in pH in the world's oceans pose a risk to many marine organisms. Explain why certain organisms, in particular those with calcium carbonate shells or exoskeletons, are threatened by the decreasing pH levels measured in seawater.

(c)(ii) Other than threats posed by decreasing pH, identify an additional anthropogenic threat to the world's coral reef ecosystems and describe how the threat damages the coral reefs and coral reef ecosystems.

Solution 3

(a)(i)

Mark scheme

- CO_2 concentration at Mauna Loa in 2005: 380 ppm (accept 375–385 ppm, i.e. ± 5 ppm read from the graph).

(a)(ii)

Mark scheme

- pH recorded at Station ALOHA in 2005: 8.08 (accept 8.06–8.10, i.e. ± 0.02 read from the graph).

Solution 3

(b)(i)

Mark scheme

- Predicted effect of increased atmospheric CO_2 on oceanic CO_2: oceanic (dissolved) CO_2 will increase. Full credit for stating that oceanic CO_2 increases as atmospheric CO_2 increases.

Solution 3

(b)(ii)

Mark scheme

- Relationship between atmospheric CO_2 and ocean pH: as atmospheric CO_2 increases, pH decreases (equivalently: as more CO_2 dissolves in the water it becomes more acidic/less alkaline; or H_3O^+/H^+ ion concentration increases as atmospheric CO_2 increases). Full credit for correctly identifying the inverse relationship.

Solution 3

(b)(iii)

Mark scheme

- Balanced chemical equation for the reaction between oceanic CO_2 and water — any one of: $CO_2 + H_2O \rightarrow H_2CO_3$ (carbon dioxide plus water produces carbonic acid); $CO_2 + H_2O \rightarrow H^+ + HCO_3^-$ (produces one hydrogen ion and one bicarbonate ion); $CO_2 + H_2O \rightarrow 2H^+ + CO_3^{2-}$ (produces two hydrogen ions and one carbonate ion). Full credit for any one correctly balanced equation.

Solution 3

(b)(iv)

Mark scheme

- Specific environmental problem resulting directly from the decrease in ocean pH: Ocean Acidification.

Solution 3

(c)(i) Mark scheme

- 2 points — 1 point for explaining the chemical impact of decreased pH on shell/coral formation, and 1 point for describing the resulting impact on organism survival. Chemical impact examples: a decrease in pH could cause shells/exoskeletons to dissolve; prevent the growth of new coral/shells; prevent renewal/maintenance of existing coral/shells. Survival impact examples: organisms such as mollusks and coral would be threatened with reduced fitness/decreased number of offspring; increased predation risk; increased threat of disease. Both a valid chemical-impact idea and a valid survival-impact idea are needed for full 2 points; either alone earns 1 point.

Solution 3

(c)(ii) Mark scheme

- 2 points — 1 point for identifying an anthropogenic threat to coral reefs other than decreasing pH, 1 point for describing how it damages coral reefs/reef ecosystems. Acceptable paired examples: Increased ocean temperature → coral bleaching (loss of the algal symbiont), reduction of dissolved oxygen concentration; Recreational activities (watercraft, scuba, snorkeling, swimming, etc.) → physical damage to/destruction of coral reefs; Fishing practices (bottom trawling, dynamite fishing, overfishing, etc.) → physical damage to/destruction of coral reefs, removal of key species disrupts the food web/causes a trophic cascade; Nutrient pollution (agricultural runoff, wastewater treatment plants) → cultural eutrophication and eventual decrease in dissolved oxygen levels, excessive algal

Solution 3

growth reduces light penetration; Sediment pollution (logging operations, mining, etc.) $\rightarrow$ increased turbidity/reduction in light penetration, deposited sediments cover/smother coral reefs; Chemical pollution (oil spills, pesticide runoff, sunscreen, etc.) $\rightarrow$ disruption of reproduction and growth cycles, disruption of metabolic processes, endocrine disruption/DNA damage, reduction in light penetration; Plastic/solid waste pollution $\rightarrow$ physical damage to/destruction of members of the coral reef ecosystem, reduction in light penetration; Introduction of invasive species (lionfish/turkey fish, Philippine mantis shrimp, etc.) $\rightarrow$ invasive species can outcompete native species. Award 1 point for a valid threat, 1 point for a correctly linked description of damage.

