Write all of your answers on your answer sheet.
Please use CAPITAL letters.

SCIENCE TEST

35 Minutes—40 Questions

DIRECTIONS: There are several passages in this test. Each passage is followed by several questions. After reading a passage, choose the best answer to each question and fill in the corresponding oval on your answer document. You may refer to the passages as often as necessary.

You are NOT permitted to use a calculator on this test.

Passage I

Finch beak depth (see Figure 1) is an *inheritable* trait (it can be passed from parents to offspring).

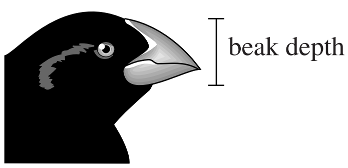


Figure 1

Researchers studied the beak depth of 2 species of finches, *Geospiza fortis* and *Geospiza fuliginosa*. Both species live on Island A. *G. fortis* alone lives on Island B, and *G. fuliginosa* alone lives on Island C. For both species, the primary food is seeds. Birds with shallower beaks can efficiently crush and eat only small seeds. Birds with deeper beaks can crush and eat both large and small seeds, but they prefer small seeds.

Study 1

Researchers captured 100 *G. fortis* finches and 100 *G. fuliginosa* finches on Island A. They tagged each bird, measured its beak depth, and released it. Then they calculated the percent of birds having each of the beak depths that had been measured. The researchers followed the same procedures with 100 *G. fortis* finches from Island B and 100 *G. fuliginosa* finches from Island C. The results of this study are shown in Figure 2.

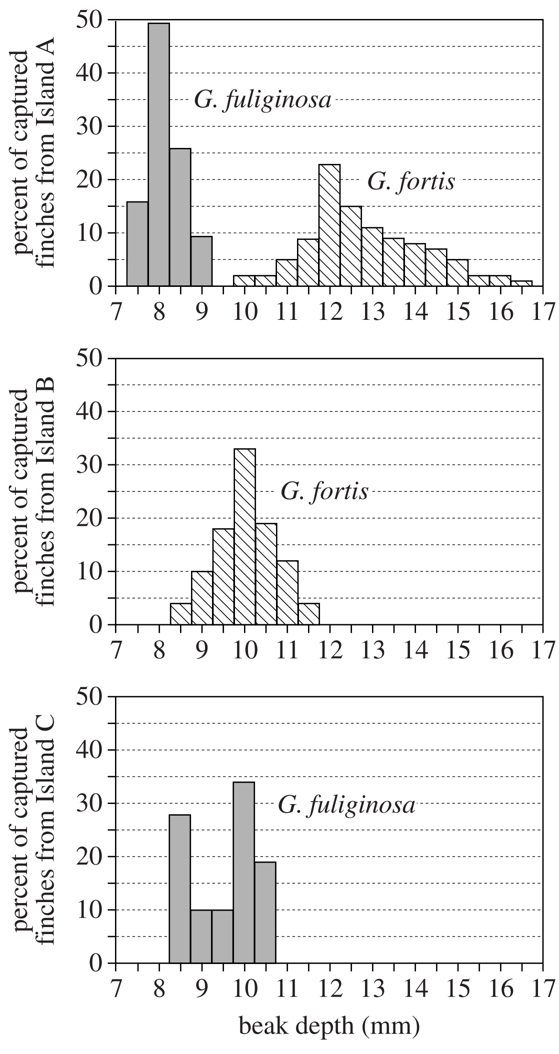


Figure 2

Study 2

After completing Study 1, the researchers returned to Island B each of the next 10 years, from 1976 to 1985. During each visit, the researchers captured at least 50 *G. fortis* finches and measured their beak depths. Then they calculated the average *G. fortis* beak depth for each of the 10 years. The researchers noted that, during the 10-year period, 3 years were exceptionally dry, and 1 year was very wet (see Figure 3). Small seeds are abundant during wet years. During dry years, all seeds are less abundant, and the average size of the available seeds is larger.

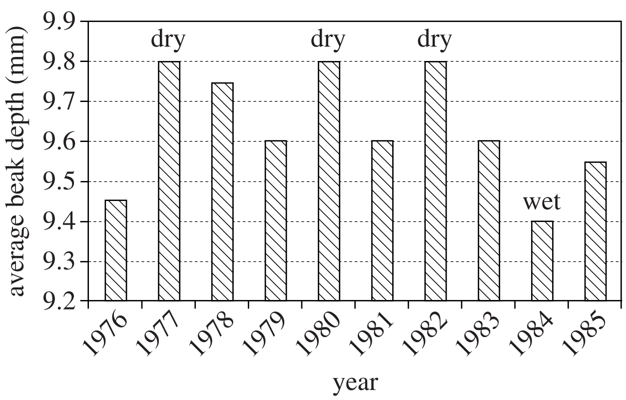


Figure 3

Figures adapted from Neil A. Campbell, Jane B. Reece, and Lawrence G. Mitchell, *Biology*, 5th ed. ©1999 by Benjamin/Cummings.

