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

Earth's climate is affected by the *total solar irradiance* (TSI), the rate at which energy from solar radiation is received by Earth per unit area of the surface. In 2000, sunspot records were used to estimate the TSI at a particular Indian Ocean location over the past 1,100 years. Ocean floor sediment that had been deposited at the location over that same period was analyzed for carbon (C), nitrogen (N), and aluminum (Al). The percents by mass of C, N, and Al, respectively, indicated the intensity of monsoons, ocean productivity, and rate of continental erosion (3 measures of climate) over the period. The results are shown in the figure.

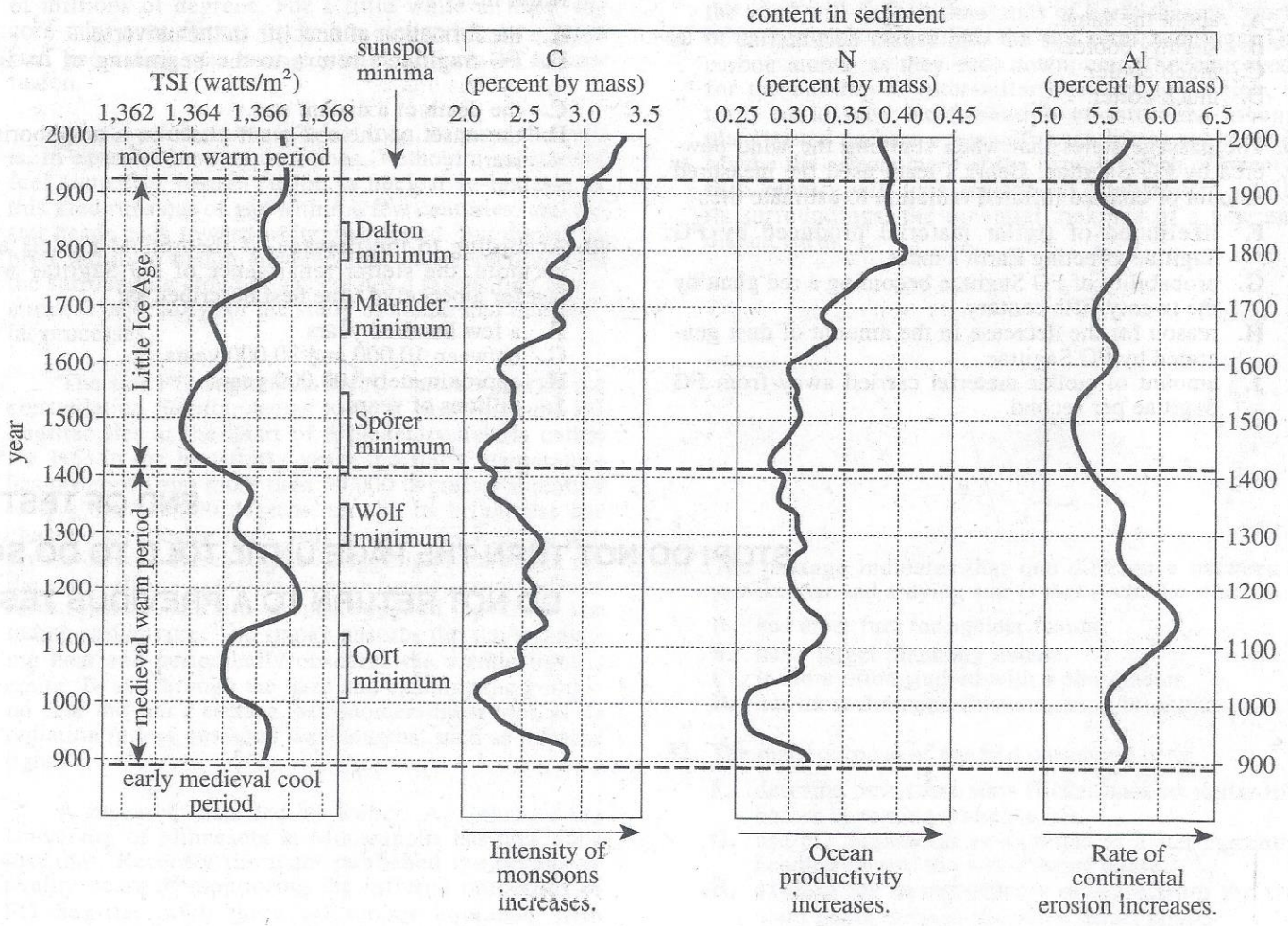


Figure adapted from R. Agnihotri et al., "Evidence for Solar Forcing on the Indian Monsoon During the Last Millenium." ©2002 by Elsevier B.V.

