Passage II

Color images of the surface of Io, one of Jupiter's moons, show plumes of gas that resemble Earth's geysers and active volcanoes that emit flows of molten material. The materials ejected from Io's volcanoes and plumes rapidly solidify at Io's cold surface temperatures. Scientists believe that these materials may be one of several *allotropes* (forms) of sulfur (S), or a sulfur compound. The following studies were performed to determine the composition of these materials.

Study 1

In a laboratory, scientists measured the *reflectances* (the fraction of light striking a surface that is reflected by that surface) of 4 allotropes of S (red, white, orange, and brown) and of a sulfur compound (sulfur dioxide [SO_2]). Reflectances were measured at visible-light wavelengths between 0.35 µm (micrometers) and 0.60 µm. Figure 1 shows the data for the various S allotropes and for SO_2.

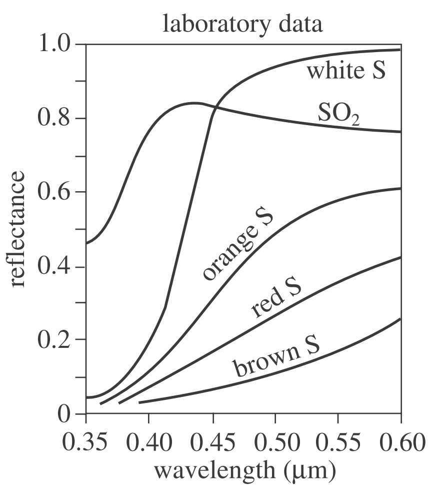


Figure 1

Io's *whole-disk reflectance* (the reflectance of Io's entire visible surface measured all at once) was measured at 2 different times. Figure 2 shows these data along with reflectance data calculated using a computer model. This model shows what combination of materials from Figure 1 would produce the closest match to the measured reflectance data. According to the model, the overall composition of Io's surface is 15% SO_2, 50% orange S, 20% red S, and 15% white S.

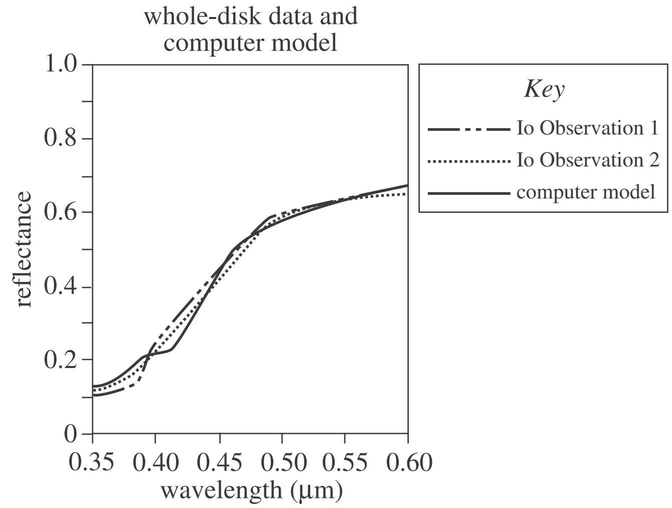


Figure 2

Study 2

At 2 different times, reflectances were measured of the crater floors of 2 volcanoes on Io: Pele and Surt. Figure 3 shows the reflectance data.