1. Based on the results of Study 1, the highest percent of finches on Island B and Island C had a beak depth of:

	Island B	Island C
A.	8 mm	8 mm
B.	9 mm	12 mm
C.	10 mm	8 mm
D.	10 mm	10 mm

2. During which of the following years were small seeds likely most abundant on Island B ?

   F. 1977
   G. 1980
   H. 1982
   J. 1984

3. Study 1 differed from Study 2 in which of the following ways?

   A. *G. fortis* finches were captured during Study 1 but not during Study 2.
   B. *G. fuliginosa* finches were captured during Study 1 but not during Study 2.
   C. The beak depth of captured birds was measured during Study 1 but not during Study 2.
   D. The beak depth of captured birds was measured during Study 2 but not during Study 1.

4. It is most likely that the researchers tagged the birds that they captured during Study 1 to:

   F. determine how beak depth was affected by rainfall on Island A.
   G. determine the average age of each finch population.
   H. ensure that the beak depth of each finch was measured multiple times during Study 1.
   J. ensure that the beak depth of each finch was measured only once during Study 1.

5. Based on the results of Study 2, would a finch with a beak depth of 9.4 mm or a finch with a beak depth of 9.9 mm more likely have had a greater chance of survival during 1977 ?

   A. A finch with a beak depth of 9.4 mm, because, on average, the size of available seeds is larger during dry years.
   B. A finch with a beak depth of 9.4 mm, because, on average, the size of available seeds is smaller during dry years.
   C. A finch with a beak depth of 9.9 mm, because, on average, the size of available seeds is larger during dry years.
   D. A finch with a beak depth of 9.9 mm, because, on average, the size of available seeds is smaller during dry years.

6. A researcher hypothesized that there would be more variation in the beak depths measured for the *G. fortis* finches when they were forced to compete with another finch species for seeds. Do the results of Study 1 support this hypothesis?

   F. Yes; the range of beak depths measured for *G. fortis* finches was greater on Island A than on Island B.
   G. Yes; the range of beak depths measured for *G. fortis* finches was greater on Island B than on Island A.
   H. No; the range of beak depths measured for *G. fortis* finches was greater on Island A than on Island B.
   J. No; the range of beak depths measured for *G. fortis* finches was greater on Island B than on Island A.

Passage II

Substances in the atmosphere, such as Cu^{2+}, Zn^{2+}, Cl^{-}, and SO_4^{2-} ions, are carried down to Earth's surface by precipitation. This process is known as *wet deposition*. Cu^{2+} and Zn^{2+} ions are put into the atmosphere by high-temperature combustion processes. The presence of Cl^{-} and SO_4^{2-} ions in the atmosphere can be attributed to road-salt dust and electrical power generation, respectively.

Study 1

A rain gauge, placed on the roof of a 1-story building, at a specific urban site was used to collect precipitation over a 12-month period. At the same time each evening, the amount of precipitation in the rain gauge was recorded, after which the collected precipitation was emptied from the gauge and stored. (Assume no measurable evaporation occurred during any day.) Figure 1 shows the measured monthly precipitation in centimeters.

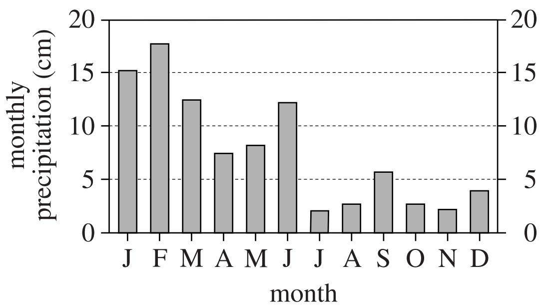


Figure 1

At the end of each month, all the samples collected during that month were mixed, and some of this combined sample was analyzed for the concentrations of Cu^{2+} and Zn^{2+} ions. Using these data, the monthly wet deposition of each substance, in micrograms (μg) per meter^2, was calculated (see Figure 2).

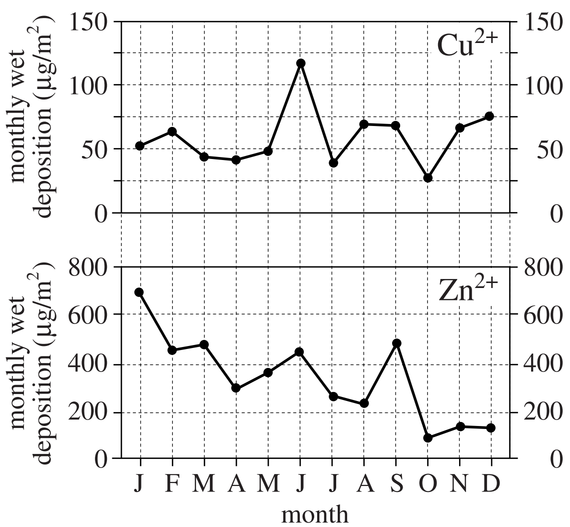


Figure 2

Study 2

Another portion of the combined sample for each month was analyzed for the concentrations of Cl^{-} and SO_4^{2-} ions. Using these data, the monthly wet deposition of each substance, in milliequivalents (meq) per m^2, was calculated (see Figure 3).

