## 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

A scientist discovered that cells of a new strain of bacteria, Bacteria X, form colonies when incubated for 72 hr at 37°C on a growth medium having a pH of 7 and an NaCl concentration of 5 g/L. To determine whether these conditions are optimal for the growth of Bacteria X, the scientist conducted an experiment in which incubation temperature, and the pH and the NaCl concentration of the growth medium, were varied. In each trial, Bacteria X cells were incubated for 72 hr, and colony growth was then assayed by determining the average colony diameter (ACD) of the colonies that grew during the incubation (see the table).

| Trial | Incubation temperature (°C) | Growth medium: pH | Growth medium: NaCl concentration (g/L) | ACD (mm) |
|---|---|---|---|---|
| 1 | 25 | 6 | 5 | 1.1 |
| 2 | 37 | 6 | 5 | 1.7 |
| 3 | 42 | 6 | 5 | 0.8 |
| 4 | 25 | 6 | 10 | 1.3 |
| 5 | 37 | 6 | 10 | 1.9 |
| 6 | 42 | 6 | 10 | 0.9 |
| 7 | 25 | 7 | 5 | 1.1 |
| 8 | 37 | 7 | 5 | 1.5 |
| 9 | 42 | 7 | 5 | 1.0 |
| 10 | 25 | 7 | 10 | 1.2 |
| 11 | 37 | 7 | 10 | 2.1 |
| 12 | 42 | 7 | 10 | 1.1 |

1. To determine whether doubling the NaCl concentration in the growth medium doubles the ACD of Bacteria X, the scientist should compare the results of which of the following 2 trials?
   - **A.** Trial 2 and Trial 3
   - **B.** Trial 2 and Trial 5
   - **C.** Trial 4 and Trial 6
   - **D.** Trial 7 and Trial 8

2. How did increasing the pH of the growth medium from pH 6 to pH 7 affect the ACD when Bacteria X cells were incubated at 42°C on a growth medium having an NaCl concentration of 5 g/L ? When the pH was increased from pH 6 to pH 7, the ACD:
   - **F.** increased; the ACD for Trial 1 was 1.1 mm and the ACD for Trial 2 was 1.7 mm.
   - **G.** increased; the ACD for Trial 3 was 0.8 mm and the ACD for Trial 9 was 1.0 mm.
   - **H.** decreased; the ACD for Trial 1 was 1.7 mm and the ACD for Trial 2 was 1.1 mm.
   - **J.** decreased; the ACD for Trial 3 was 1.0 mm and the ACD for Trial 9 was 0.8 mm.

3. Which of the growth conditions was(were) varied among Trials 10–12 ?
   - **A.** Temperature only
   - **B.** pH only
   - **C.** Temperature and pH only
   - **D.** pH and NaCl concentration only

4. The scientist predicted that the ACD for Bacteria X colonies would be greatest when the bacteria were incubated at a temperature of 37°C on a growth medium having a pH of 7 and an NaCl concentration of 5 g/L. Are the results in the table consistent with this prediction?
   - **F.** Yes; the ACD for Bacteria X colonies was greatest in Trial 8.
   - **G.** Yes; the ACD for Bacteria X colonies was greatest in Trial 11.
   - **H.** No; the ACD for Bacteria X colonies was greatest in Trial 8.
   - **J.** No; the ACD for Bacteria X colonies was greatest in Trial 11.

5. The growth mediums tested in Trial 4 and Trial 10 differed in which of the following ways?
   - **A.** The growth medium in Trial 4 was more acidic than the growth medium in Trial 10.
   - **B.** The growth medium in Trial 10 was more acidic than the growth medium in Trial 4.
   - **C.** The NaCl concentration of the growth medium was greater in Trial 4 than in Trial 10.
   - **D.** The NaCl concentration of the growth medium was greater in Trial 10 than in Trial 4.

## Passage II

When a sphere falls through air, the sphere is subjected to a drag force, $F$, that resists its motion. $F$ depends on the sphere's diameter, $D$; the air temperature, $T$; the sphere's speed, $V$; and atmospheric pressure.

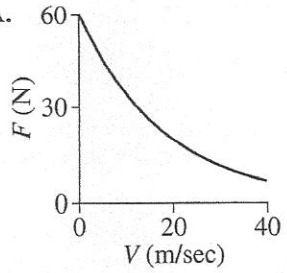
The table below gives $F$, in newtons (N), on a sphere falling through air near Earth's surface, for various combinations of $D$, in meters (m); $T$, in degrees Celsius (°C); and $V$, in meters per second (m/sec). For each combination, air pressure is 1 atmosphere.