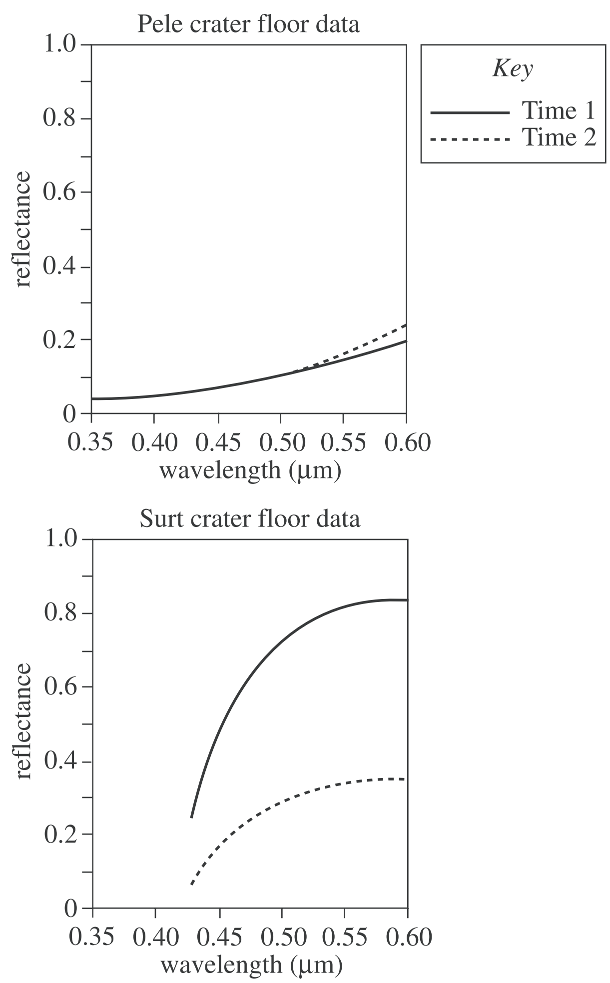


Figure 3

Study 3

Reflectance data were taken from several large plumes and several small plumes on Io. The averaged data are in Figure 4.

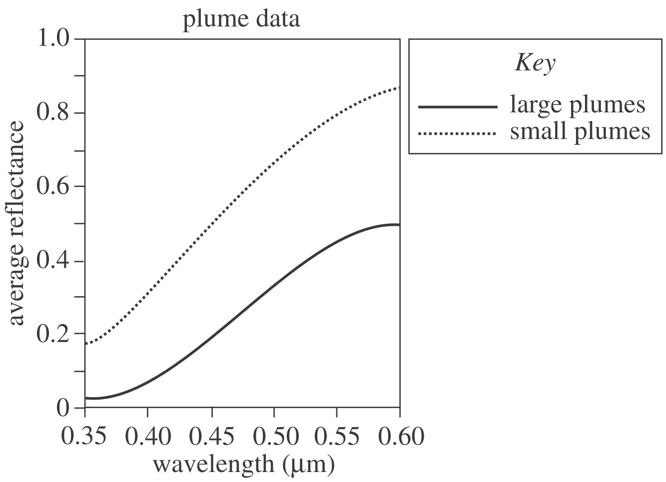


Figure 4

Figures 1, 3, and 4 adapted from Alfred McEwen and Laurence Soderblom, "Two Classes of Volcanic Plumes on Io." ©1983 by Academic Press, Inc.

Figure 2 adapted from Julianne Moses and Douglas Nash, "Phase Transformations and the Spectral Reflectance of Solid Sulfur: Can Metastable Sulfur Allotropes Exist on Io?" ©1991 by Academic Press, Inc.

8. At the wavelengths used in Study 1, as the wavelength of the light increases, the reflectances of the S allotropes and of SO_2 do which of the following?

	S allotropes	SO_2
F.	Increase only	Increase only
G.	Increase only	Increase, then decrease
H.	Decrease only	Decrease only
J.	Decrease only	Increase, then decrease

9. According to Study 3, compared with the corresponding average reflectance for small plumes, large plumes on Io have an average reflectance at a given wavelength that is:

A. always higher.
B. always the same.
C. always lower.
D. sometimes higher and sometimes lower.

10. According to Study 1, the reflectance of white S at a wavelength of 0.40 μm is closest to which of the following?

F. 0.0
G. 0.1
H. 0.2
J. 0.3

11. According to Study 1 and Study 2, the crater floor of the volcano Pele has reflectances most similar to which of the following S allotropes?

A. White S
B. Orange S
C. Red S
D. Brown S

12. If the averaged reflectances for large plumes and for small plumes had been measured at a wavelength of 0.61 μm in Study 3, those reflectances would have been closest to which of the following?

	Large plumes	Small plumes
F.	0.2	0.5
G.	0.5	0.2
H.	0.5	0.9
J.	0.9	0.5

13. According to Study 1, white S has a reflectance of 0.98 at a wavelength of 0.60 μm. This means that white S reflects:

A. 2% of the 0.60 μm wavelength light that strikes its surface.
B. 98% of the 0.60 μm wavelength light that strikes its surface.
C. 2% of all the visible light that strikes its surface.
D. 98% of all the visible light that strikes its surface.

Passage III

An electrical circuit contained a 12-volt (V) battery, a *resistor* (a device that resists the flow of electricity), a *capacitor* (a device that stores electrical charge and electrical energy), a *voltmeter* (an instrument for measuring voltage), and a switch, as shown in Figure 1.

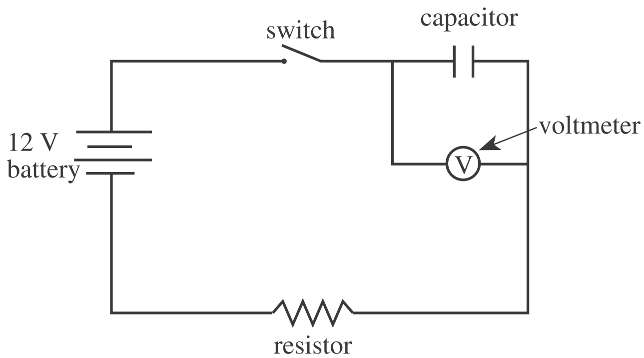


Figure 1

Some students studied the behavior of the circuit.