1. The respective percents by mass of C, N, and Al at the Indian Ocean location in the year 1500 were closest to which of the following?

	C	N	Al
A.	2.2	0.31	5.0
B.	2.2	0.33	5.2
C.	2.4	0.31	5.2
D.	2.4	0.33	5.4

2. The figure indicates that the greatest increase in percent by mass of N at the Indian Ocean location occurred over which of the following 100-year periods?

F. 1200 to 1300
G. 1400 to 1500
H. 1600 to 1700
J. 1700 to 1800

3. Based on the figure, at the Indian Ocean location, were monsoons, on average, more intense during the Dalton minimum or during the Spörer minimum, and was ocean productivity, on average, greater during the Dalton minimum or during the Spörer minimum?

	more intense monsoons	greater ocean productivity
A.	Dalton minimum	Dalton minimum
B.	Dalton minimum	Spörer minimum
C.	Spörer minimum	Dalton minimum
D.	Spörer minimum	Spörer minimum

4. During the Little Ice Age, the greatest TSI value at the Indian Ocean location was closest to which of the following?

F. 1,365 watts/m^2
G. 1,366 watts/m^2
H. 1,367 watts/m^2
J. 1,368 watts/m^2

5. Does the figure indicate that the rate of continental erosion in the region of the Indian Ocean location was greater in the year 1150 or in the year 1250 ?

A. 1150, because the percent by mass of N was greater in 1150 than in 1250.
B. 1150, because the percent by mass of Al was greater in 1150 than in 1250.
C. 1250, because the percent by mass of N was greater in 1250 than in 1150.
D. 1250, because the percent by mass of Al was greater in 1250 than in 1150.

6. Over the 1,100-year period, the total solar irradiance at the Indian Ocean location was *least* during which sunspot minimum?

F. Maunder minimum
G. Spörer minimum
H. Wolf minimum
J. Oort minimum

Passage II

Seven 4 g mixtures of glycerol and agar were prepared, each having a different percent glycerol by mass. A plastic film was made from each mixture; all the films were rectangular and had the same dimensions.

Each film was clamped and stretched (see Figure 1) at 25°C until it broke.

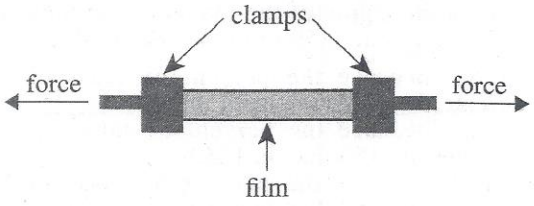


Figure 1

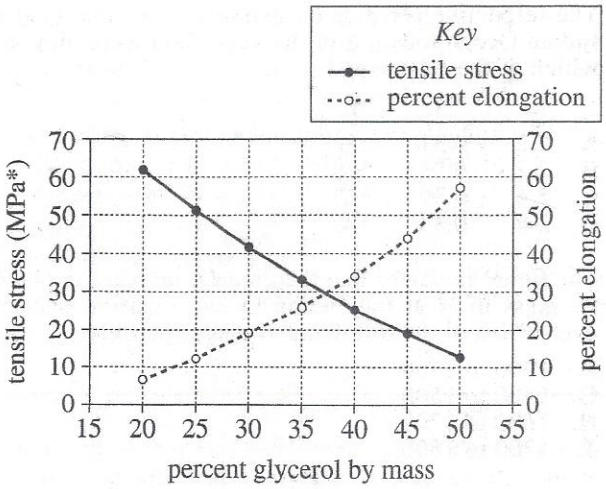
Three properties of the film were determined:

- *Tensile stress*, the force applied per unit area of the film as the film broke
- *Percent elongation*, given by:

$$\frac{\text{final film length} - \text{initial film length}}{\text{initial film length}} \times 100$$

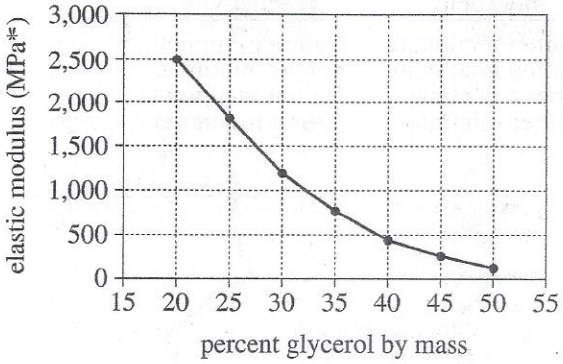
- *Elastic modulus*, a measure of the rigidity of the film

The results for all 7 films are shown in Figures 2 and 3.