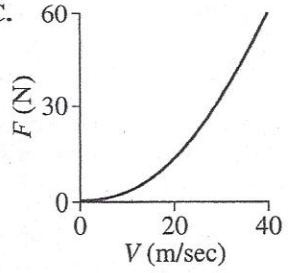
| Combination | $D$ (m) | $T$ (°C) | $V$ (m/sec) | $F$ (N) |
|---|---|---|---|---|
| 1 | 0.050 | 25.0 | 20.0 | 0.93 |
| 2 | 0.100 | 25.0 | 20.0 | 3.71 |
| 3 | 0.150 | 25.0 | 20.0 | 8.34 |
| 4 | 0.200 | 25.0 | 20.0 | 14.9 |
| 5 | 0.200 | 10.0 | 20.0 | 15.8 |
| 6 | 0.200 | 15.0 | 20.0 | 15.5 |
| 7 | 0.200 | 20.0 | 20.0 | 15.1 |
| 8 | 0.200 | 25.0 | 20.0 | 14.9 |
| 9 | 0.200 | 25.0 | 10.0 | 3.72 |
| 10 | 0.200 | 25.0 | 20.0 | 14.9 |
| 11 | 0.200 | 25.0 | 30.0 | 33.5 |
| 12 | 0.200 | 25.0 | 40.0 | 59.5 |

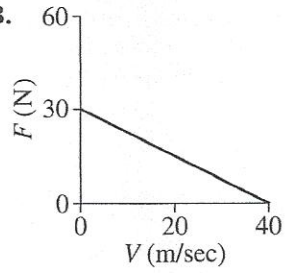
6. According to Combinations 5–8, as $T$ increases, $F$:

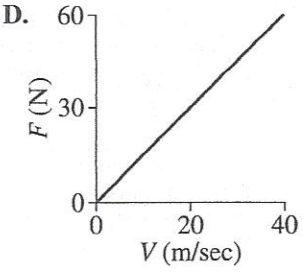
F. increases only.
G. decreases only.
H. varies, but with no general trend.
J. remains the same.

7. Based on Combinations 9–12, the relationship between $F$ and $V$ is best represented by which of the following graphs?

A.



C.



B.



D.



8. Based on the table, $F$ will be greatest for which of the following $D$, $T$, and $V$?

| | $D$ (m) | $T$ (°C) | $V$ (m/sec) |
|---|---|---|---|
| F. | 0.400 | 30 | 100 |
| G. | 0.400 | 60 | 200 |
| H. | 0.800 | 60 | 100 |
| J. | 0.800 | 30 | 200 |

9. If experimental trials were conducted in which Combinations 1–4 were tested, what would be the independent variable and what would be the dependent variable?

| | independent | dependent |
|---|---|---|
| A. | $V$ | $T$ |
| B. | $T$ | $V$ |
| C. | $F$ | $D$ |
| D. | $D$ | $F$ |

10. As a sphere moves as described in the passage, a transformation of energy takes place involving the sphere's kinetic energy ($KE_S$), the sphere's potential energy due to Earth's gravity ($GPE_S$), and heat ($Q$). Which of the following statements best describes this transformation?

F. Both $GPE_S$ and $Q$ are converted to $KE_S$.
G. Both $KE_S$ and $Q$ are converted to $GPE_S$.
H. $GPE_S$ is converted to $KE_S$ and $Q$.
J. $Q$ is converted to $GPE_S$ and $KE_S$.

## Passage III

When *t*-butyl chloride [$(CH_3)_3CCl$] is dissolved in an acetone-$H_2O$ solution, it reacts with $H_2O$ completely to form *t*-butyl alcohol [$(CH_3)_3COH$]:

$$(CH_3)_3CCl + H_2O \xrightarrow[\text{acetone-}H_2O]{} (CH_3)_3COH + H^+ + Cl^-$$

Acetone is less polar than $H_2O$. Thus, increasing the concentration of acetone in $H_2O$ *decreases* the polarity of the reaction solution.

Figures 1 and 2 show how the electrical conductivity of each of 5 acetone-$H_2O$ solutions varied over time after 1 mg of $(CH_3)_3CCl$ was dissolved in 100 mL of each solution. The conductivity (which increased as the solution's ion concentration increased) stopped increasing when the reaction had run to completion (indicated by the point labeled "RC").