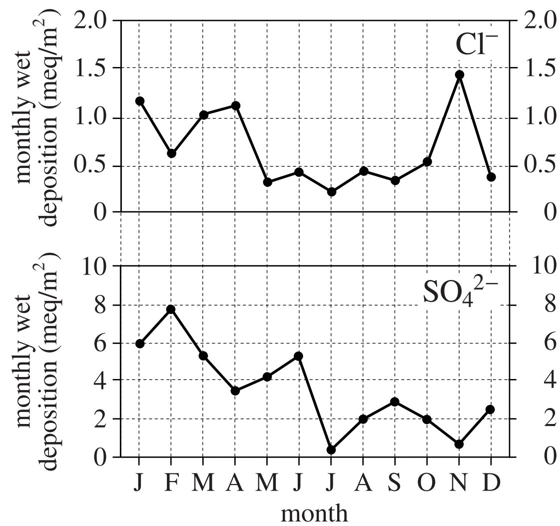


Figure 3

Study 3

The *annual* wet deposition of Cu^{2+} and of Zn^{2+} for the 12-month period, in μg/m^2, was calculated for the urban site (the source of the Cu^{2+} and Zn^{2+}) and also for Rural Sites 1 and 2, located 50 km and 100 km east, respectively, of the urban site (see Figure 4).

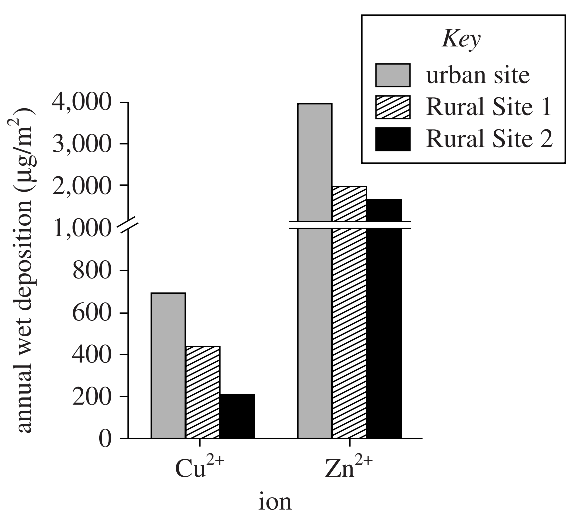


Figure 4

Figures adapted from Kathryn Conko et al., "Atmospheric Wet Deposition of Trace Elements to a Suburban Environment, Reston, Virginia, USA." ©2004 by Elsevier, Ltd.

7. According to Figure 1, over the 12-month period, the monthly precipitation at the urban site was maximum in February and minimum in July. According to Figures 2 and 3, the wet deposition of which ion was also maximum in February and minimum in July?

A. Cu^{2+}
B. Zn^{2+}
C. Cl^{-}
D. SO_4^{2-}

8. Based on the results of Study 1, the average monthly wet deposition for Cu^{2+} over the 12-month period was:

F. less than 50 $\mu g/m^2$.
G. between 50 $\mu g/m^2$ and 75 $\mu g/m^2$.
H. between 75 $\mu g/m^2$ and 100 $\mu g/m^2$.
J. greater than 100 $\mu g/m^2$.

9. Is the statement "The values for Cl^{-} wet deposition were greater during the winter and early spring when road salt is typically applied" supported by the results of Study 2 ?

A. Yes, because Cl^{-} wet deposition values were, on average, greater from November to April than they were from May to October.
B. Yes, because Cl^{-} wet deposition values were, on average, less from November to April than they were from May to October.
C. No, because Cl^{-} wet deposition values were, on average, greater from November to April than they were from May to October.
D. No, because Cl^{-} wet deposition values were, on average, less from November to April than they were from May to October.

10. Suppose there had been no precipitation during 1 entire month of the 12-month period. Based on the information provided, during that month there would have been:

F. significant wet deposition of all 4 substances.
G. significant wet deposition of Cu^{2+} and Zn^{2+}, but no wet deposition of Cl^{-} and SO_4^{2-}.
H. no wet deposition of any of the 4 substances.
J. no wet deposition of Cu^{2+} and Zn^{2+}, but significant wet deposition of Cl^{-} and SO_4^{2-}.

11. According to Study 3, as distance from the urban site increased, the annual wet deposition:

A. increased for both Cu^{2+} and Zn^{2+}.
B. increased for Cu^{2+} but decreased for Zn^{2+}.
C. decreased for both Cu^{2+} and Zn^{2+}.
D. remained the same for both Cu^{2+} and Zn^{2+}.

12. Which of the following variables was kept constant in Study 2 ?

F. Site
G. Monthly rainfall
H. Wet deposition of Zn^{2+}
J. Wet deposition of Cl^{-}

Passage III

Cloud cover is the percent of Earth's surface covered by clouds. Cloud cover may increase because of an increase in the *cosmic ray flux* (number of high-energy particles from space reaching Earth per m^2 per hour). Table 1 shows how Earth's cover of *low clouds* (0 km to 3.2 km altitude) varies with the cosmic ray flux. Figures 1–3 show the *relative cosmic ray flux*, RCRF (the percent below the flux measured on October 1, 1965), and the monthly average cover of *high clouds* (6.0 km to 16.0 km altitude), *middle clouds* (3.2 km to 6.0 km altitude), and low clouds, respectively, from January 1980 to January 1995.