*megapascals; 1 MPa = 10^6 newtons per meter squared (N/m^2)

Figure 2



*megapascals

Figure 3

Figures adapted from Eugene S. Stevens et al., "Polymer–Plastics Experiments for the Chemistry Curriculum." ©2006 by Division of Chemical Education, Inc., American Chemical Society.

7. A student predicted that as the percent glycerol by mass increased from 20% to 45%, the elastic modulus would decrease by more than 2,000 MPa. Do the results shown in Figure 3 support this claim?

   A. No; the elastic modulus increased from about 250 MPa to 2,500 MPa.
   B. No; the elastic modulus increased from about 1,200 MPa to 2,500 MPa.
   C. Yes; the elastic modulus decreased from 2,500 MPa to about 250 MPa.
   D. Yes; the elastic modulus decreased from 2,500 MPa to about 1,200 MPa.

8. Suppose a film made from a mixture that was 55% glycerol by mass had been tested. Based on Figure 2, the tensile stress of the film would most likely have been:

   F. less than 13 MPa.
   G. between 13 MPa and 19 MPa.
   H. between 19 MPa and 25 MPa.
   J. greater than 25 MPa.

9. Suppose the initial length of a certain film was 5.0 cm and the final length of the film was 6.0 cm. The percent elongation of the film was:

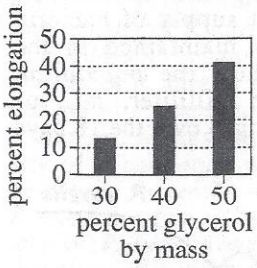
   A. 20%.
   B. 30%.
   C. 40%.
   D. 50%.

10. Based on Figures 2 and 3, as the elastic modulus decreased, the percent elongation:

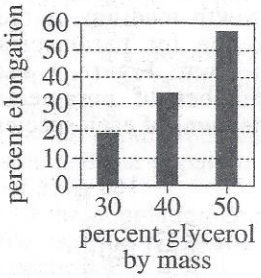
    F. increased only.
    G. decreased only.
    H. increased, then decreased.
    J. decreased, then increased.

11. Based on Figure 2, which of the following graphs best shows the percent elongation results for the films made from mixtures that were, respectively, 30%, 40%, and 50% glycerol by mass?

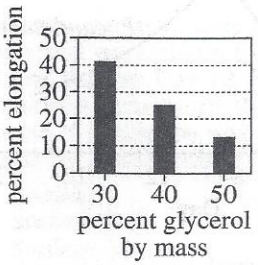
A.



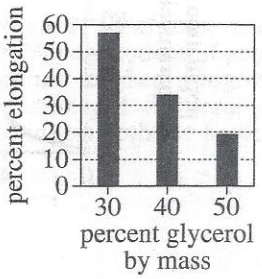
C.



B.



D.



12. At the breaking point of a certain film, a force of 8.0 N was applied to a 2.0×10^{-7} m^2 area of the film. The tensile stress of the film, in N/m^2, is given by which of the following expressions?

    F. $8.0 \times (2.0 \times 10^{-7})$
    G. $8.0 - (2.0 \times 10^{-7})$
    H. $\frac{2.0 \times 10^{-7}}{8.0}$
    J. $\frac{8.0}{2.0 \times 10^{-7}}$

Passage III

Students grew 2 different species of *paramecia* (microscopic, unicellular organisms)—*P. caudatum* and *P. aurelia*—together for 18 days in a test tube containing a growth medium. A constant supply of bacteria (a food source for paramecia) was maintained in the growth medium. Figure 1 shows how the *population density* (number of paramecia per milliliter, mL, of growth medium) of each species changed over the 18 days.