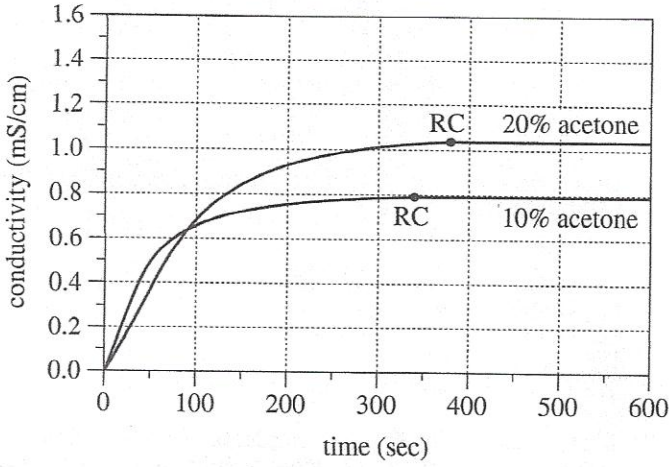
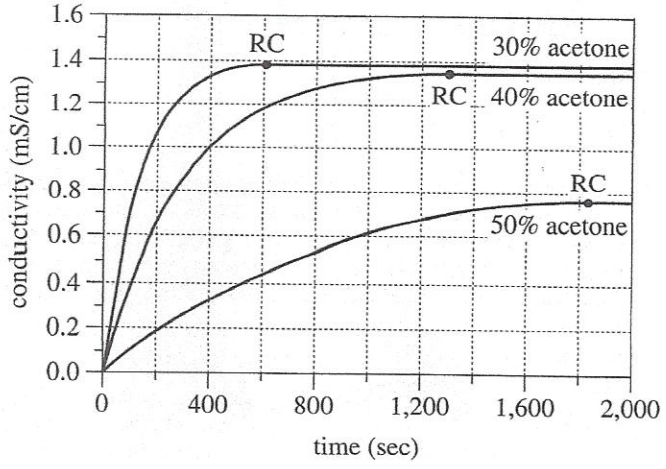



Figure 1



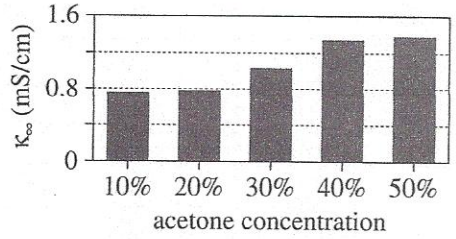

Note: In Figures 1 and 2, concentration is given as the percent by mass of acetone in the solution, and conductivity is given as millisiemens per centimeter, mS/cm.

Figure 2

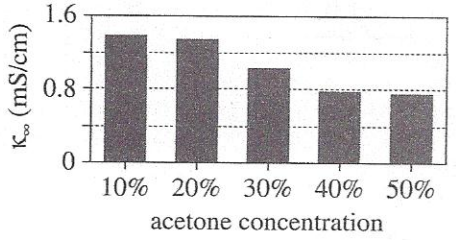
Figures adapted from Peter Keusch, "Kinetics: Hydrolysis of Tertiary Butyl Halides – First Order Reaction." ©2000 by Universität Regensburg.

**11.** The conductivity of the reaction solution at the end of a reaction is $\kappa_\infty$. Which of the following graphs best shows how $\kappa_\infty$ varied with acetone concentration?

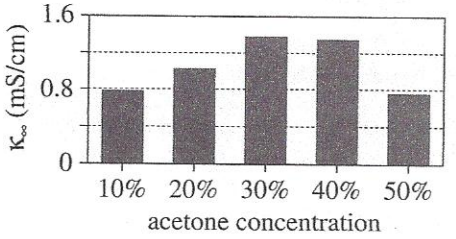
**A.**



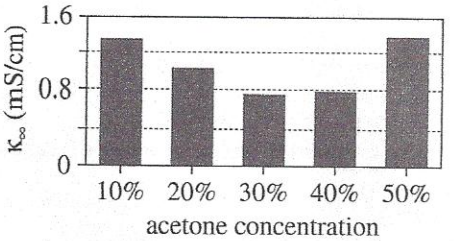

**B.**




**C.**




**D.**




**12.** Based on Figure 2, if a 45% acetone solution had been tested, the reaction would most likely have reached completion at a time:

**F.** less than 600 sec.
**G.** between 600 sec and 1,200 sec.
**H.** between 1,200 sec and 1,800 sec.
**J.** greater than 1,800 sec.

13. Based on Figures 1 and 2, the reaction was completed soonest when the acetone concentration was:

A. 10%.
B. 20%.
C. 40%.
D. 50%.

14. Consider the acetone-$H_2O$ solution that resulted in the greatest maximum conductivity shown in Figures 1 and 2. What masses of acetone and $H_2O$ can be mixed together to make 100 g of this solution?

| | acetone | $H_2O$ |
|---|---|---|
| F. | 20 g | 80 g |
| G. | 20 g | 100 g |
| H. | 30 g | 70 g |
| J. | 30 g | 100 g |

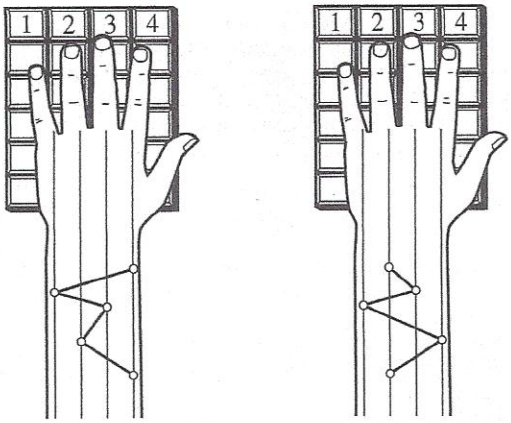
15. As *resistivity* increases, the ability to conduct electricity *decreases*. Based on Figures 1 and 2, which of the solutions had the highest resistivity at RC ?