Experiment 1

The students used a 1×10^7 ohm (Ω) resistor and a capacitor with a *capacitance* of 1×10^{-6} farad (F). (Capacitance is a measure of the maximum amount of electrical charge and electrical energy a capacitor can store.) The capacitor was initially uncharged. At time zero, the students simultaneously closed the switch and started a stopwatch. At time zero and at 12 sec intervals thereafter, they recorded the voltage across the capacitor. Their results are shown in Table 1.

Table 1

Time (sec)	Voltage across capacitor (V)
0	0.0
12	8.4
24	10.9
36	11.7
48	11.9
60	12.0

Experiment 2

Using the 1×10^7 Ω resistor and several different capacitors, the students determined the length of time from when the switch was closed until the voltage across the capacitor reached 6 V. Their results are shown in Table 2.

Table 2

Capacitance ($\times 10^{-6}$ F)	Time to reach 6 V across capacitor (sec)
1.2	8.3
0.6	4.2
0.3	2.1
0.1	0.7

Experiment 3

The students conducted the same procedure described in Experiment 2, except that they used a constant capacitance of 1×10^{-6} F and several different resistors. Their results are shown in Table 3.

Table 3

Resistance ($\times 10^7$ Ω)	Time to reach 6 V across capacitor (sec)
0.75	5.2
0.50	3.5
0.25	1.7

14. In Experiment 1, the *time constant* of the circuit was the time required for the voltage across the capacitor to reach approximately 7.6 V. The time constant of the circuit used in Experiment 1 was:

F. less than 12 sec.
G. between 12 sec and 24 sec.
H. between 24 sec and 36 sec.
J. greater than 36 sec.

15. If, in Experiment 2, a 1.5×10^{-6} F capacitor had been used, the time required for the voltage across the capacitor to reach 6 V would have been closest to:

A. 4.2 sec.
B. 7.0 sec.
C. 10.5 sec.
D. 15.0 sec.

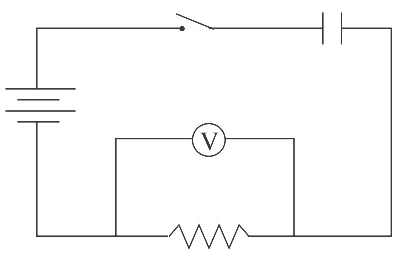
GO ON TO THE NEXT PAGE.

16. The main purpose of Experiment 3 was to determine how varying the:

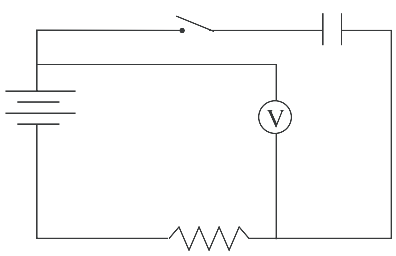
F. battery's voltage affected the resistor's resistance at a given time.
G. capacitor's capacitance affected the time required for the voltage across the capacitor to reach a set value.
H. capacitor's capacitance affected the voltage across the battery at a given time.
J. resistor's resistance affected the time required for the voltage across the capacitor to reach a set value.

17. Based on Figure 1, to measure the voltage across the resistor only, which of the following circuits should one use?

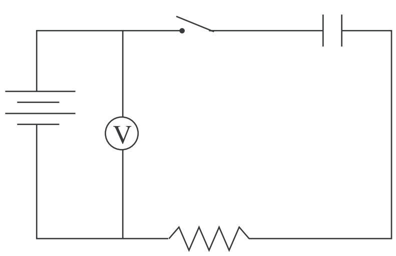
A.



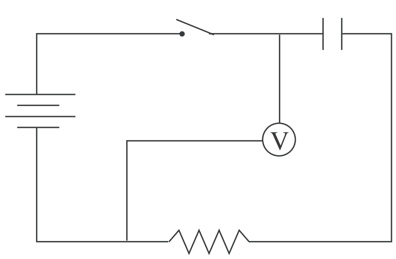
B.



C.



D.



18. Consider a circuit like that shown in Figure 1. Based on Experiments 2 and 3, the voltage across the capacitor will reach a given value in the shortest amount of time if the circuit contains which of the following capacitances and resistances, respectively?