Table 1

Cosmic ray flux (particles/m^2/hr)	Cover of low clouds (%)
340,000	27.8
360,000	28.1
380,000	28.4
400,000	28.7
420,000	29.0

Table 1 adapted from E. Palle Bagó and C. J. Butler, "The Influence of Cosmic Rays on Terrestrial Clouds and Global Warming." ©2000 by Institute of Physics Publications, Ltd.

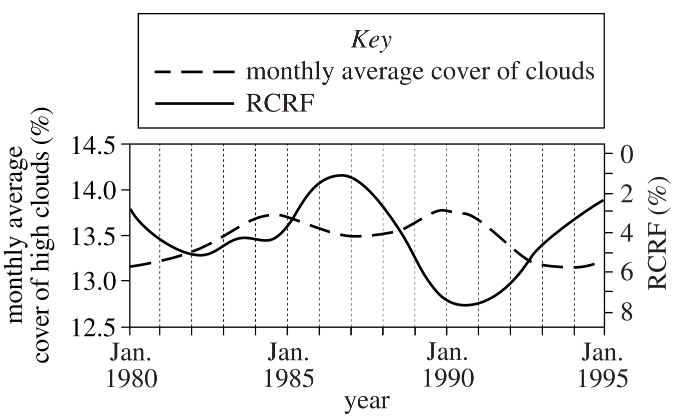


Figure 1

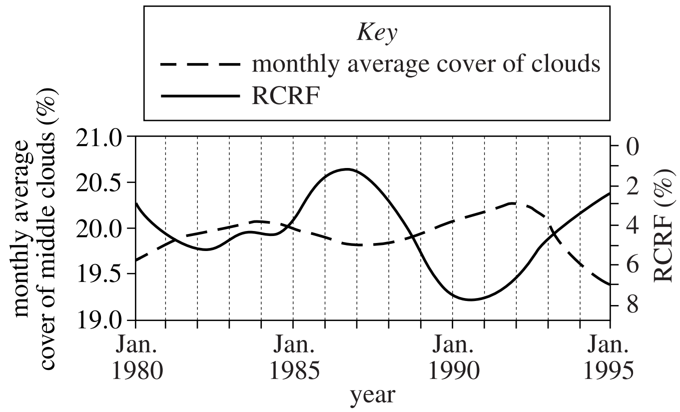


Figure 2

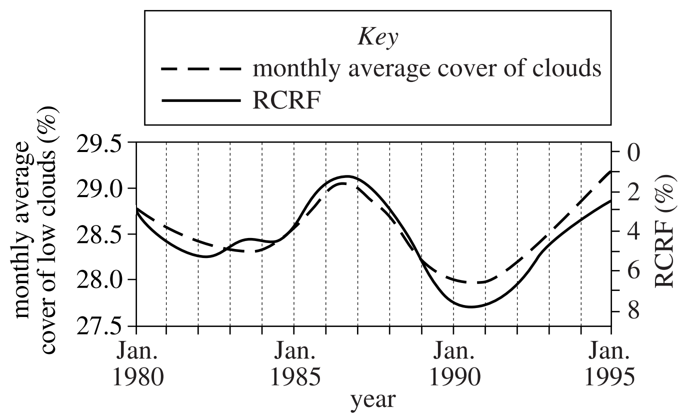


Figure 3

Figures adapted from Nigel Marsh and Henrik Svensmark, "Low Cloud Properties Influenced by Cosmic Rays." ©2000 by The American Physical Society.

13. The percent of Earth's surface covered by high clouds in January 1987 was closest to which of the following?

A. 13.0%
B. 13.5%
C. 14.0%
D. 14.5%

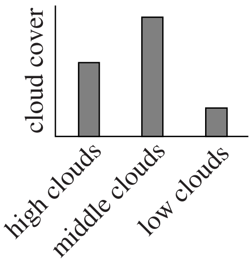
14. Based on Table 1, a cosmic ray flux of 440,000 particles/m^2/hr would correspond to a cover of low clouds that is closest to which of the following?

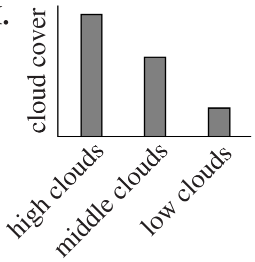
F. 28.7%
G. 29.0%
H. 29.3%
J. 29.6%

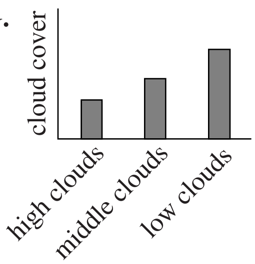
15. Is the statement "The monthly average cover of low clouds is more directly correlated with cosmic ray flux than is the monthly average cover of high clouds" consistent with Figures 1 and 3 ?