A. 20% acetone
B. 30% acetone
C. 40% acetone
D. 50% acetone

## Passage IV

Scientists investigated whether sleep improves *procedural memory* (memory of skilled movements).

Subjects trained to tap their fingers in 1 or 2 sequences: Sequence X only, or Sequence X followed by Sequence Y (see Figure 1). To train for a sequence, the subjects attempted to tap the sequence for 30 sec and then rested for 30 sec, 12 times in succession. During the last 3 of these 12 cycles, the subjects' accuracy was tested.




Seq X: "4-1-3-2-4"

Seq Y: "2-3-1-4-2"

Figure 1

The subjects' accuracy was *retested*—either immediately after training or after a full night's sleep—as they attempted to tap the sequence during 3 cycles.

Six groups, each consisting of 15 people, were subjected to different protocols:

Group 1 trained for Seq X and was immediately retested.

Group 2 trained for Seq X, slept overnight, and was retested the next day.

Group 3 trained for Seq X, immediately trained for Seq Y, and was immediately retested.

Group 4 trained for Seq X, immediately trained for Seq Y, slept overnight, and was retested the next day.

Group 5 trained for Seq X, waited for 6 hr, trained for Seq Y, slept overnight, and was retested the next day.

Group 6 trained for Seq X, waited for 9 hr, trained for Seq Y, slept overnight, and was retested the next day.

The table shows, for each group, the percent change in the average accuracy of the subjects between their initial testing (during training) and their retesting.

Table 1

| Group | Sequences taught | Time between training sessions (hr) | Sleep before retesting | Percent change in average accuracy for Sequence: X | Y |
|---|---|---|---|---|---|
| 1 | X only | n.a. | no | −4 | n.a. |
| 2 | X only | n.a. | yes | 25 | n.a. |
| 3 | X and Y | 0 | no | −9 | −10 |
| 4 | X and Y | 0 | yes | −1 | 42 |
| 5 | X and Y | 6 | yes | 23 | 40 |
| 6 | X and Y | 9 | yes | 25 | 40 |

Note: n.a. indicates that the conditions are not applicable.

Figure 1 and Table 1 adapted from Matthew P. Walker et al., "Dissociable Stages of Human Memory Consolidation and Reconsolidation." ©2003 by Nature Publishing Group.

**16.** When subjects were *not* trained for Seq Y, did retesting after a full night's sleep result in an increase in the percent change in average accuracy for Seq X ?

- **F.** Yes; the percent change in average accuracy for Group 2 was 25%, compared to −4% for Group 1.
- **G.** Yes; the percent change in average accuracy for Group 3 was −9%, compared to −4% for Group 1.
- **H.** No; the percent change in average accuracy for Group 2 was 25%, compared to −4% for Group 1.
- **J.** No; the percent change in average accuracy for Group 3 was −9%, compared to −4% for Group 1.

**17.** To consider whether Seq Y was finger-tapped with greater accuracy after a full night's sleep than it was immediately after training, one should compare the results for:

- **A.** Groups 1 and 2.
- **B.** Groups 2 and 3.
- **C.** Groups 3 and 4.
- **D.** Groups 4 and 5.

18. The results of the study are most consistent with which of the following conclusions about the effect of sleep on procedural memory?

F. Sleep before learning can improve procedural memory.
G. Sleep after learning can improve procedural memory.
H. Sleep before learning cannot improve procedural memory.
J. Sleep after learning cannot improve procedural memory.

19. How did the behavior of a subject training for Seq X differ from the behavior of a subject training for Seq Y ? A subject training for Seq X finger-tapped:

A. for 30 sec intervals, whereas a subject training for Seq Y finger-tapped for 1 min intervals.
B. with the right hand, whereas a subject training for Seq Y finger-tapped with the left hand.
C. for a total of 12 intervals, whereas a subject training for Seq Y finger-tapped for a total of 3 intervals.
D. 4-1-3-2-4, whereas a subject training for Seq Y finger-tapped 2-3-1-4-2.

20. Based on the results in the table, when subjects in Group 3 were retested, was their average accuracy for finger-tapping Seq X less than or greater than that during training?

F. Less, because the percent change in average accuracy was less than 0.
G. Less, because the percent change in average accuracy was greater than 0.
H. Greater, because the percent change in average accuracy was less than 0.
J. Greater, because the percent change in average accuracy was greater than 0.

21. One of the scientists predicted that increasing the time between training for Seq X and training for Seq Y from 0 hr to 6 hr would have no effect on the percent change in average accuracy for Seq X. Was the scientist's prediction correct?