F. 0.1×10^{-6} F, 0.3×10^{7} Ω
G. 0.1×10^{-6} F, 1.0×10^{7} Ω
H. 1.2×10^{-6} F, 0.3×10^{7} Ω
J. 1.2×10^{-6} F, 1.0×10^{7} Ω

19. Consider the following hypothesis: In a circuit arranged as in Figure 1 containing a battery, a capacitor, and a constant resistance, as capacitance increases, the time required to reach a given voltage across the capacitor increases. Do the experiments support this hypothesis?

A. Yes; in Experiment 1, as capacitance increased, the time required to reach a given voltage increased.
B. Yes; in Experiment 2, as capacitance increased, the time required to reach a given voltage increased.
C. No; in Experiment 1, as capacitance increased, the time required to reach a given voltage decreased.
D. No; in Experiment 2, as capacitance increased, the time required to reach a given voltage decreased.

Passage IV

A *bomb calorimeter* is used to determine the amount of heat released when a substance is burned in oxygen (Figure 1). The heat, measured in kilojoules (kJ), is calculated from the change in temperature of the water in the bomb calorimeter. Table 1 shows the amounts of heat released when different foods were burned in a bomb calorimeter. Table 2 shows the amounts of heat released when different amounts of sucrose (table sugar) were burned. Table 3 shows the amounts of heat released when various chemical compounds were burned.

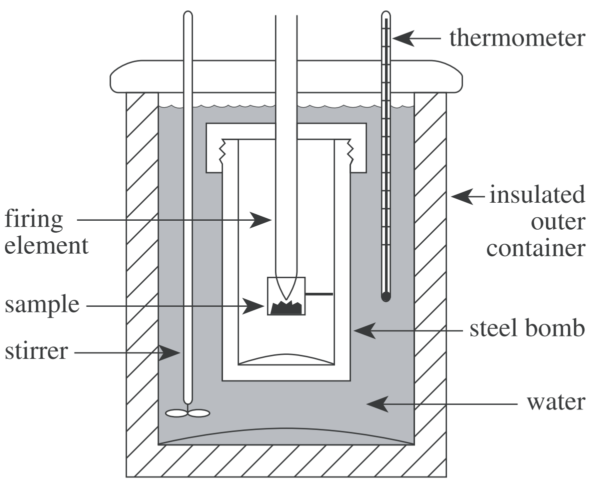


Figure 1

Figure 1 adapted from Antony C. Wilbraham, Dennis D. Staley, and Michael S. Matta, *Chemistry*. ©1995 by Addison-Wesley Publishing Company, Inc.

Table 1

Food	Mass (g)	Change in water temperature (°C)	Heat released (kJ)
Bread	1.0	8.3	10.0
Cheese	1.0	14.1	17.0
Egg	1.0	5.6	6.7
Potato	1.0	2.7	3.2

Table 1 adapted from American Chemical Society, *ChemCom: Chemistry in the Community*. ©1993 by American Chemical Society.

Table 2

Amount of sucrose (g)	Heat released (kJ)
0.1	1.6
0.5	8.0
1.0	16.0
2.0	32.1
4.0	64.0

Table 3

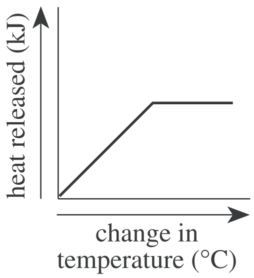
Chemical compound	Molecular formula	Mass (g)	Heat released (kJ)
Methanol	CH_3OH	0.5	11.4
Ethanol	C_2H_5OH	0.5	14.9
Benzene	C_6H_6	0.5	21.0
Octane	C_8H_{18}	0.5	23.9

20. According to Tables 1 and 2, as the mass of successive sucrose samples increased, the change in the water temperature produced when the sample was burned most likely:

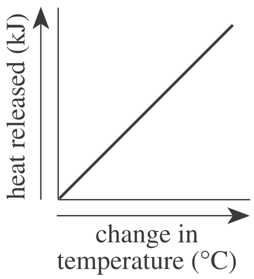
F. increased only.
G. decreased only.
H. increased, then decreased.
J. remained the same.

21. Which of the following graphs best illustrates the relationship between the heat released by the foods listed in Table 1 and the change in water temperature?

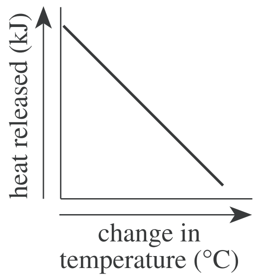
A.