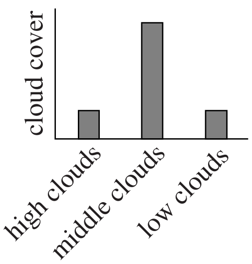
A. Yes, because the plot for the monthly average cover of low clouds more closely parallels the plot for RCRF.
B. Yes, because the plot for the monthly average cover of high clouds more closely parallels the plot for RCRF.
C. No, because the plot for the monthly average cover of low clouds more closely parallels the plot for RCRF.
D. No, because the plot for the monthly average cover of high clouds more closely parallels the plot for RCRF.

16. Which of the following figures best represents the monthly average cover of high, middle, and low clouds in January 1992 ?

F.


H.


G.


J.


17. High clouds are composed primarily of ice crystals, whereas low clouds are composed primarily of water droplets. This difference is most likely because the average air temperature at altitudes from:

A. 0 km to 3.2 km is at or below 0°C, whereas the average air temperature at altitudes from 3.2 km to 6.0 km is above 0°C.
B. 0 km to 3.2 km is at or below 0°C, whereas the average air temperature at altitudes from 6.0 km to 16.0 km is above 0°C.
C. 0 km to 3.2 km is above 0°C, whereas the average air temperature at altitudes from 3.2 km to 6.0 km is at or below 0°C.
D. 0 km to 3.2 km is above 0°C, whereas the average air temperature at altitudes from 6.0 km to 16.0 km is at or below 0°C.

Passage IV

Acid-base titration is a technique in which precise volumes of a *titrant* (an acid or base solution) are added incrementally to a known volume of a *sample solution* (a base or acid solution, respectively). This process can be monitored by adding an *acid-base indicator* (a substance that changes color over a certain pH range) to the sample solution or by measuring the sample solution's *conductivity*. Conductivity (measured in kilosiemens per centimeter, kS/cm) is a measure of a substance's ability to conduct electricity.

Two titration experiments were done at 25°C using a 0.10 M sodium hydroxide (NaOH) solution and either a 0.0010 M hydrochloric acid (HCl) solution or a 0.0010 M acetic acid solution (where M is moles of acid or base per liter of solution). All solutions were aqueous. An acid-base indicator solution of *nitrazine yellow* was also used. Nitrazine yellow is yellow if the pH is less than 6.0 or blue if the pH is greater than 7.0.

Experiment 1

A drop of nitrazine yellow solution was added to a flask containing 100.0 mL of the HCl solution. A probe that measures conductivity was placed in the solution. The NaOH solution was slowly added to the HCl solution in small increments. After each addition, the HCl solution was stirred and then the solution's color and conductivity were recorded (see Figure 1).

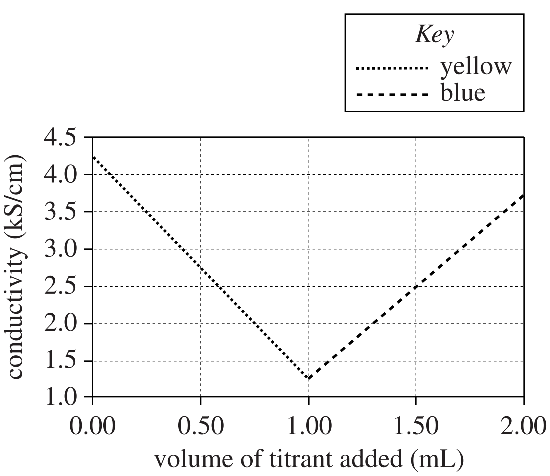


Figure 1

Experiment 2

Experiment 1 was repeated, except that the acetic acid solution was used instead of the HCl solution (see Figure 2).

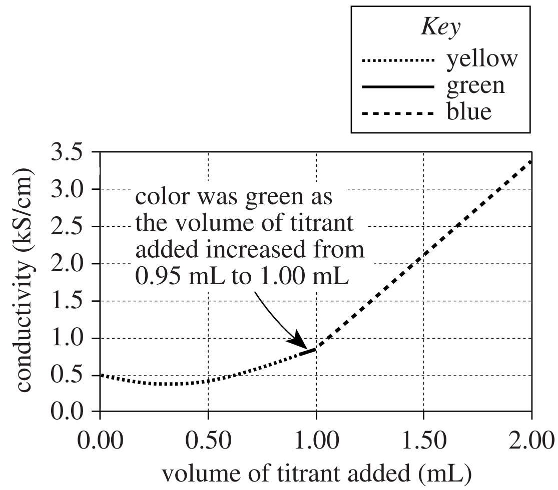


Figure 2

Figures adapted from J. West Loveland, "Conductance and Oscillometry," in Gary D. Christian and James E. O'Reilly, eds., *Instrumental Analysis*, 2nd ed. ©1986 by Allyn and Bacon, Inc.

18. In Experiment 1, the sample solution was yellow at which of the following values for the volume of titrant added?

F. 0.80 mL
G. 1.20 mL
H. 1.60 mL
J. 2.00 mL

19. In Experiment 2, the sample solution was neutral at which of the following values for the volume of titrant added?

A. 0.50 mL
B. 1.00 mL
C. 1.50 mL
D. 2.00 mL

20. In Experiment 1, if 2.30 mL of titrant had been added to the sample solution, the conductivity would most likely have been:

F. less than 0.80 kS/cm.
G. between 0.80 kS/cm and 2.30 kS/cm.
H. between 2.30 kS/cm and 3.80 kS/cm.
J. greater than 3.80 kS/cm.