A. Yes; the percent change in average accuracy for Seq X was the same for Group 4 as it was for Group 3.
B. Yes; the percent change in average accuracy for Seq X was the same for Group 5 as it was for Group 4.
C. No; the percent change in average accuracy for Seq X was greater for Group 4 than it was for Group 3.
D. No; the percent change in average accuracy for Seq X was greater for Group 5 than it was for Group 4.

## Passage V

*Gas-giant planets* have a solid core surrounded by a massive envelope of gases. Gas-giant planets form within *stellar nebulae*—large, flattened clouds of gas and dust that surround newly formed stars. Planet formation begins when some of the solid material within a stellar nebula clumps together to form a spherical body called a *planet core*. Two scientists discuss how gas-giant planets like Jupiter form from planet cores in stellar nebulae.

*Scientist 1*

A planet core continuously attracts additional solid particles from the stellar nebula, gradually increasing its mass. If a planet core reaches a minimum mass of 10 times the mass of Earth (10 $M_E$), its gravity is then strong enough to attract and hold gases from the surrounding stellar nebula. The formation of a 10 $M_E$ planet core takes approximately 1 million years. The time required for a 10 $M_E$ planet core to then attract a minimum 300 $M_E$ of gases and thus become a gas-giant planet like Jupiter is 10 million to 100 million years more. Because it takes so long to form gas-giant planets like Jupiter, they are very rare in our galaxy.

*Scientist 2*

Gas-giant planets form in a stellar nebula if gravity variations cause the nebula to suddenly fragment into 2 or more massive spherical clumps of gas and dust called *gas-giant protoplanets* (GGPP), each having a planet core at the center that is no larger than 6 $M_E$. A GGPP forms in less than 1,000 years. After formation, the GGPP contracts to form a gas-giant planet. The entire process from the start of GGPP formation to a new gas-giant planet takes only about 1 million years.

Gas-giant planets like Jupiter would not have time to form as described by Scientist 1. Observations indicate that stellar nebulae around newly formed stars do not remain in existence longer than 7 million years after the stars are formed. Also, planet cores that are not part of a GGPP do not have enough momentum to keep them from spiraling into the star at the center of the nebula within 100,000 years. Gas-giant planets like Jupiter are not rare. At least 130 gas-giant planets as large as or larger than Jupiter have been identified in our galaxy.

**22.** What are the 2 scientists' estimates of the mass of a planet core that later becomes the center of a gas-giant planet?

| | Scientist 1 | Scientist 2 |
|---|---|---|
| **F.** | exactly 10 $M_E$ | exactly 6 $M_E$ |
| **G.** | exactly 6 $M_E$ | exactly 10 $M_E$ |
| **H.** | at least 10 $M_E$ | at most 6 $M_E$ |
| **J.** | at least 6 $M_E$ | at most 10 $M_E$ |

**23.** Based on Scientist 1's discussion, which of the following statements gives the most likely reason Earth is not a gas-giant planet? At the time the planets were forming in the Sun's stellar nebula, the:

**A.** planet core that became Earth was not massive enough to attract and hold a sufficient amount of gases.
**B.** planet core that became Earth was massive enough to attract and hold a large quantity of gases.
**C.** nebula did not contain enough gases to form any gas-giant planets.
**D.** nebula contained only enough gases to form 2 gas-giant planets.

**24.** The discovery that some stellar nebulae remain in existence for more than 10 million years would *contradict* a statement made by:

**F.** Scientist 1 only.
**G.** Scientist 2 only.
**H.** both Scientist 1 and Scientist 2.
**J.** neither Scientist 1 nor Scientist 2.

**25.** Suppose a planet core in a stellar nebula has, over time, attracted and held 200 $M_E$ of gases from the nebula. Would Scientist 1 be likely to claim that this planet core surrounded by 200 $M_E$ of gases is a gas-giant planet like Jupiter?

**A.** Yes, because Scientist 1 claims that less than 200 $M_E$ of gases must be attracted and held by a planet core to form such a gas-giant planet.
**B.** Yes, because Scientist 1 claims that no less than 200 $M_E$ of gases must be attracted and held by a planet core to form such a gas-giant planet.
**C.** No, because Scientist 1 claims that more than 200 $M_E$ of gases must be attracted and held by a planet core to form such a gas-giant planet.
**D.** No, because Scientist 1 claims that no more than 200 $M_E$ of gases must be attracted and held by a planet core to form such a gas-giant planet.

**26.** The discovery of which of the following objects would provide the strongest support for Scientist 2's viewpoint?

- **F.** Several 1-million-year-old stars, none with orbiting gas-giant planets
- **G.** Several 1-million-year-old stars, each with 2 orbiting gas-giant planets
- **H.** Several 100-million-year-old stars, none with orbiting gas-giant planets
- **J.** Several 100-million-year-old stars, each with 2 orbiting gas-giant planets

**27.** Assume that the gas-giant planets and the non-gas-giant planets (*terrestrial planets*) in another solar system in our galaxy have spatial and size relationships the same as those of the gas-giant planets and the terrestrial planets in our solar system. Given this assumption, in the other solar system, an existing gas-giant planet would most likely be:

- **A.** located at a greater distance from the star than would any of the terrestrial planets.
- **B.** located at a lesser distance from the star than would any of the terrestrial planets.
- **C.** the same diameter as the largest terrestrial planet.
- **D.** a lesser diameter than any of the terrestrial planets.