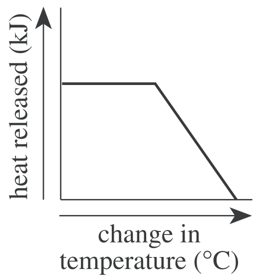
B.



C.



D.



22. Based on the data in Table 2, one can conclude that when the mass of sucrose is decreased by one-half, the amount of heat released when it is burned in a bomb calorimeter will:

F. increase by one-half.
G. decrease by one-half.
H. increase by one-fourth.
J. decrease by one-fourth.

23. Which of the following lists the foods from Tables 1 and 2 in increasing order of the amount of heat released per gram of food?

A. Potato, egg, bread, sucrose, cheese
B. Sucrose, cheese, bread, egg, potato
C. Bread, cheese, egg, potato, sucrose
D. Sucrose, potato, egg, bread, cheese

24. Based on the information in Tables 1 and 2, the heat released from the burning of 5.0 g of potato in a bomb calorimeter would be closest to which of the following?

F. 5 kJ
G. 10 kJ
H. 15 kJ
J. 20 kJ

Passage V

Density is defined as the mass of a substance divided by its volume:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Table 1 lists the phases and the densities, in grams per cubic centimeter (g/cm^3), of various pure substances at 25°C and 1 atmosphere (atm) of pressure.

Table 1

Substance	Phase	Density (g/cm^3)
Arsenic	solid	5.73
Glucose	solid	1.56
Iron	solid	7.86
Lead	solid	11.34
Zinc	solid	7.14
Ethanol	liquid	0.79
Ethyl ether	liquid	0.71
Glycerol	liquid	1.26
Mercury	liquid	13.59
Freon-12	gas	0.00495
Krypton	gas	0.00343
Methane	gas	0.00065

Figure 1 shows how the density of liquid water changes with temperature.

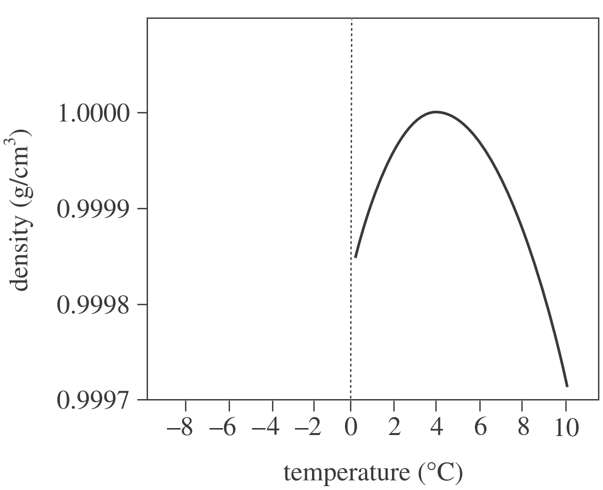


Figure 1

Figure 2 shows how the density of solid water changes with temperature.

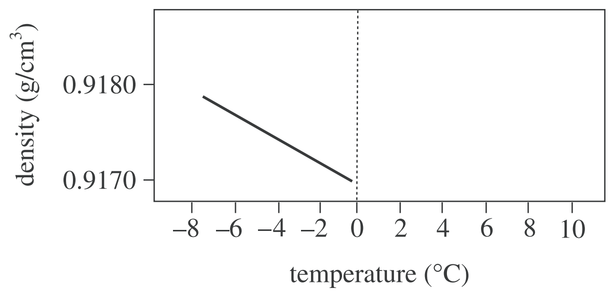


Figure 2

Figures adapted from John C. Kotz and Keith F. Purcell, *Chemistry & Chemical Reactivity*. ©1987 by CBS College Publishing.

25. According to Figure 1, as the temperature of liquid water decreases from 10°C to 0°C, the density:

A. increases only.
B. decreases only.
C. decreases, then increases.
D. increases, then decreases.

26. A student claimed that "If the masses of 1 cm^3 of any solid and 1 cm^3 of any liquid are compared, the mass of the solid will be greater." Do the data in Table 1 support his claim?

F. No; lead has a higher density than any of the liquids listed.
G. No; mercury has a higher density than any of the solids listed.
H. Yes; lead has a higher density than any of the liquids listed.
J. Yes; mercury has a higher density than any of the solids listed.

27. Which of the following hypotheses about the relationship between the temperature and the density of a solid is best supported by the data in Figure 2 ? As the temperature of a solid increases, the density of the solid:

A. increases only.
B. decreases only.
C. increases, then decreases.
D. decreases, then increases.

28. Equal amounts of ethyl ether, mercury, and water (density = 0.9971 g/cm^3) at 25°C are poured into a single beaker. Three distinct layers of liquid form in the beaker. Based on the data in Table 1, which of the following diagrams represents the order, from top to bottom, of the liquids in the beaker?