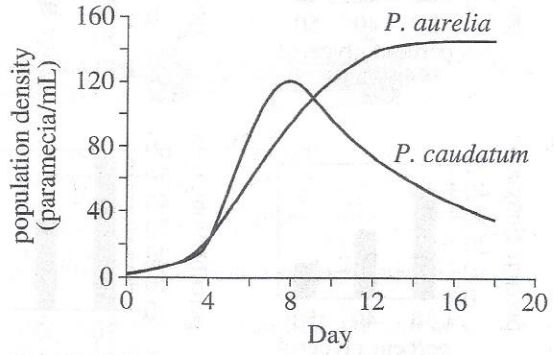


Figure 1

The procedure was repeated except that *P. caudatum* was grown together with *P. bursaria* (see Figure 2).

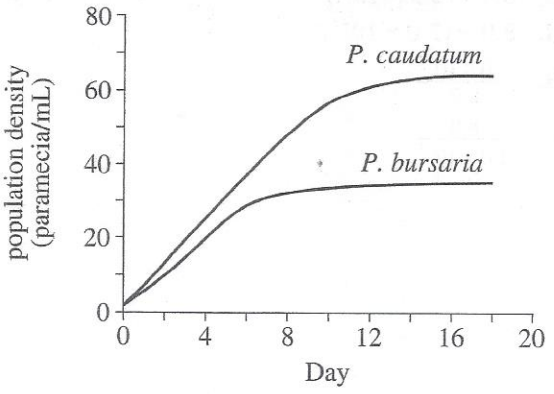


Figure 2

Each of 3 students attempted to explain the results.

Student 1

P. caudatum and *P. aurelia* can grow only near the surface of the growth medium. As the population densities increased, competition for food increased. Eventually, one species outcompeted the other.

Unlike *P. caudatum* and *P. aurelia*, *P. bursaria* harbor cells of photosynthetic algae, called *Chlorella*, in their cytoplasm. *Chlorella* produce O_2 for *P. bursaria*. This allowed *P. bursaria* to feed on bacteria at the bottom of the growth medium. Because *P. caudatum* and *P. bursaria* occupied different regions in the growth medium, there was little competition for food between the 2 species, and they were able to reach stable population densities.

Student 2

Initially, both *P. caudatum* and *P. aurelia* fed on bacteria. But *P. aurelia* can also feed on other paramecia. Thus, when the population densities increased, and competition for bacteria increased, *P. aurelia* began to feed on *P. caudatum*.

P. caudatum and *P. bursaria* are unable to ingest other paramecia, so *P. caudatum* and *P. bursaria* were able to reach stable population densities.

Student 3

P. caudatum and *P. aurelia* were able to find food when their population densities were low. When population densities became too high, *P. aurelia* released a toxin that instantly stopped the *cilia* (short, hairlike projections) on competing paramecia from moving. Because the movement of cilia is necessary to ingest food, the population density of *P. caudatum* declined.

P. caudatum and *P. bursaria* were able to reach stable population densities because neither species can produce the toxin.

13. Based on Student 3's explanation, had *P. aurelia* released the toxin by Day 9?

- **A.** No, because the population density of *P. caudatum* was still increasing after Day 9.
- **B.** No, because the population density of *P. aurelia* was still increasing after Day 9.
- **C.** Yes, because the population density of *P. caudatum* was declining by Day 9.
- **D.** Yes, because the population density of *P. aurelia* was declining by Day 9.

14. According to Student 1, when *P. caudatum* and *P. bursaria* were grown together, where in the growth medium—near the top or at the bottom—was each species more likely to be found on Day 16 ?

	P. caudatum	*P. bursaria*
F.	top	top
G.	top	bottom
H.	bottom	top
J.	bottom	bottom

15. Suppose that over the 18 days, the test tubes had been kept in the dark. This information would *weaken* the explanation(s) of which of the students?

A. Student 1 only
B. Student 3 only
C. Students 1 and 3 only
D. Students 2 and 3 only

16. Based on Figure 1, Student 2 would most likely make which of the following statements about food consumption when *P. caudatum* and *P. aurelia* were grown together?

F. *P. caudatum* began to feed on *P. aurelia* by Day 8, causing *P. aurelia*'s population density to decline.
G. *P. caudatum* began to feed on *P. aurelia* by Day 8, causing *P. caudatum*'s population density to decline.
H. *P. aurelia* began to feed on *P. caudatum* by Day 8, causing *P. aurelia*'s population density to decline.
J. *P. aurelia* began to feed on *P. caudatum* by Day 8, causing *P. caudatum*'s population density to decline.