**28.** Based on Scientist 2's discussion, in a stellar nebula, a 10 $M_E$ planet core that was NOT part of a GGPP would most likely:

- **F.** form a gas-giant planet in fewer than 10 million years.
- **G.** escape from the central star's gravity and travel out into space.
- **H.** continue to revolve around the central star at a constant distance and speed.
- **J.** move in toward the central star and eventually be destroyed.

## Passage VI

In a hydrothermal vent, *anaerobic oxidation of methane* (AOM) occurs in the top 20 cm of ocean-floor sediment (see Figure 1). This reaction begins when hot fluid containing methane ($CH_4$) rises from a source deep beneath the ocean-floor surface and mixes with seawater containing sulfate ($SO_4^{2-}$).

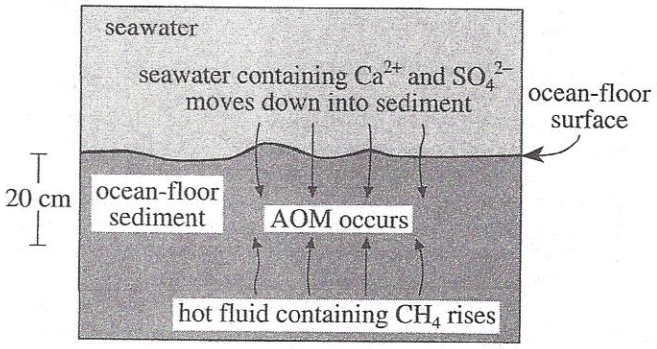



Figure 1

AOM is represented by the following equation:

$$CH_4 + SO_4^{2-} \rightarrow HCO_3^- + HS^- + H_2O$$

One of the 3 direct products of this reaction, $HCO_3^-$, can then combine with calcium ($Ca^{2+}$) in the seawater in a second reaction to produce solid calcium carbonate ($CaCO_3$). This $CaCO_3$ exists as *calcite* crystals and/or *aragonite* crystals. Over time, the crystals fill in the pores in the sediment.

At each of 10 locations in a hydrothermal vent, 2 vertical cylindrical cores of the top 20 cm of ocean-floor sediment were collected.

*Study 1*

One of the 2 cores from each of the 10 locations was cut every 0.5 cm along its length. Each piece of core was squeezed to extract all of the *pore water* (water present in the sediment's pores). The 10 pore water samples from the pieces at the same depth interval in each core were combined and then analyzed for $SO_4^{2-}$ and $CH_4$. The average $SO_4^{2-}$ and $CH_4$ concentrations, in millimoles per liter (mmol/L), from 0 cm to 20 cm depth are shown in Figure 2.

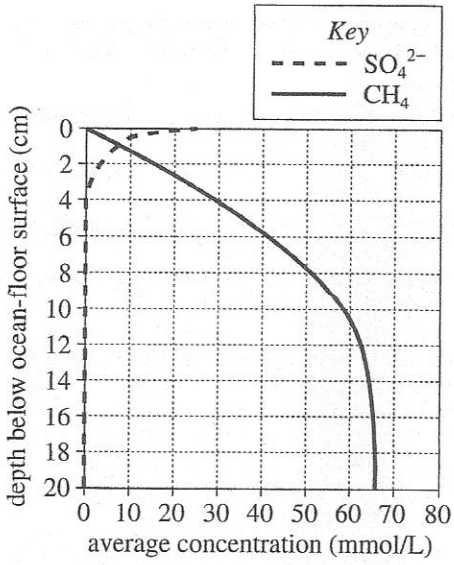



Figure 2

*Study 2*

The sediment in the other core from each of the 10 locations was sampled at the top of the core (0 cm depth), then every 0.5 cm along the core's length. The 10 samples from the same depth in each core were combined and then analyzed to determine the average percent by mass of calcite and the average percent by mass of aragonite in the sediment from 0 cm to 20 cm depth (see Figure 3).