Question 1

2014 ▪ Q1

Read the article below and answer the questions that follow.

[Newspaper clipping] The Fremont Plaindealer — May 1, 2013

Last night the county council discussed a motion to support the construction of a new nuclear power plant on the Fremont River to address the rising demand for electrical power in Fremont County. Councilperson Pamela Kull spoke in support of the plant, remarking that "nuclear power plants produce no dangerous solid waste" and "using nuclear power avoids the release of greenhouse gases." Councilperson Chinh Serach said that Dr. Kull's remarks were incorrect and then introduced a different motion to provide funding to help Fremont homeowners and businesses reduce electricity use. He stated that such steps could make building the nuclear plant unnecessary.

(a)(i) State whether you agree or disagree with each of the following remarks made by Dr. Kull. For each remark, provide one justification for your position.

Question 1

"Nuclear power plants produce no dangerous solid waste."
(a)(ii) State whether you agree or disagree with each of the following remarks made by Dr. Kull. For each remark, provide one justification for your position.
"Using nuclear power avoids the release of greenhouse gases."

Question 1

The Fremont Plaindealer **May 1, 2013**

Last night the county council discussed a motion to support the construction of a new nuclear power plant on the Fremont River to address the rising demand for electrical power in Fremont County. Councilperson Pamela Kull spoke in support of the plant, remarking that "nuclear power plants produce no dangerous solid waste" and "using nuclear power avoids the release of greenhouse gases."

Councilperson Chinh Serach said that Dr. Kull's remarks were incorrect and then introduced a different motion to provide funding to help Fremont homeowners and businesses reduce electricity use. He stated that such steps could make building the nuclear plant unnecessary.

Question 1

2014 ▪ Q1

Read the article below and answer the questions that follow.

[Newspaper clipping] The Fremont Plaindealer — May 1, 2013

Last night the county council discussed a motion to support the construction of a new nuclear power plant on the Fremont River to address the rising demand for electrical power in Fremont County. Councilperson Pamela Kull spoke in support of the plant, remarking that "nuclear power plants produce no dangerous solid waste" and "using nuclear power avoids the release of greenhouse gases." Councilperson Chinh Serach said that Dr. Kull's remarks were incorrect and then introduced a different motion to provide funding to help Fremont homeowners and businesses reduce electricity use. He stated that such steps could make building the nuclear plant unnecessary.

Question 1

(b) If the plan for a nuclear power plant in Fremont is approved, it will take several years for the plant to be built. Describe TWO environmental problems that could result from the construction of the plant (i.e., prior to operation).

Question 1

2014 ▪ Q1

Read the article below and answer the questions that follow.

[Newspaper clipping] The Fremont Plaindealer — May 1, 2013

Last night the county council discussed a motion to support the construction of a new nuclear power plant on the Fremont River to address the rising demand for electrical power in Fremont County. Councilperson Pamela Kull spoke in support of the plant, remarking that "nuclear power plants produce no dangerous solid waste" and "using nuclear power avoids the release of greenhouse gases." Councilperson Chinh Serach said that Dr. Kull's remarks were incorrect and then introduced a different motion to provide funding to help Fremont homeowners and businesses reduce electricity use. He stated that such steps could make building the nuclear plant unnecessary.

(c)(i) Suppose that the nuclear power plant is constructed on the Fremont River site.

Question 1

Identify the most likely pollution threat that the plant will pose to the Fremont River as a result of the plant's normal daily operation.

(c)(ii) Discuss one potential ecological consequence of the pollution threat that you identified in part (i).

(c)(iii) Identify a system often used in nuclear power plants to reduce the pollution you identified in part (i).

Question 1

2014 ▪ Q1

Read the article below and answer the questions that follow.

[Newspaper clipping] The Fremont Plaindealer — May 1, 2013

Last night the county council discussed a motion to support the construction of a new nuclear power plant on the Fremont River to address the rising demand for electrical power in Fremont County. Councilperson Pamela Kull spoke in support of the plant, remarking that "nuclear power plants produce no dangerous solid waste" and "using nuclear power avoids the release of greenhouse gases." Councilperson Chinh Serach said that Dr. Kull's remarks were incorrect and then introduced a different motion to provide funding to help Fremont homeowners and businesses reduce electricity use. He stated that such steps could make building the nuclear plant unnecessary.