F.

Ethyl ether
Water
Mercury

G.

Ethyl ether
Mercury
Water

H.

Mercury
Water
Ethyl ether

J.

Water
Ethyl ether
Mercury

29. According to Figure 1, 100 g of water at 4°C would exactly fill a container having which of the following volumes?

A. 1 cm^3
B. 10 cm^3
C. 100 cm^3
D. 1,000 cm^3

Passage VI

The clearing of rain forests results in *forest fragmentation* (the breakup of large forest tracts into small patches). Researchers predicted that fragmentation would result in a decrease in animal populations and *aboveground tree biomass* (AGTB) in the resulting fragments. They did 4 studies to test this prediction.

Study 1

The researchers monitored the AGTB of twenty-five 100 m × 100 m forest plots near areas that had recently been cleared of vegetation. The distance from the center of each plot to the nearest clearing was measured. Figure 1 shows the average change per plot in AGTB in metric tons per year (t/yr) over 17 yr.

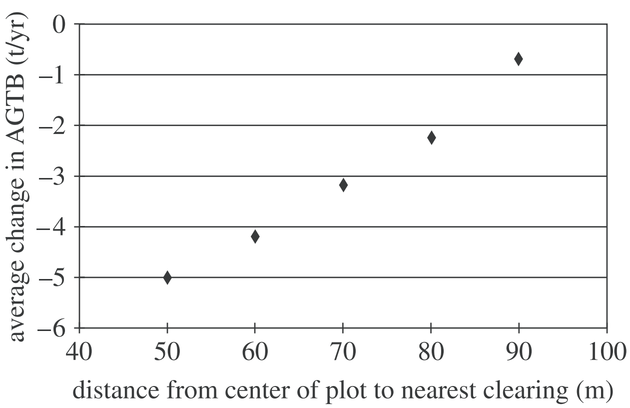


Figure 1

Study 2

Twenty-five 100 m × 100 m forest plots were monitored as in Study 1. The center of each of these plots was at least 500 m from the nearest clearing. The average change in AGTB over 17 yr for these 25 plots was 0 t/yr.

Study 3

Researchers monitored sixteen 100 m × 100 m forest plots near areas that had recently been cleared of vegetation. Each plot was bordered on 1 side by a clearing. Figure 2 shows the average cumulative percent change in AGTB at these plots following fragmentation. (Note: Year 0 represents results prior to fragmentation.)

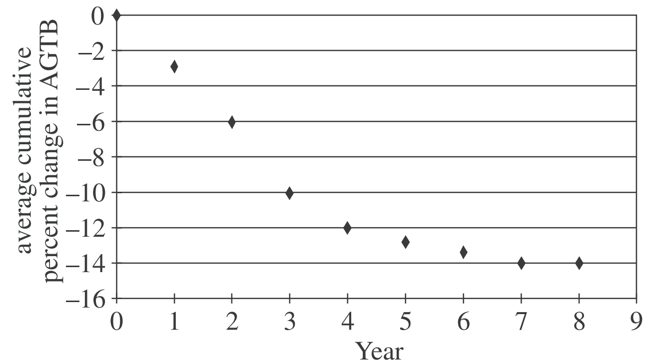


Figure 2

Study 4

Researchers trapped and released birds in 10 forest fragments adjacent to areas that had recently been cleared of vegetation. Three types of birds were monitored: insectivores, frugivores (fruit eaters), and hummingbirds. Figure 3 shows the number of captures per 1,000 hours (hr) of trapping. (Note: Year 0 represents results prior to fragmentation.)

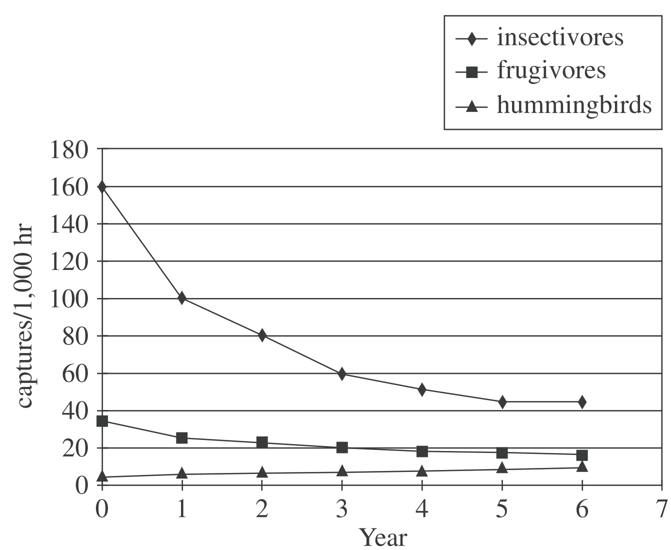


Figure 3

Figures adapted from William F. Laurance et al., "Biomass Collapse in Amazonian Forest Fragments." ©1998 by the American Association for the Advancement of Science.