Write your answers for #21-40 in the second column of your answer sheet

21. In Experiment 2, which solution was the titrant and which solution was the sample solution?

	titrant	sample solution
A.	acetic acid	NaOH
B.	HCl	NaOH
C.	NaOH	acetic acid
D.	NaOH	HCl

22. In Experiments 1 and 2, the probe that was placed in the sample solution most likely did which of the following?

F. Cooled the solution to its freezing point
G. Heated the solution to its boiling point
H. Detected the concentration of nitrazine yellow in the solution
J. Passed an electrical current through a portion of the solution

23. A chemist claimed that in Experiment 2, the pH of the sample solution was greater at a value of 0.2 mL of titrant added than at a value of 1.8 mL of titrant added. Do the results of Experiment 2 support this claim?

A. No; at a value of 0.2 mL of titrant added, the sample solution was yellow, and at a value of 1.8 mL of titrant added, the sample solution was blue.
B. No; at a value of 0.2 mL of titrant added, the sample solution was blue, and at a value of 1.8 mL of titrant added, the sample solution was yellow.
C. Yes; at a value of 0.2 mL of titrant added, the sample solution was yellow, and at a value of 1.8 mL of titrant added, the sample solution was blue.
D. Yes; at a value of 0.2 mL of titrant added, the sample solution was blue, and at a value of 1.8 mL of titrant added, the sample solution was yellow.

Passage V

An astronomy class is given the following facts about stellar evolution.

1. A star's evolution can be divided into 3 stages: *pre-main sequence* (pre-MS), *main sequence* (MS), and *post-main sequence* (post-MS).

2. Gravity causes part of a cloud of gas and dust to collapse and heat up, creating a pre-MS star. The star's hot dust and gas emit its energy.

3. A pre-MS star becomes an MS star when the star produces the majority of its energy by fusing hydrogen nuclei (protons) at its center to make helium nuclei.

4. An MS star becomes a post-MS star when the star expands in volume and produces the majority of its energy by fusing hydrogen to make helium in a shell surrounding its center.

5. The more massive a star, the more rapidly the star passes through each of the 3 stages of its evolution.

Two students discuss the evolution of the *Algol system*—Algol A, a 3.6-solar-mass MS star; Algol B, a 0.8-solar-mass post-MS star; and Algol C, a 1.7-solar-mass MS star. (One solar mass = the Sun's mass.) The 3 stars orbit a mutual center of mass, with Algol A and Algol B much closer to each other and to the center of mass than to Algol C.

Student 1

The 3 stars of the Algol system formed at the same time from the same cloud of gas and dust. Algol B, originally the most massive of the 3 stars, became a post-MS star and expanded in volume while Algol A remained an MS star. Because the matter in the outer parts of Algol B was more strongly attracted to Algol A than to the matter in the inner parts of Algol B, this matter flowed from Algol B to Algol A, and, over time, Algol A became more massive than Algol B.

Student 2

Algol B was not part of the original Algol system (Algol A and Algol C). Algol B and the original Algol system formed in different clouds of gas and dust at different times and moved in 2 different but intersecting orbits around the center of the galaxy. During a particular orbit, Algol B encountered the original Algol system at the intersection of the 2 orbits and became part of the Algol system.

Algol B became a post-MS star while Algol A and Algol C remained MS stars. Algol B never lost mass to Algol A. Algol B was always less massive than Algol A.

24. Based on Student 2's discussion, Algol B is part of the present Algol system because of which of the following forces exerted on Algol B by the original Algol system?

F. Electric force
G. Magnetic force
H. Gravitational force
J. Nuclear force

25. Based on Student 1's discussion and Fact 4, while matter flowed between Algol A and Algol B, Algol B produced the majority of its energy by fusing:

A. hydrogen nuclei to make helium nuclei at its center.
B. hydrogen nuclei to make helium nuclei in a shell surrounding its center.
C. helium nuclei to make hydrogen nuclei at its center.
D. helium nuclei to make hydrogen nuclei in a shell surrounding its center.

26. Suppose that chemical composition is uniform among stars formed from the same cloud of gas and dust, but that chemical composition varies among stars formed from different clouds of gas and dust. Student 2 would most likely agree with which of the following statements comparing the chemical compositions of the stars in the present-day Algol system at the time they formed?

F. Algol A and Algol B had the most similar compositions.
G. Algol A and Algol C had the most similar compositions.
H. Algol B and Algol C had the most similar compositions.
J. Algol A, Algol B, and Algol C had the same composition.

27. If the mass of the Sun is 2.0×10^{30} kg, what is the mass of Algol C ?

A. 1.6×10^{30} kg
B. 2.0×10^{30} kg
C. 3.4×10^{30} kg
D. 7.2×10^{30} kg

28. Which of the following statements best explains why the reaction described in Fact 3 requires a high temperature and pressure?

F. All protons are positively charged, and like charges attract each other.
G. All protons are positively charged, and like charges repel each other.
H. All electrons are negatively charged, and like charges attract each other.
J. All electrons are negatively charged, and like charges repel each other.

