SCIENCE TEST

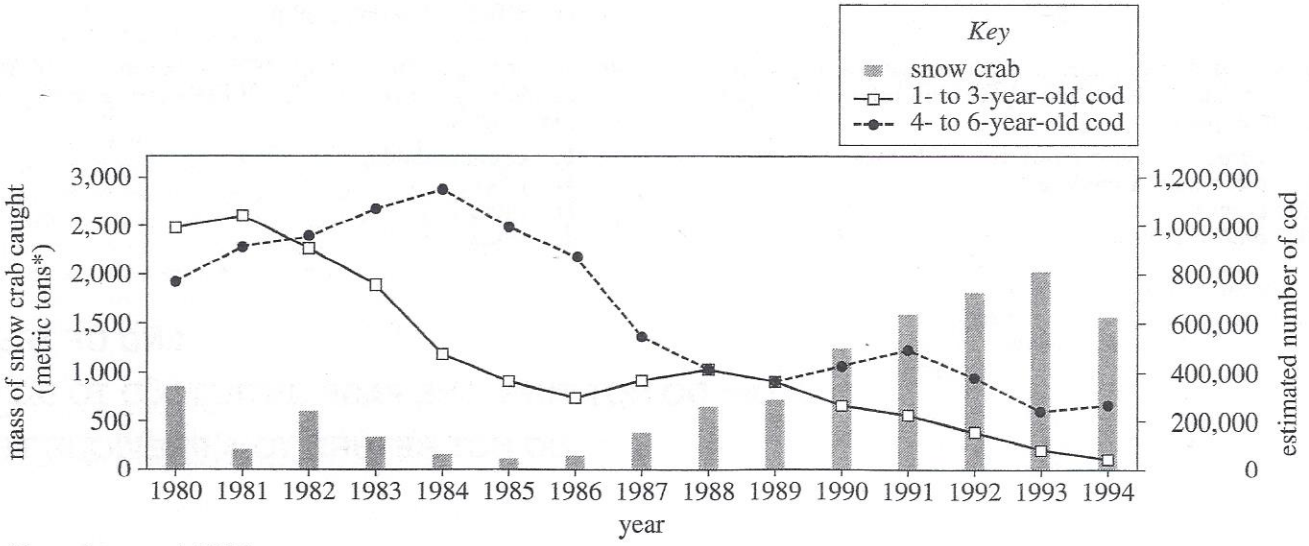
35 Minutes—40 Questions

DIRECTIONS: There are seven 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

Snow crab (*Chionoecetes opilio*) is a subarctic species of crab that is commercially fished in the Atlantic Ocean. Because snow crab are eaten by fish such as cod, the number of cod present in an area may affect snow crab populations. The figure below shows the mass of snow crab caught on the eastern Scotian Shelf in the Atlantic Ocean each year from 1980 through 1994. The figure also shows, for the same area, the estimated number of 1- to 3-year-old cod and the estimated number of 4- to 6-year-old cod present each year from 1980 through 1994.



*1 metric ton = 1,000 kg

Figure adapted from M. J. Tremblay, "Snow Crab (*Chionoecetes opilio*) Distribution Limits and Abundance Trends on the Scotian Shelf." ©1997 by Journal of Northwest Atlantic Fishery Science.

1. According to the figure, the estimated number of 1- to 3-year-old cod present in 1980 was approximately:

   A. 100,000.
   B. 200,000.
   C. 600,000.
   D. 1,000,000.

2. According to the figure, when the estimated number of 1- to 3-year-old cod was the greatest, the number of metric tons of snow crab caught was closest to which of the following values?

   F. 200
   G. 500
   H. 800
   J. 1,500

3. In the relationship between cod and snow crab described in the passage, are the cod the predators or are they the prey?

   A. Predators, because the cod eat the snow crab.
   B. Predators, because the cod are eaten by the snow crab.
   C. Prey, because the cod eat the snow crab.
   D. Prey, because the cod are eaten by the snow crab.

4. Consider the statement "When the total estimated number of cod (including both 1- to 3-year-old cod and 4- to 6-year-old cod) was relatively high, the mass of snow crab caught was relatively low." Are the data in the figure for 1984 through 1986 and for 1992 through 1994 consistent with this statement?

   F. Yes; from 1984 through 1986 the mass of snow crab caught was relatively low compared to the mass of snow crab caught from 1992 through 1994.
   G. Yes; from 1984 through 1986 the mass of snow crab caught was relatively high compared to the mass of snow crab caught from 1992 through 1994.
   H. No; from 1984 through 1986 the mass of snow crab caught was relatively low compared to the mass of snow crab caught from 1992 through 1994.
   J. No; from 1984 through 1986 the mass of snow crab caught was relatively high compared to the mass of snow crab caught from 1992 through 1994.

5. Based on the figure, the mass of snow crab caught was closest to *500,000 kg* in which of the following years?

   A. 1980
   B. 1987
   C. 1991
   D. 1994

Passage II

Bone mineral density (BMD) is an indicator of overall bone health. Low BMD increases the risk for bone fracture. Scientists have determined that BMD is linked to dietary intake. Two studies, one with humans and one with rats, examined the effect of caffeinated cola consumption on BMD.