17. Based on Figure 1 and Student 1's explanation, was *P. caudatum* or *P. aurelia* better able to compete for the bacteria?

A. *P. caudatum*, because by Day 18 the population density of *P. caudatum* was stable and the population density of *P. aurelia* was declining.
B. *P. caudatum*, because by Day 18 the population density of *P. aurelia* was stable and the population density of *P. caudatum* was declining.
C. *P. aurelia*, because by Day 18 the population density of *P. caudatum* was stable and the population density of *P. aurelia* was declining.
D. *P. aurelia*, because by Day 18 the population density of *P. aurelia* was stable and the population density of *P. caudatum* was declining.

18. Consider the test tube in which *P. caudatum* and *P. bursaria* were grown together. Which student, if any, claimed that by Day 18 *P. caudatum* reached a higher population density in the tube than did *P. bursaria* because *P. caudatum* was able to ingest both the bacteria and the *P. bursaria* ?

F. Student 1
G. Student 2
H. Student 3
J. None of the students

19. Which of the students described a symbiotic relationship between a paramecium species and another species that is not a paramecium?

A. Student 1 only
B. Student 3 only
C. Students 1 and 3 only
D. Students 2 and 3 only

Passage IV

Paper electrophoresis can be used to separate and identify amino acids:

1. A strip of paper is wetted with a solution of known pH, and a mixture of amino acids is applied as a spot to the middle of the strip.
2. Each end of the strip is immersed in the solution of known pH, and an electric field is applied to the strip such that one end is positive and the other end is negative.
3. Different amino acids travel along the strip different distances and/or in different directions.

Figure 1 illustrates this process.

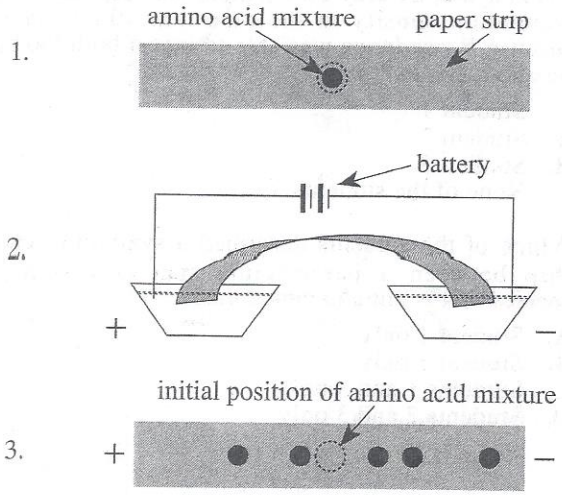


Figure 1

Figure 1 adapted from William B. Wood et al., *Biochemistry: A Problems Approach*. ©1981 by The Benjamin/Cummings Publishing Company, Inc.

The net charge of an amino acid varies with the pH of the solution. The *isoelectric point*, pI, of an amino acid is the pH at which the amino acid has no net charge. At all other pH values, the amino acid *does* have a net charge, and, consequently, will travel along the strip. The direction of travel depends on the sign of the net charge (see Table 1).

Table 1

If solution:	Then net charge of amino acid is:
pH = pI	zero
pH < pI	+
pH > pI	−

Experiment 1

In each of 5 trials (Trials 1–5), paper electrophoresis was performed on leucine (an amino acid) using a solution of known pH. The greater the difference between the pH and leucine's pI, the farther leucine traveled. From the results (see Figure 2), leucine's pI was determined.

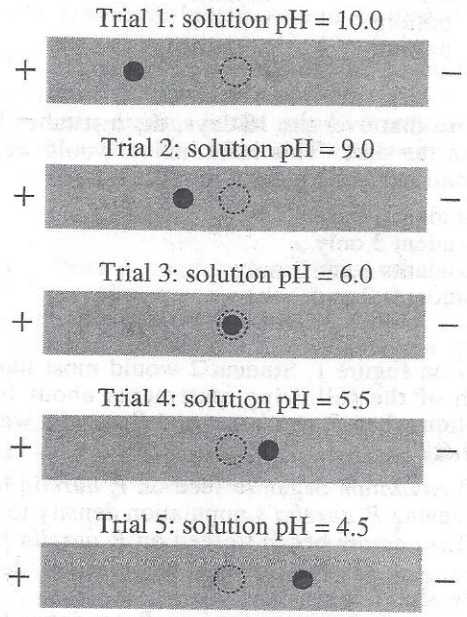


Figure 2

The pI of each of 3 additional amino acids was likewise determined (see Table 2).