29. Based on Fact 5 and Student 1's discussion, which of the 3 stars in the Algol system, if any, was most likely the first to become an MS star?

A. Algol A
B. Algol B
C. Algol C
D. The 3 stars became MS stars at the same time.

30. Based on Fact 5, would Student 2 agree that by the time Algol A stops being an MS star, Algol A will have spent as much time being an MS star as Algol B spent being an MS star?

F. Yes, because according to Student 2, Algol A has always been more massive than Algol B.
G. Yes, because according to Student 2, Algol A has always been less massive than Algol B.
H. No, because according to Student 2, Algol A has always been more massive than Algol B.
J. No, because according to Student 2, Algol A has always been less massive than Algol B.

Passage VI

Three experiments were done using CO_2, krypton (Kr), or O_2. For each gas:

1. A 3 L steel vessel was fitted with a cap that contained a gas inlet valve and a pressure and temperature sensor.
2. Air was pumped out of the vessel until the pressure measured 0.00 torr.
3. The vessel was placed on a balance, and the balance was reset to 0.000 g.
4. Some of the gas was added to the vessel.
5. When the gas in the vessel reached room temperature (22°C), mass and pressure were recorded.
6. Steps 4 and 5 were repeated several times.

The experiments were then repeated, except that a 6 L vessel was used (see Figures 1 and 2).

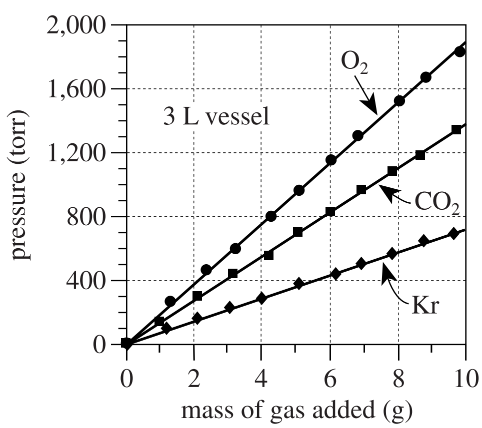


Figure 1

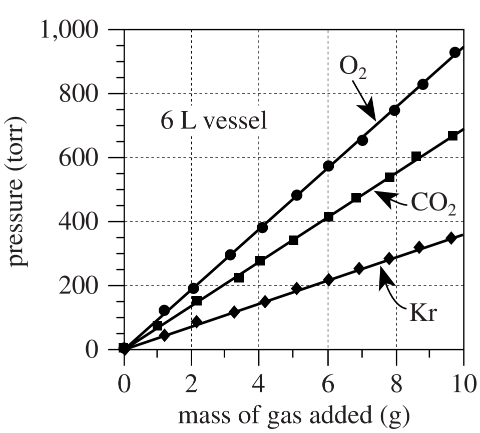


Figure 2

31. Based on Figure 2, if 13 g of Kr had been added to the 6 L vessel, the pressure would have been:

A. less than 200 torr.
B. between 200 torr and 400 torr.
C. between 400 torr and 600 torr.
D. greater than 600 torr.

32. Suppose the experiments had been repeated, except with a 5 L vessel. Based on Figures 1 and 2, the pressure exerted by 7 g of CO_2 would most likely have been:

F. less than 500 torr.
G. between 500 torr and 1,000 torr.
H. between 1,000 torr and 1,500 torr.
J. greater than 1,500 torr.

33. Based on Figures 1 and 2, for a given mass of O_2 at 22°C, how does the pressure exerted by the O_2 in a 6 L vessel compare to the pressure exerted by the O_2 in a 3 L vessel? In the 6 L vessel, the O_2 pressure will be:

A. $\frac{1}{2}$ as great as in the 3 L vessel.
B. the same as in the 3 L vessel.
C. 2 times as great as in the 3 L vessel.
D. 4 times as great as in the 3 L vessel.

34. Which of the following best explains why equal masses of O_2 and CO_2 at the same temperature and in the same-size vessel had different pressures? The pressure exerted by the O_2 was:

F. less, because there were fewer O_2 molecules per gram than there were CO_2 molecules per gram.
G. less, because there were more O_2 molecules per gram than there were CO_2 molecules per gram.
H. greater, because there were fewer O_2 molecules per gram than there were CO_2 molecules per gram.
J. greater, because there were more O_2 molecules per gram than there were CO_2 molecules per gram.

35. Suppose the experiment involving O_2 and the 6 L vessel had been repeated, except at a room temperature of 14°C. For a given mass of O_2, compared to the pressure measured in the original experiment, the pressure measured at 14°C would have been:

A. less, because pressure is directly proportional to temperature.
B. less, because pressure is inversely proportional to temperature.
C. greater, because pressure is directly proportional to temperature.
D. greater, because pressure is inversely proportional to temperature.

Passage VII

The *human threshold of hearing* is the minimum intensity at each sound frequency required for a sound to be heard by humans. The *human threshold of pain* is the maximum intensity at each sound frequency that humans can tolerate without pain.

The figure below displays, for sounds in water and in air, the human thresholds of hearing and of pain. The figure also shows S, the percent increase in air density and water density that accompanies the compression of air and water by sound waves of given intensities. Sound intensities are given in decibels (db) and frequencies are given in hertz [(Hz); 1 Hz = 1 cycle/sec].