Study 1

A food-and-drink questionnaire was given to 1,413 adult women who had an average age of 58.2 yr. Each woman was assigned to 1 of 5 groups according to her caffeinated cola consumption. The average BMD for each group is shown in Figure 1.

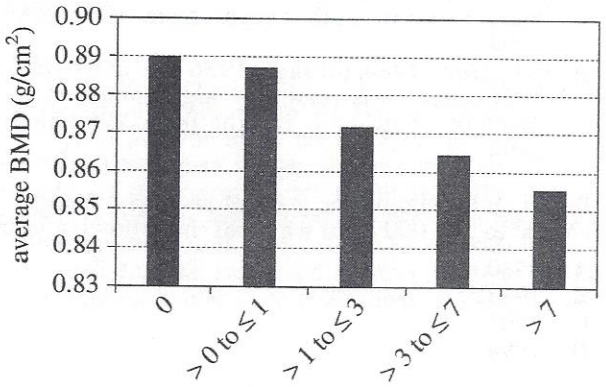
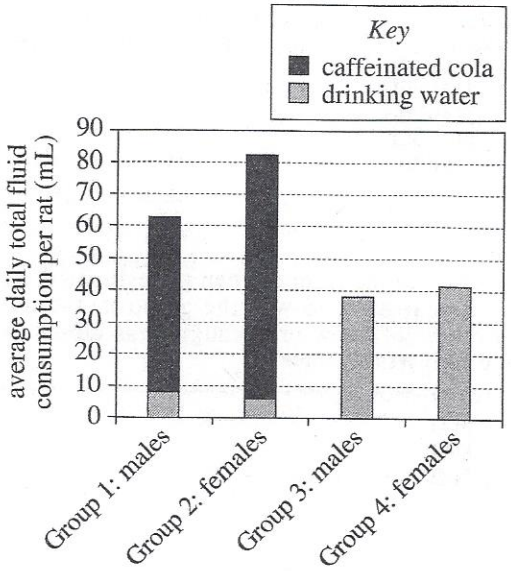


Figure 1

Figure 1 adapted from Katherine L. Tucker et al., "Colas, but Not Other Carbonated Beverages, Are Associated with Low Bone Mineral Density in Older Women: The Framingham Osteoporosis Study." ©2006 by American Society for Nutrition.

Study 2

Thirty 10-week-old rats were divided into 4 groups: Groups 1 and 2 consisted of 10 male and 10 female rats, respectively; Groups 3 and 4 consisted of 5 male and 5 female rats, respectively. Each rat in Groups 1 and 2 was provided with unlimited supplies of a solid rat food, drinking water, and caffeinated cola for 30 days. Each rat in Groups 3 and 4 was provided with unlimited supplies of the rat food and drinking water, but no cola, for 30 days. Figure 2 shows, for each group, the average daily caffeinated cola consumption per rat, the average daily drinking water consumption per rat, and the average daily total fluid consumption per rat.



Note: Bars are stacked.

Figure 2

Figure 3 shows, for each group, the average BMD on Day 30.

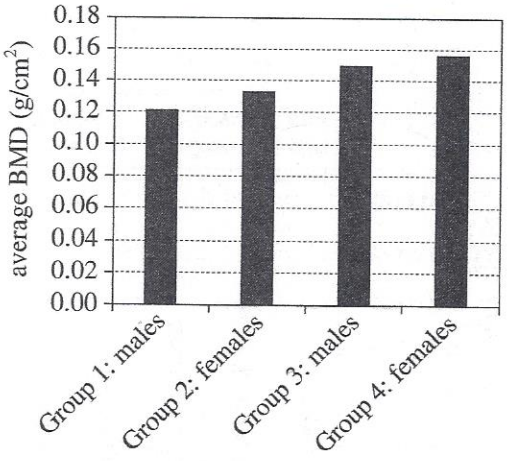


Figure 3

Figures 2 and 3 adapted from Recai Ogur et al., "Evaluation of the Effect of Cola Drinks on Bone Mineral Density and Associated Factors." ©2007 by Nordic Pharmacological Society.

6. Based on the results of Study 2, on average, did male rats or did female rats consume more caffeinated cola per day?

   F. Female rats; Group 1 rats, on average, consumed more caffeinated cola per day than did the Group 2 rats.
   G. Female rats; Group 2 rats, on average, consumed more caffeinated cola per day than did the Group 1 rats.
   H. Male rats; Group 1 rats, on average, consumed more caffeinated cola per day than did the Group 2 rats.
   J. Male rats; Group 2 rats, on average, consumed more caffeinated cola per day than did the Group 1 rats.

7. Which 2 groups of rats served as the control groups in Study 2 ?

   A. Group 1 and Group 2
   B. Group 1 and Group 3
   C. Group 2 and Group 4
   D. Group 3 and Group 4

8. In Study 2, the average daily total fluid consumption per rat for Group 4 was approximately half that of the average daily total fluid consumption per rat for Group 2. Which of the following statements gives the most likely reason for this difference?