30. In Study 4, as time increased from Year 0 to Year 6, the captures/1,000 hr of frugivores:

F. decreased only.
G. increased only.
H. decreased, then increased.
J. increased, then decreased.

31. Based on the results of Study 4, how did fragmentation most likely affect the population sizes of insectivores and hummingbirds in the fragments studied?

A. Fragmentation increased the population sizes of both insectivores and hummingbirds.
B. Fragmentation decreased the population sizes of both insectivores and hummingbirds.
C. Fragmentation increased the population size of insectivores and decreased the population size of hummingbirds.
D. Fragmentation decreased the population size of insectivores and increased the population size of hummingbirds.

32. Based on the results of Study 1, if the distance from the center of a 100 m × 100 m plot were 75 m from the nearest clearing, the expected average change in AGTB at the plot over 17 yr would be closest to which of the following values?

F. –1.1 t/yr
G. –2.6 t/yr
H. +1.1 t/yr
J. +2.6 t/yr

33. After examining the results of Study 2, a student concluded that the AGTB at each of the 25 plots remained constant. Which of the following alternative explanations is also consistent with the results?

A. The AGTB at all 25 plots increased.
B. The AGTB at all 25 plots decreased.
C. The AGTB at some of the plots increased and the AGTB at some of the plots decreased.
D. The AGTB at plots bounded by forest increased and the AGTB at plots bounded by clearings remained constant.

34. Which of the following sets of results from the studies is *least* consistent with the prediction proposed by the researchers?

F. The results of Study 1 for AGTB
G. The results of Study 3 for AGTB
H. The results of Study 4 for frugivores
J. The results of Study 4 for hummingbirds

35. In Study 4, the researchers trapped birds for 10,000 hr per year. Thus, how many insectivores were trapped in Year 2 ?

A. 80
B. 100
C. 800
D. 1,000

GO ON TO THE NEXT PAGE.

Passage VII

Glaciers deposit *till* (a poorly sorted sediment). If glaciers repeatedly advance over an area and then melt back, thick till deposits may form. Figure 1 shows a vertical core taken through layers of till, non-glacial sediments, and bedrock at a site in Canada. The *resistivity* (an electrical property of a material) and CO_2 measurements taken along the core are also shown. Resistivity is related to a sediment's particle sizes, compaction, and mineral composition. Table 1 shows the average percent sand, silt, and clay contents and descriptions of the various till layers.