(d) Describe TWO specific steps that Fremont residents and/or businesses could take to reduce the use of electricity.

Question 1

2014 ▪ Q1

Read the article below and answer the questions that follow.

[Newspaper clipping] The Fremont Plaindealer — May 1, 2013

Last night the county council discussed a motion to support the construction of a new nuclear power plant on the Fremont River to address the rising demand for electrical power in Fremont County. Councilperson Pamela Kull spoke in support of the plant, remarking that "nuclear power plants produce no dangerous solid waste" and "using nuclear power avoids the release of greenhouse gases." Councilperson Chinh Serach said that Dr. Kull's remarks were incorrect and then introduced a different motion to provide funding to help Fremont homeowners and businesses reduce electricity use. He stated that such steps could make building the nuclear plant unnecessary.

Question 1

(e) Identify a specific nuclear power plant at which a major accident has occurred. Explain one environmental consequence (other than effects on human health) of a nuclear power plant accident.

Question 4

2014 ▪ Q4

Biogeochemical cycles describe the movement of certain elements (typically bound with other elements in compounds) through Earth's atmosphere, hydrosphere, biosphere, and lithosphere. These elements and their compounds are necessary components of all life, and because they cycle, they can be used repeatedly by new generations of organisms. Each biogeochemical cycle has different pathways with various reservoirs (sources and sinks) where elements may reside for days or millions of years.

(a)(i) The atmosphere is one important carbon reservoir.
Describe a biological process by which carbon is removed from the atmosphere and converted to organic molecules.

(a)(ii) Describe a biological process by which carbon is converted from organic molecules to a gas and returned to the atmosphere.

Question 4

2014 ▪ Q4

Biogeochemical cycles describe the movement of certain elements (typically bound with other elements in compounds) through Earth's atmosphere, hydrosphere, biosphere, and lithosphere. These elements and their compounds are necessary components of all life, and because they cycle, they can be used repeatedly by new generations of organisms. Each biogeochemical cycle has different pathways with various reservoirs (sources and sinks) where elements may reside for days or millions of years.

(b)(i) Oceans and terrestrial systems are also important carbon reservoirs. Explain how atmospheric carbon is incorporated into two oceanic sinks.

(b)(ii) Identify one terrestrial sink, other than fossil fuels, that stores carbon for thousands to millions of years.

Question 4

2014 ▪ Q4

Biogeochemical cycles describe the movement of certain elements (typically bound with other elements in compounds) through Earth's atmosphere, hydrosphere, biosphere, and lithosphere. These elements and their compounds are necessary components of all life, and because they cycle, they can be used repeatedly by new generations of organisms. Each biogeochemical cycle has different pathways with various reservoirs (sources and sinks) where elements may reside for days or millions of years.

(c) The burning of fossil fuels has been shown to increase the concentration of carbon in the atmosphere. Discuss TWO other human activities that increase the concentration of carbon in the atmosphere.

Question 4

2014 ▪ Q4

Biogeochemical cycles describe the movement of certain elements (typically bound with other elements in compounds) through Earth's atmosphere, hydrosphere, biosphere, and lithosphere. These elements and their compounds are necessary components of all life, and because they cycle, they can be used repeatedly by new generations of organisms. Each biogeochemical cycle has different pathways with various reservoirs (sources and sinks) where elements may reside for days or millions of years.

(d) Identify an environmental problem that results from elevated atmospheric carbon concentrations. Discuss one consequence of the problem you identified.

Question 4

2014 ▪ Q4

Biogeochemical cycles describe the movement of certain elements (typically bound with other elements in compounds) through Earth's atmosphere, hydrosphere, biosphere, and lithosphere. These elements and their compounds are necessary components of all life, and because they cycle, they can be used repeatedly by new generations of organisms. Each biogeochemical cycle has different pathways with various reservoirs (sources and sinks) where elements may reside for days or millions of years.

(e)(i) Phosphorus is another element important to all organisms.
Describe one major way in which the phosphorus cycle differs from the carbon cycle.

(e)(ii) Identify one reason that phosphorus is necessary for organisms.