   F. There were half as many rats in Group 2 as were in Group 4.
   G. There were half as many rats in Group 4 as were in Group 2.
   H. The average daily total fluid consumption per rat was higher for Group 2 rats because they preferred cola over water.
   J. The average daily total fluid consumption per rat was lower for Group 4 rats because they were provided cola, and rats do not consume cola.

9. In Study 1, the greatest number of women were assigned to the group that consumed how many servings of caffeinated cola per week?

   A. > 0 to ≤ 1 servings
   B. > 1 to ≤ 3 servings
   C. > 7 servings
   D. Cannot be determined from the given information

10. The BMDs of the subjects in Studies 1 and 2 were determined by scans of their hip bones. Based on Figures 1 and 3, was the average BMD for any group of rats greater than or less than the average BMD for any group of women?

    F. Greater; a rat's hip bone is less dense than is a woman's hip bone.
    G. Greater; a rat's hip bone is more dense than is a woman's hip bone.
    H. Less; a rat's hip bone is less dense than is a woman's hip bone.
    J. Less; a rat's hip bone is more dense than is a woman's hip bone.

11. Consider the statement "It is possible that average BMD differed among the groups in the study partly because the subjects in the study ate different types of solid food." This statement applies to which of the studies, if either?

    A. Study 1 only
    B. Study 2 only
    C. Both Study 1 and Study 2
    D. Neither Study 1 nor Study 2

Passage III

In an experiment to study the effect of circulation on ice formation in water, 2 identical insulated containers without lids (Tank X and Tank Y) were each fitted with 2 thermometers as shown in Figure 1. A pump was mounted on the base of Tank X. Each tank was filled with 20 L of 14°C water. Both filled tanks were then placed in a temperature-controlled freezer set to −12°C, and the pump was switched on, circulating the water in Tank X. The temperature from each thermometer was recorded every hour for 30 hours (see Figures 2 and 3).

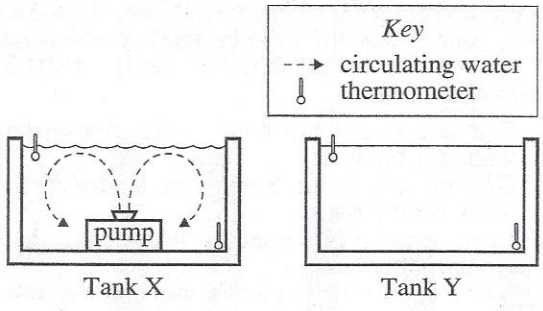


Figure 1

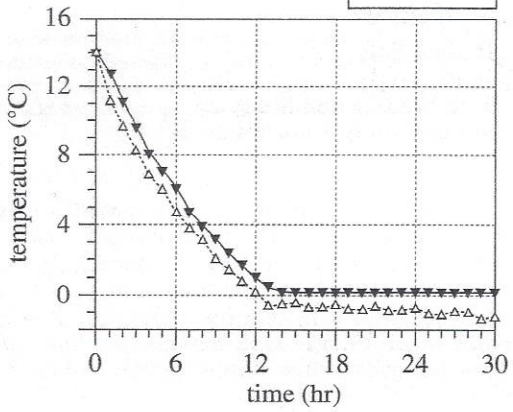


Figure 2

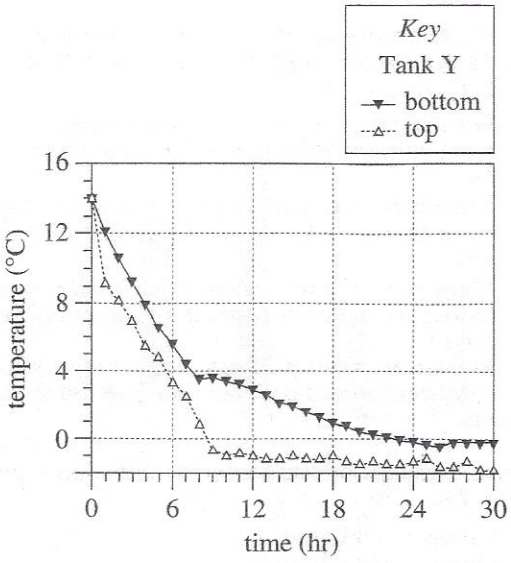


Figure 3

Figures 2 and 3 adapted from T. Moreau, R. Lamontagne, and D. Letzring, "How Circulation of Water Affects Freezing in Ponds." ©2007 by the American Association of Physics Teachers.

12. Over the 30 hr of the experiment, the temperature of the water at the bottom of Tank X:

- **F.** increased, then fluctuated up and down.
- **G.** decreased, then fluctuated up and down.
- **H.** increased, then remained constant.
- **J.** decreased, then remained constant.

13. Compared to the water at the top of Tank Y, the water at the bottom of Tank Y took approximately how many more hours, or how many fewer hours, to reach 0°C ?