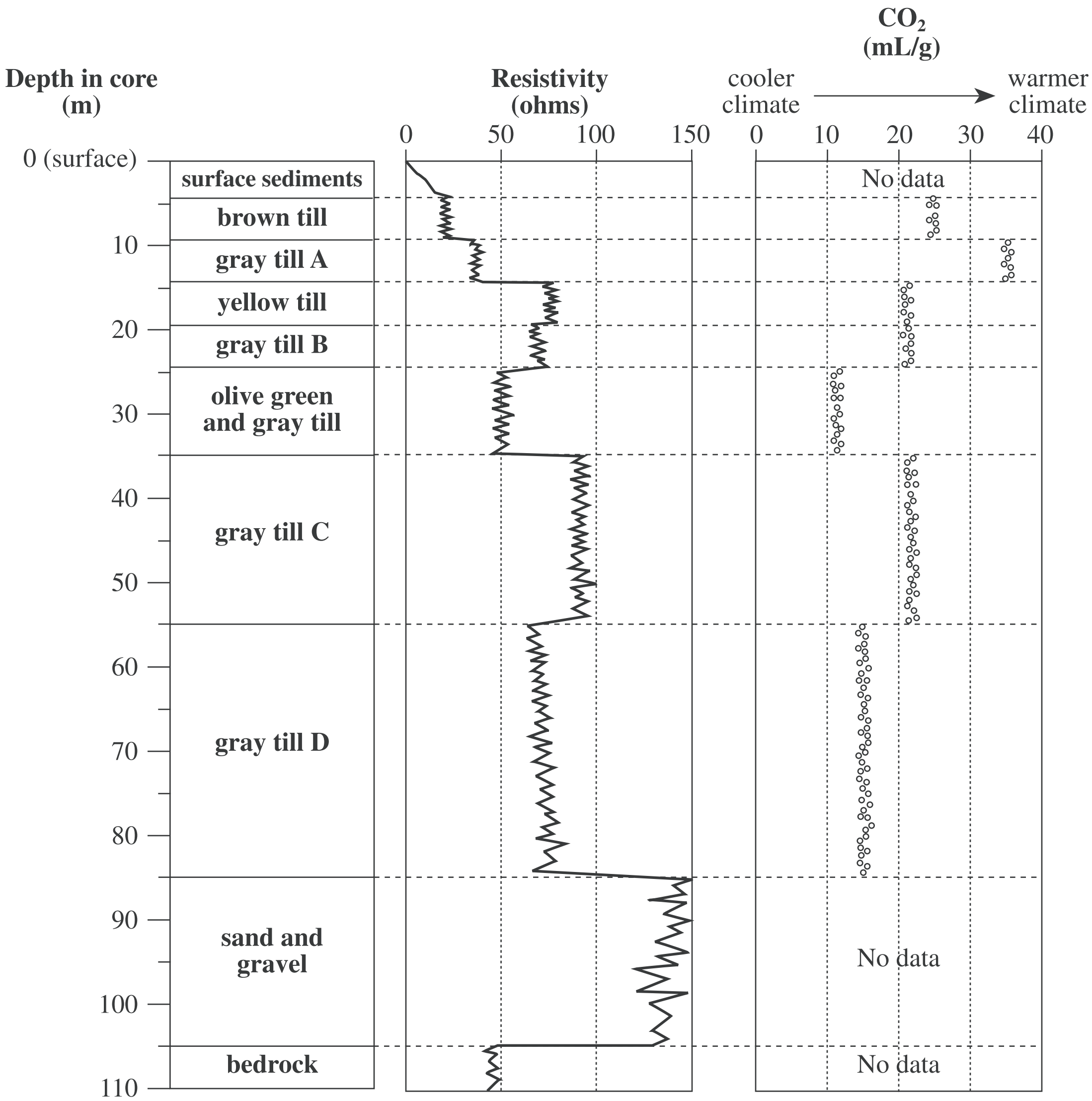


Figure 1

Table 1				
Depth of till layer (m)	Description of till	Average percent by volume of: larger particle → smaller particle		
		sand	silt	clay
4–9	brown (oxidized*)	54.1	31.7	14.2
9–14	gray A	44.8	36.6	18.6
14–19	yellow (oxidized)	43.5	31.7	24.8
19–24	gray B	37.4	34.3	28.3
24–35	olive green and gray	25.5	34.3	40.2
35–55	gray C	31.7	33.6	34.7
55–85	gray D	37.5	31.7	30.8

*Oxidized sediments have at some time been exposed to the air. Sediments that have been *deprived* of oxygen will be gray or green.

Figure 1 and Table 1 adapted from E. A. Christiansen, "Pleistocene Stratigraphy of the Saskatoon Area, Saskatchewan, Canada: An Update."

36. A sample of gray till was recovered from another core taken from a nearby area. The table below shows the results of an analysis of the sample.

Percent by volume of:			Resistivity (ohms)	CO_2 content (mL/g)
sand	silt	clay		
31.5	33.7	34.8	85	22

Based on these data and the data provided in Figure 1 and Table 1, the sample of gray till corresponds most closely with which till from Figure 1 ?

F. Gray till A
G. Gray till B
H. Gray till C
J. Gray till D

37. According to Figure 1, the *oldest* glacial advance in this area deposited which of the following till layers?

A. Gray till A
B. Yellow till
C. Olive green and gray till
D. Gray till D

38. According to Figure 1, which of the following statements best describes how the resistivity of the sand and gravel layer compares to the resistivity of the till layers? The resistivity measured in the sand and gravel layer is:

F. lower than the resistivities measured in any of the till layers.
G. higher than the resistivities measured in any of the till layers.
H. the same as the resistivities measured in the surface sediments.
J. lower than the resistivities measured in the bedrock.

39. The average resistivity of the bedrock in the core is most similar to the average resistivity of which of the following till layers?

A. Yellow till
B. Gray till B
C. Olive green and gray till
D. Gray till C

40. The sediments being deposited at the present time at the site where the core was taken have a much higher CO_2 content than any of the tills. Given this information and the information in Figure 1, the CO_2 content of sediments recently deposited at the site would most likely be in which of the following ranges?

F. Less than 10 mL/g
G. Between 10 mL/g and 25 mL/g
H. Between 25 mL/g and 35 mL/g
J. Greater than 35 mL/g

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.

[See Note on page 56.]