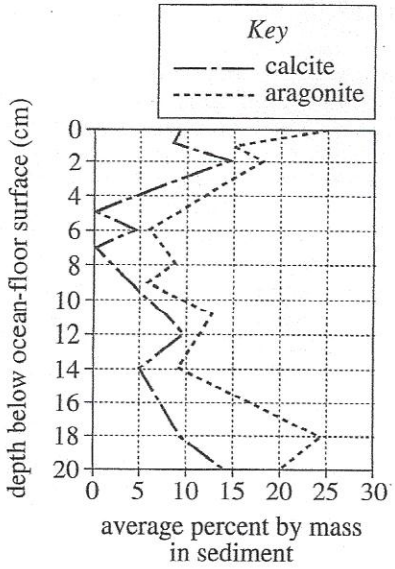



Figure 3

Figures 2 and 3 adapted from Roger Luff et al., "Simulation of Long-Term Feedbacks from Authigenic Carbonate Crust Formation at Cold Vent Sites." ©2004 by Elsevier B.V.

29. According to the results of Study 2, there was NO calcite found at which of the following depths?

A. 2 cm
B. 5 cm
C. 8 cm
D. 11 cm

30. Suppose that in Study 1, at the same locations, samples of ocean-floor sediment from 20 cm to 20.5 cm below the ocean-floor surface had been collected and combined. The pore water extracted from those combined samples would most likely have had an average $SO_4^{2-}$ concentration and an average $CH_4$ concentration, respectively, closest to which of the following?

| | $SO_4^{2-}$ (mmol/L) | $CH_4$ (mmol/L) |
|---|---|---|
| F. | 0 | 0 |
| G. | 0 | 65 |
| H. | 20 | 0 |
| J. | 20 | 65 |

31. Is the statement "Some $SO_4^{2-}$ was found in the pore water from each depth interval in the cores" supported by Figure 2 ?

A. Yes, because Figure 2 indicates that the average $SO_4^{2-}$ concentration was zero at depths of 4 cm or greater.
B. Yes, because Figure 2 indicates that the average $SO_4^{2-}$ concentration was greater than zero at all depths.
C. No, because Figure 2 indicates that the average $SO_4^{2-}$ concentration was zero at depths of 4 cm or greater.
D. No, because Figure 2 indicates that the average $SO_4^{2-}$ concentration was greater than zero at all depths.

32. According to the results of Study 2, over the top 20 cm of sediment, how did the average percent by mass of calcite compare to the average percent by mass of aragonite? The average percent by mass of calcite was:

F. greater at each depth.
G. less at each depth.
H. greater at some depths but less at all other depths.
J. greater at some depths but the same at all other depths.

33. Consider the average percent by mass of aragonite at a depth of 10 cm shown in Figure 3. On average, the mass in grams of aragonite present in a 50 g sample of sediment taken from that depth would be closest to which of the following?

A. 2.5 g
B. 5 g
C. 25 g
D. 50 g

34. The procedures of Studies 1 and 2 differed in which of the following ways? In Study 1, samples were:

F. analyzed for the reactants of AOM, whereas in Study 2, samples were not analyzed for the reactants of AOM.
G. not analyzed for the reactants of AOM, whereas in Study 2, samples were analyzed for the reactants of AOM.
H. analyzed for the direct products of AOM, whereas in Study 2, samples were not analyzed for the direct products of AOM.
J. not analyzed for the direct products of AOM, whereas in Study 2, samples were analyzed for the direct products of AOM.

## Passage VII

A physicist tested various sheets for their ability to stop *gamma rays* (γ-rays) that had different energies. Any γ-ray that was not stopped by a sheet struck a detector (see Figure 1), which then registered a detection, or *count*.

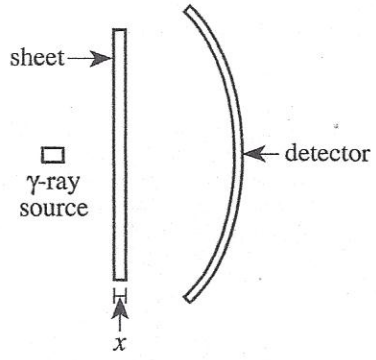



Figure 1

Each sheet was made of either Material 1, Material 2, or Material 3. The thickness, $x$, of each sheet was uniform, but sheets of the same material had different thicknesses.

$I_0$ represented the number of counts per minute (cpm) with no sheet between the γ-ray source and the detector, and $I$ represented the cpm with 1 sheet between the source and the detector.

*Experiment 1*

First, the physicist measured $I_0$ for a source of γ-rays having an energy of 4 *million electron volts* (MeV). Next, with this same γ-ray source, she measured $I$ for various sheets of Material 1, each having a different thickness $x$. Then, she plotted a graph of $I$ versus $x$ (in cm) for Material 1. Similarly, she produced graphs of $I$ versus $x$ for Material 2 and Material 3 (see Figure 2).