- **A.** 10 fewer hours
- **B.** 24 fewer hours
- **C.** 15 more hours
- **D.** 30 more hours

14. Two streams, Stream A and Stream B, are identical in all respects, except that water flows rapidly in Stream A but is nearly at rest in Stream B. Based on the results of the experiment, during a prolonged period of −5°C weather, water at the top of which stream is *less* likely to begin freezing first, and why?

F. Stream A, because Figures 2 and 3 indicate that turbulent water freezes more slowly than does water at rest.
G. Stream A, because Figures 2 and 3 indicate that turbulent water freezes more quickly than does water at rest.
H. Stream B, because Figures 2 and 3 indicate that turbulent water freezes more slowly than does water at rest.
J. Stream B, because Figures 2 and 3 indicate that turbulent water freezes more quickly than does water at rest.

15. Suppose that Tank Y had been covered throughout the experiment with a lid made of the same insulating material, and having the same thickness, as the walls and base of the tank. At 2 hr, the temperature of the water at the top of Tank Y would most likely have been:

A. less than or equal to 8°C.
B. greater than 8°C, but less than or equal to 14°C.
C. greater than 14°C, but less than or equal to 16°C.
D. greater than 16°C.

16. Suppose both tanks were left in the freezer until the H_2O in each reached thermal equilibrium with the air in the freezer. Based on the passage, the temperature of the H_2O in each tank would most likely have been:

F. 0°C.
G. −2°C.
H. −12°C.
J. −14°C.

Passage IV

Four 1800s scientists provide different gas models that attempt to explain what happens when a gas is released into an evacuated container and what happens when a gas in a closed container of fixed volume is heated.

Scientist 1

A gas is composed of small particles that repel each other. The particles are bound together in a 3-dimensional lattice, but are never in contact with each other. If a gas is released into an evacuated container, the particles in the lattice will move apart from each other until the gas completely fills the container, then stop moving. Thus, the particles can move only if the size of their container changes.

If a gas in a closed container of fixed volume is heated, the repulsive forces between particles will increase. This cannot change the distance between the particles in the gas lattice, but does cause the lattice to push harder against the container, and thus increases the pressure.

Scientist 2

Scientist 1's model is correct with only one exception. If a gas in a closed container of fixed volume is heated, the repulsive force between particles will decrease, causing the gas lattice to push less hard against the container.

Scientist 3

A gas is composed of small particles that repel each other. The particles are not bound to each other and are in constant, random motion. If a gas is released into an evacuated container, the random motion will cause the gas to spread out to fill the container. If gas particles are on path to collide, the repulsive force between the particles will push each particle into a new path. Thus, gas particles never collide.

If a gas in a closed container of fixed volume is heated, the speed of the gas particles will increase. Therefore, the number of particles colliding with the walls of the container will increase, which will cause the pressure to increase. Increasing the temperature has no effect on the repulsive force.

Scientist 4

Scientist 3's model is correct, except that gas particles do not repel each other. (Nor do they attract each other.) Thus, gas particles can collide with each other. When they do collide, the collisions are *elastic* because no energy is lost during the collision.

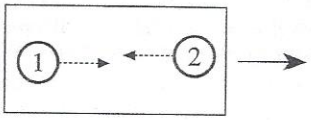
17. Which of the scientists, if any, claimed that gas particles are attracted to each other?

A. Scientist 2 only
B. Scientist 4 only
C. All of the scientists
D. None of the scientists

18. Which scientist would be most likely to predict that heating the air inside a sealed balloon will cause the balloon to *decrease* in size?

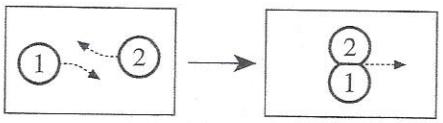
F. Scientist 1
G. Scientist 2
H. Scientist 3
J. Scientist 4

19. Gas Particles 1 and 2 are moving straight toward each other, as indicated by the dotted arrows in the diagram shown below:

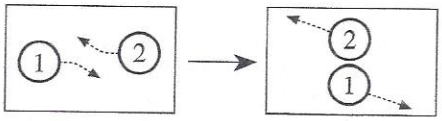


Based on Scientist 3's model, which of the following diagrams best shows, in sequence, how these particles will behave as they continue in motion?

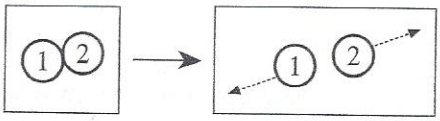
A.



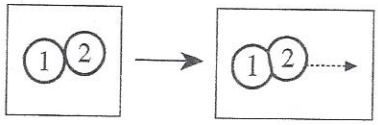
B.



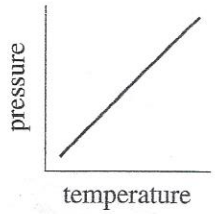
C.



D.



20. Consider the graph shown below of pressure versus temperature for a gas in a closed container of fixed volume:



This graph is consistent with the model(s) provided by which of the scientists?