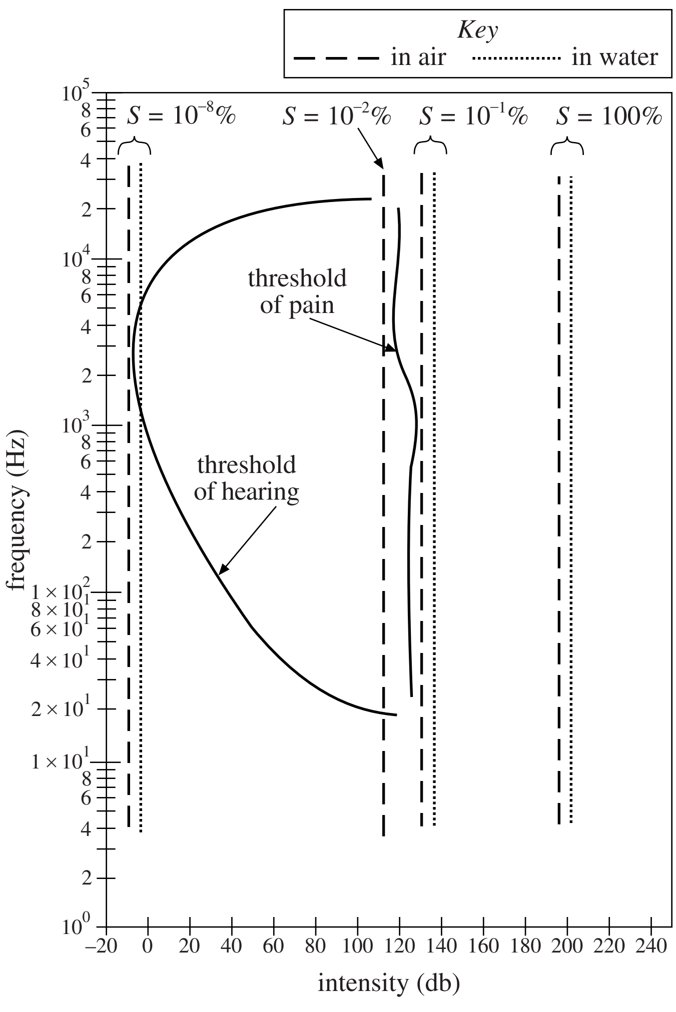
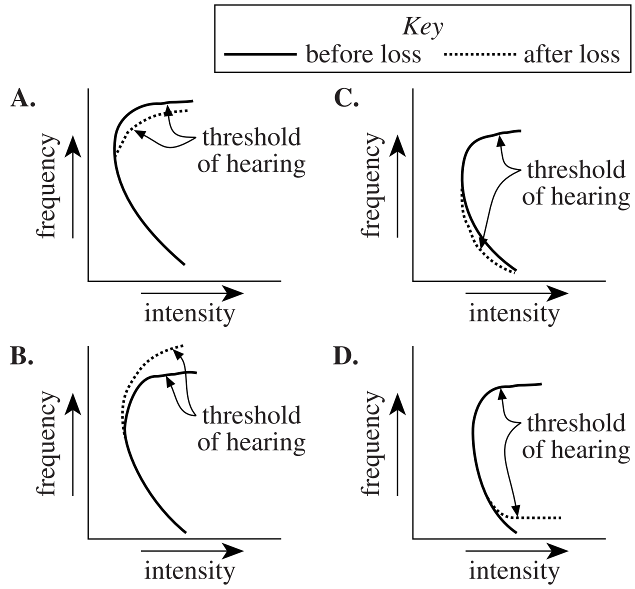


Figure adapted from Rita G. Lerner and George L. Trigg, eds., *Encyclopedia of Physics*, 2nd ed. ©1991 by VCH Publishers, Inc.

36. According to the figure, which of the following is closest to the lowest frequency that can be heard by a human being?

F. 8 Hz
G. 20 Hz
H. 1,000 Hz
J. 20,000 Hz

37. As humans age, it is common for selective hearing loss to occur at high sound frequencies. Which of the following figures best illustrates this loss?



38. Based on the figure, a sound of a given frequency will have the highest intensity for which of the following sets of conditions?

	Sound is passing through:	S
F.	water	100%
G.	water	10^{-8}%
H.	air	100%
J.	air	10^{-8}%

39. A student hypothesized that sounds of any intensity at a frequency of 10^5 Hz would be painful for humans to hear. Do the data in the figure support this hypothesis?

A. Yes, because the threshold of pain is relatively constant with changes in frequency.
B. Yes, because as frequency increases above 10^5 Hz, the threshold of pain increases.
C. No, because humans cannot hear sounds at 10^5 Hz.
D. No, because the threshold of pain is relatively constant with changes in frequency.

40. Based on the figure, does S depend on the frequency of a sound wave of a given intensity?

F. Yes, because as frequency increases, S increases.
G. Yes, because as frequency increases, S remains constant.
H. No, because as frequency increases, S increases.
J. No, because as frequency increases, S remains constant.

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.

[See Note on page 52.]