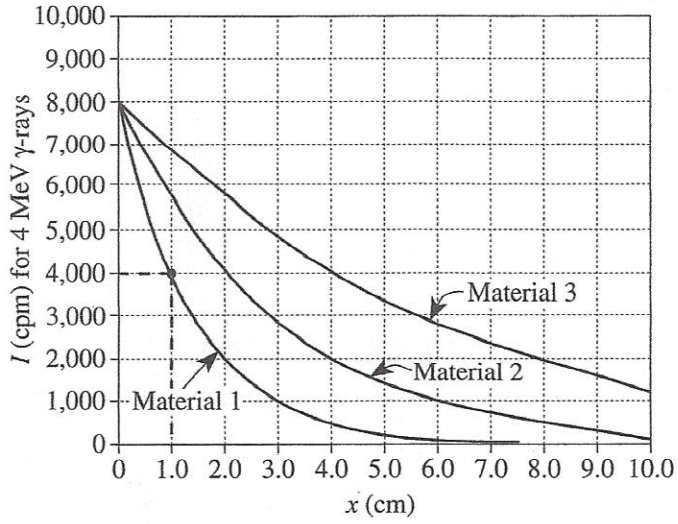



Figure 2

*Experiment 2*

The physicist repeated the procedures from Experiment 1 with other sources of γ-rays having different energies. For each combination of sheet material and γ-ray energy, she produced a graph of $I$ versus $x$. These graphs are not shown.

From the graphs of $I$ versus $x$, she found the *half-value thickness*, $x_{half}$, for each combination of sheet material and γ-ray energy. A sheet of thickness $x_{half}$ stopped half of the γ-rays striking the sheet; that is, $I$ equaled $\frac{I_0}{2}$. (For example, based on Figure 2, for 4 MeV γ-rays striking sheets of Material 1, $x_{half}$ equaled 1.0 cm.) Finally, the physicist plotted a graph of $x_{half}$ versus γ-ray energy for each material (see Figure 3).

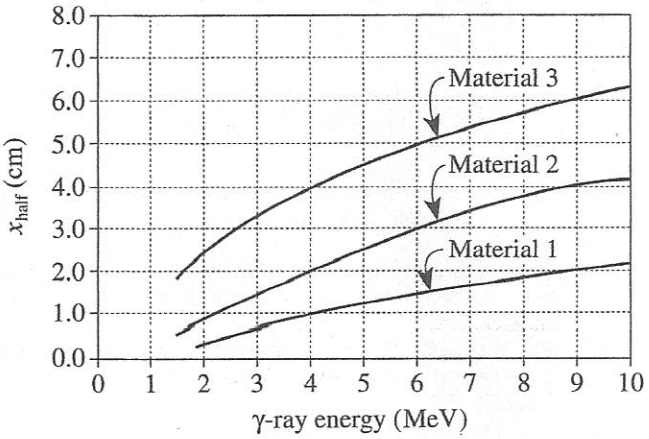



Figure 3

**35.** Based on the results of Experiment 2, for a given material, as γ-ray energy increased, $x_{half}$:

- **A.** increased only.
- **B.** decreased only.
- **C.** varied, but with no general trend.
- **D.** remained the same.

**36.** Based on the results of Experiment 1, $x_{half}$ for Material 3 and a γ-ray energy of 4 MeV was closest to which of the following values?

- **F.** 1.0 cm
- **G.** 2.0 cm
- **H.** 3.0 cm
- **J.** 4.0 cm

37. Based on the results of Experiment 2, to stop a given number of γ-rays of a given energy, which sheet had to be thicker, a sheet made of Material 1 or a sheet made of Material 3 ?

A. Material 1, because at every energy plotted in Figure 3, $x_{half}$ for Material 1 is greater than $x_{half}$ for Material 3.
B. Material 1, because at every energy plotted in Figure 3, $x_{half}$ for Material 1 is less than $x_{half}$ for Material 3.
C. Material 3, because at every energy plotted in Figure 3, $x_{half}$ for Material 3 is greater than $x_{half}$ for Material 1.
D. Material 3, because at every energy plotted in Figure 3, $x_{half}$ for Material 3 is less than $x_{half}$ for Material 1.

38. Based on the description of the experiments, for γ-rays of a given energy, as the ability of materials to stop γ-rays increased, did $I$ decrease or increase, and why?

F. Decrease, because the number of γ-rays reaching the detector per minute increased.
G. Decrease, because the number of γ-rays reaching the detector per minute decreased.
H. Increase, because the number of γ-rays reaching the detector per minute increased.
J. Increase, because the number of γ-rays reaching the detector per minute decreased.

39. The physicist must prepare a sheet that will yield a detection rate of 1,000 cpm when the sheet is struck by 4 MeV γ-rays, as in Experiment 1. This sheet can be no thicker than 10.0 cm. Based on the results of Experiment 1, the physicist can satisfy these requirements by constructing the sheet out of which of the materials tested?

A. Either Material 1 or Material 2
B. Either Material 1 or Material 3
C. Either Material 2 or Material 3
D. Either Material 1, Material 2, or Material 3

40. In Experiment 1, what was the value of $I_0$ ?

F. 0 cpm
G. 1 cpm
H. 4,000 cpm
J. 8,000 cpm

**END OF TEST 4**

**STOP! DO NOT RETURN TO ANY OTHER TEST.**