F. Scientist 2 only
G. Scientists 3 and 4 only
H. Scientists 1, 3, and 4 only
J. Scientists 1, 2, 3, and 4

21. Tank A contains 5 g of helium (He) and Tank B contains 10 g of He. The temperature of the gas in each tank is 25°C, and the tanks have the same volume. Would Scientist 4 more likely predict that the pressure would be greater in Tank A or in Tank B ?

A. Tank A, because more He atoms would be striking the walls of Tank A.
B. Tank A, because the greater number of He atoms in Tank A would produce the greater repulsive force between the He atoms in the gas lattice.
C. Tank B, because more He atoms would be striking the walls of Tank B.
D. Tank B, because the greater number of He atoms in Tank B would produce the greater repulsive force between the He atoms in the gas lattice.

22. Which of the scientists would agree with the statement "If a gas is kept at a constant volume and temperature, the gas molecules will have no motion"?

F. Scientist 1 only
G. Scientists 1 and 2 only
H. Scientists 3 and 4 only
J. Scientists 1, 2, 3, and 4

23. Science textbooks describe gases according to a model called the *kinetic theory of gases*. The kinetic theory of gases is most consistent with the model provided by which scientist?

A. Scientist 1
B. Scientist 2
C. Scientist 3
D. Scientist 4

Passage V

To treat water for drinking, *ozone* (O_3) gas can be bubbled through the water to kill bacteria and viruses. This process is called *ozonation*. When *bromide ions*, Br^-, are present in the water, O_3 reacts with the Br^- to produce *bromate ions*, BrO_3^-. In drinking water, a BrO_3^- concentration at or above 10 micrograms per liter (µg/L) is considered unsafe.

Three studies examined how initial Br^- concentration, *contact time* (the amount of time O_3 has been bubbled through the water), pH, and the addition of ammonia affected BrO_3^- formation during ozonation of 25°C water from a particular source. Each water sample was buffered to maintain a constant pH during ozonation.

Study 1

Three 1 L water samples were prepared, all having the same pH but each having a different initial Br^- concentration: 50 µg/L, 200 µg/L, or 500 µg/L. Each sample was then placed in a separate 2 L container and ozonated at a rate of 10 L O_3/hr for 30 min. At various times during ozonation, a small volume of water was removed from each container and analyzed for BrO_3^- (see Figure 1).

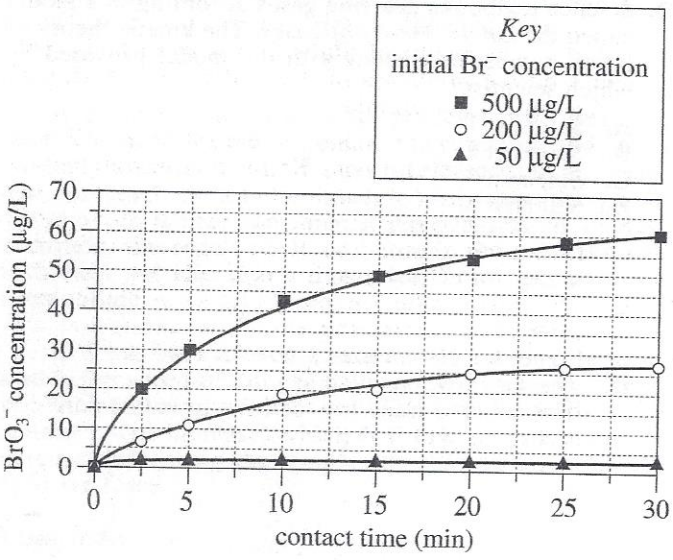


Figure 1

Study 2

Three 1 L water samples were prepared, all having an initial Br^- concentration of 200 µg/L but each having a different pH: 8.4, 7.0, or 6.4. Each sample was then ozonated and analyzed as in Study 1 (see Figure 2).

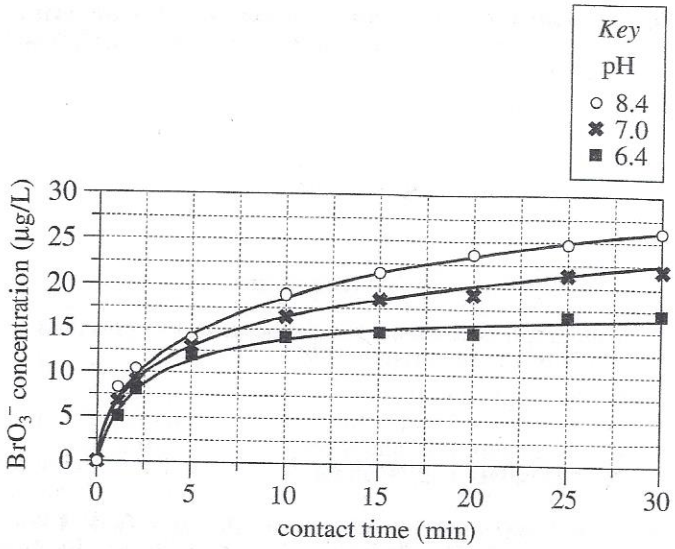


Figure 2

Study 3

Two 1 L water samples were prepared, both having an initial Br^- concentration of 200 µg/L and a pH of 8.4. Ten mL of ammonia solution having a concentration of 0.2 mg/L was added to one sample. No ammonia was added to the other sample. Each sample was then ozonated and analyzed as in Study 1 (see Figure 3).

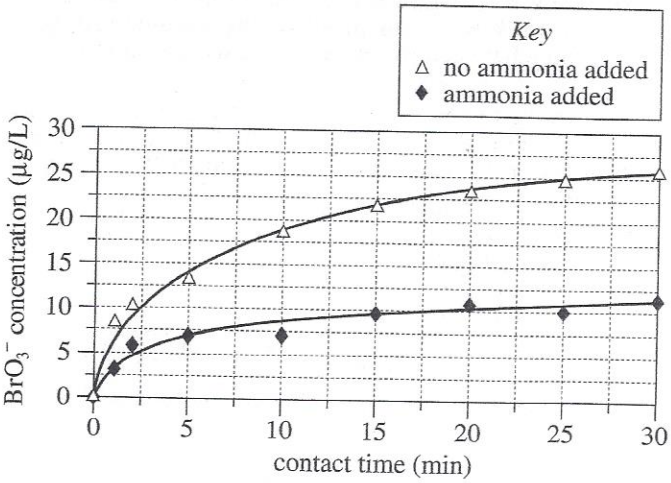


Figure 3

Figures adapted from J. P. Croué, B. K. Koudjonou, and B. Legube, "Parameters Affecting the Formation of Bromate Ion During Ozonation." ©1996 by the International Ozone Association.

24. According to the results of Study 1, for an initial Br^- concentration of 200 μg/L or 500 μg/L, as contact time increased, BrO_3^- concentration:

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

25. Suppose that in Study 1 a 1 L water sample having an initial Br^- concentration of 350 μg/L and the same pH as the other 3 samples had also been tested. At a contact time of 15 min, the BrO_3^- concentration for this sample would most likely have been:

A. less than 5 μg/L.
B. between 5 μg/L and 20 μg/L.
C. between 20 μg/L and 50 μg/L.
D. greater than 50 μg/L.

26. According to the results of Studies 1–3, from 5 min until 30 min, how often was a small volume of water removed from each container for analysis?

F. Every 1 min
G. Every 2 min
H. Every 5 min
J. Every 10 min

27. According to the results of Study 3, for contact times after 0 min, how did the addition of ammonia to the water sample affect the production of BrO_3^-, if at all?

A. At all times after 0 min, the BrO_3^- concentration was less with ammonia added than it was with no ammonia added.
B. At all times after 0 min, the BrO_3^- concentration was the same with ammonia added as it was with no ammonia added.
C. At all times after 0 min, the BrO_3^- concentration was greater with ammonia added than it was with no ammonia added.
D. At some of the times after 0 min, the BrO_3^- concentration was greater with ammonia added than it was with no ammonia added; at the other times after 0 min, the BrO_3^- concentration was less with ammonia added than it was with no ammonia added.

28. What variable had the same value for all the water samples in Study 1 but did not have the same value for all the water samples in Study 2 ?

F. Initial Br^- concentration
G. BrO_3^- concentration
H. Water temperature
J. pH

29. Based on the results of Study 2, was more BrO_3^- produced during ozonation of the acidic water sample or of the basic water sample?

A. The acidic water sample, because at any contact time after 0 min, the BrO_3^- concentration was higher for pH 6.4 than it was for pH 8.4.
B. The acidic water sample, because at any contact time after 0 min, the BrO_3^- concentration was higher for pH 8.4 than it was for pH 6.4.
C. The basic water sample, because at any contact time after 0 min, the BrO_3^- concentration was higher for pH 6.4 than it was for pH 8.4.
D. The basic water sample, because at any contact time after 0 min, the BrO_3^- concentration was higher for pH 8.4 than it was for pH 6.4.

Passage VI

A star's brightness is described by its *magnitude*. As magnitude increases, brightness *decreases*. A star's *apparent magnitude* is measured from Earth. A star's *absolute magnitude* is the magnitude that would be measured 10 *parsecs* from the star (1 parsec [pc] = 3.1×10^{16} m). V represents the apparent magnitude of a star's visible light. M_V and M_B represent the absolute magnitudes of a star's visible light and blue light, respectively.

Table 1 lists V, M_V, $V - M_V$, and $M_B - M_V$ for particular stars in each of 4 hypothetical star clusters (SCs). Figure 1 shows SC age versus $M_B - M_V$. Figure 2 shows SC distance from Earth versus $V - M_V$. Table 2 lists a star's power output of visible light for a given M_V.

Table 1

SC	V	M_V	$V - M_V$	$M_B - M_V$
I	10.5	1.5	9.0	0.00
II	11.8	−2.1	13.9	−0.25
III	12.1	2.1	10.0	0.15
IV	15.3	2.8	10.5	0.30

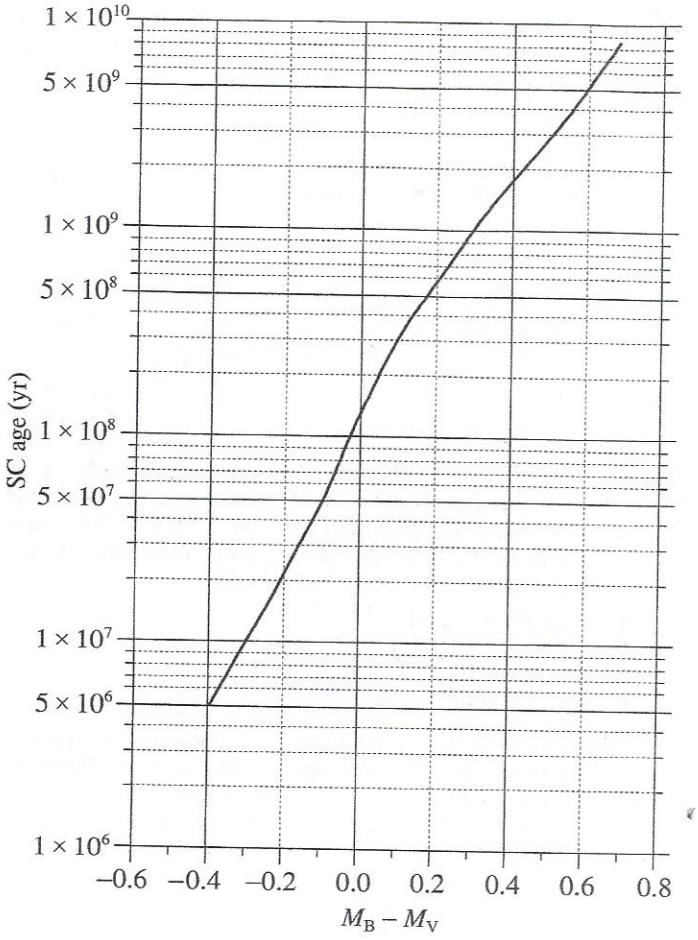


Figure 1

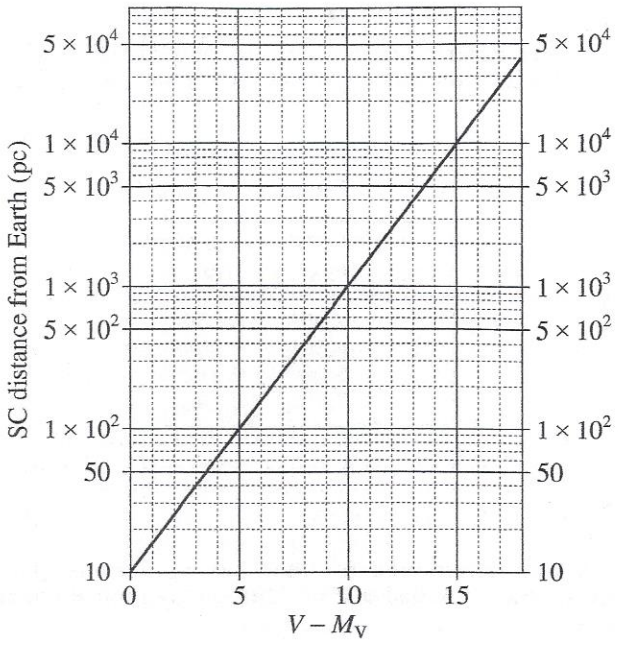


Figure 2

Figures adapted from Darrel B. Hoff, Linda J. Kelsey, and John S. Neff, *Activities in Astronomy*, 2nd ed. ©1984 by Kendall/Hunt Publishing Company.

Table 2

M_V	Power output (W*)
−3.0	5.0×10^{29}
−2.0	2.0×10^{29}
−1.0	8.1×10^{28}
0.0	3.2×10^{28}
1.0	1.3×10^{28}
2.0	5.0×10^{27}
3.0	2.0×10^{27}
4.0	8.1×10^{26}
5.0	3.2×10^{26}

*W = watts

30. Based on Figure 1, for a star cluster that is 5.0×10^9 years old, $M_B - M_V$ will be closest to which of the following?

F. −0.6
G. −0.2
H. 0.2
J. 0.6

31. Consider a star cluster having a particular star for which $V = M_V$. Based on Figure 2, the distance from Earth to the particular star will be which of the following?

A. 1 pc
B. 10 pc
C. 15 pc
D. 20 pc

32. Based on Tables 1 and 2, the power output of visible light is greatest from the particular stars in which of the 4 star clusters?

F. SC I
G. SC II
H. SC III
J. SC IV

33. Based on Table 1, M_B for the particular stars in SC I is which of the following?

A. −1.5
B. 0.0
C. 1.5
D. 3.0

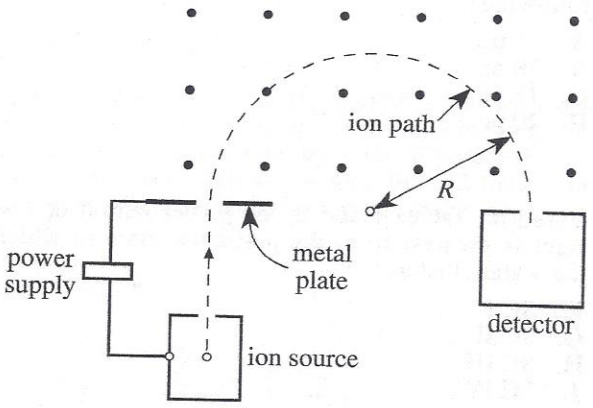
34. As $M_B - M_V$ increases, stellar surface temperature decreases. Based on Table 1, is the surface temperature lower for the particular stars in SC III or for the particular stars in SC IV ?

F. SC III, because $M_B - M_V$ is less for SC III than for SC IV.
G. SC III, because $M_B - M_V$ is greater for SC III than for SC IV.
H. SC IV, because $M_B - M_V$ is less for SC IV than for SC III.
J. SC IV, because $M_B - M_V$ is greater for SC IV than for SC III.

Passage VII

When an ion moves through a uniform magnetic field, the ion follows a circular path having a radius R. A group of students conducted 3 studies to determine R under a variety of conditions for ions having the same mass.

The students used an apparatus consisting of an ion source, a metal plate with a hole in it, a power supply for generating various voltages between the ion source and the metal plate, and a movable charged-particle detector. Figure 1 shows the apparatus with the detector positioned to detect particular ions.



top view

Note: The black dots represent the uniform magnetic field.

Figure 1

Figure 1 adapted from John D. Cutnell and Kenneth W. Johnson, *Physics*, 7th ed. ©2007 by John Wiley and Sons, Inc.

In each trial, the following occurred: Ions with the same electrical charge, Q, as well as the same mass were emitted by the ion source. The ions sped up, due to the voltage provided by the power supply, until they reached the hole in the plate. At the hole, their speed was V. After passing through the hole, they entered a uniform magnetic field of strength B. Under the influence of the field, they traveled along a circular path, still at speed V. The students moved the detector from side to side until it intercepted the ions and detected them. The students measured the distance between the hole in the metal plate and the ions' point of entry into the detector; R equaled this distance divided by 2.

Study 1

R was determined for ions having different V (see Table 1). Each ion had a Q of +1, and B equaled 0.10 tesla (T).

Table 1

Trial	V (m/sec)	R (m)
1	3,000	0.056
2	4,500	0.084
3	6,000	0.112
4	7,500	0.140

Study 2

R was determined for ions having various Q (see Table 2). Each ion had a V of 7,500 m/sec, and B equaled 0.10 T.

Table 2

Trial	Q	R (m)
5	+2	0.070
6	+3	0.047
7	+4	0.035

Study 3

R was determined for various B (see Table 3). Each ion had a Q of +1 and a V of 7,500 m/sec.

Table 3

Trial	B (T)	R (m)
8	0.04	0.352
9	0.08	0.176
10	0.12	0.117

35. If, in Study 1, a trial had been conducted in which V equaled 9,000 m/sec, R would most likely have been closest to which of the following values?

A. 0.098 m
B. 0.126 m
C. 0.140 m
D. 0.168 m

36. Suppose that in a new trial, the students repeated the procedure used in Trial 6, but the ion source malfunctioned, and the students detected ions at 2 values of R: 0.047 m and 0.070 m. Which of the following statements regarding the electrical charge(s) of the ions in this new trial best explains this result?

F. Each ion had a Q of +2.
G. Each ion had a Q of +2.5.
H. For a portion of the ions, Q was +3; for the remainder of the ions, Q was +2.
J. For a portion of the ions, Q was +3; for the remainder of the ions, Q was +4.

37. As the ions traveled from the ion source to the hole in the metal plate, they were accelerating. They were also accelerating as they traveled from the hole in the metal plate to the detector. For each interval of motion, were the ions accelerating because the *magnitude* of their velocity was changing or because the *direction* of their velocity was changing?

	from ion source to hole	from hole to detector
A.	magnitude of velocity	magnitude of velocity
B.	magnitude of velocity	direction of velocity
C.	direction of velocity	magnitude of velocity
D.	direction of velocity	direction of velocity

38. Based on the results of the 3 studies, R is directly proportional to which of the variables tested, and R is inversely proportional to which of the variables tested?

	directly proportional	inversely proportional
F.	V only	Q and B only
G.	B only	V and Q only
H.	V and Q only	B only
J.	Q and B only	V only

39. Suppose that the procedure used in Trial 7 had been repeated in a new trial, except that B equaled 0.12 T instead of 0.10 T. Based on the results of Studies 2 and 3, R would most likely have been:

A. less than 0.035 m.
B. between 0.035 m and 0.047 m.
C. between 0.047 m and 0.070 m.
D. greater than 0.070 m.

40. Based on Figure 1, the distance each ion traveled along its path from the time it left the hole in the metal plate until the time it entered the detector is given by which of the following expressions?

F. R
G. $2R$
H. πR
J. $2\pi R$

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.