Table 2

Amino acid	pI
Aspartic acid	4
Lysine	10
Arginine	12

Experiment 2

In each of 4 trials (Trials 6–9), paper electrophoresis was performed on a mixture of 2 or more of the amino acids studied in Experiment 1 using a solution of known pH. The distance traveled by an amino acid depended only on the difference between the pH and the amino acid's pI: the greater the difference, the farther the amino acid traveled (see Figure 3).

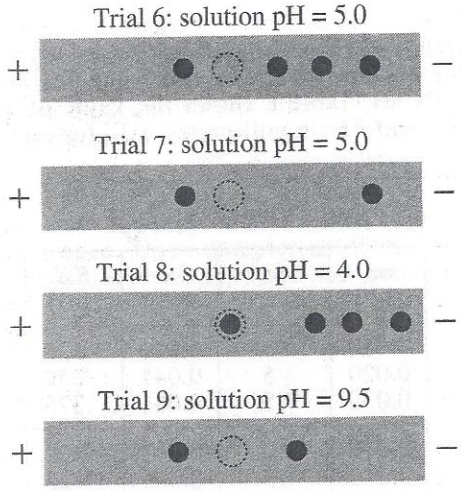


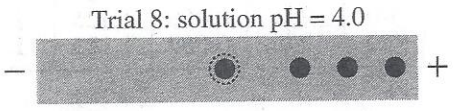
Figure 3

20. What was the purpose of the battery shown in Figure 1 ? The battery was used to:

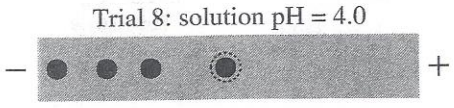
- **F.** apply an amino acid mixture to the paper strip.
- **G.** apply an electric field to the paper strip.
- **H.** immerse the ends of the paper strip in the solution of known pH.
- **J.** wet the paper strip with the solution of known pH.

21. Suppose that in Trial 8 the left end of the paper strip had been negative and the right end of the paper strip had been positive. The results of the trial would have most closely corresponded to which of the following figures?

A.



B.



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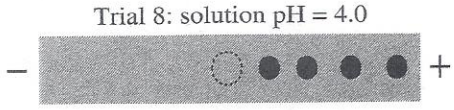
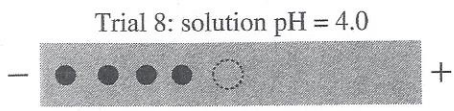


D.



22. Based on the results of Experiment 1, the pI of leucine is approximately:

- **F.** 3.
- **G.** 5.
- **H.** 6.
- **J.** 8.

23. Which of the following statements best explains the result shown in Figure 3 for Trial 9 ? The amino acid mixture contained 2 amino acids; at a solution pH of:

- **A.** 5.0, one of the amino acids had a net positive charge and one of the amino acids had a net negative charge.
- **B.** 5.0, both of the amino acids had a net negative charge.
- **C.** 9.5, one of the amino acids had a net positive charge and one of the amino acids had a net negative charge.
- **D.** 9.5, both of the amino acids had a net negative charge.

24. In Trial 8, the amino acid that traveled the farthest was:

- **F.** leucine.
- **G.** aspartic acid.
- **H.** lysine.
- **J.** arginine.

25. In Experiment 2, Trial 6 and Trial 7 differed in which of the following ways?

- **A.** The mixture in Trial 6 was made up of more amino acids than was the mixture in Trial 7.
- **B.** The mixture in Trial 7 was made up of more amino acids than was the mixture in Trial 6.
- **C.** The solution used in Trial 6 was more acidic than the solution used in Trial 7.
- **D.** The solution used in Trial 7 was more acidic than the solution used in Trial 6.

26. Suppose paper electrophoresis is performed on 2 amino acids: Amino Acid 1, which has a pI of x, and Amino Acid 2, which has a pI of y. If the solution used has a pH of z, under which of the following conditions would each amino acid most likely have a net negative charge?

- **F.** $x > y > z$
- **G.** $x > z > y$
- **H.** $y > z > x$
- **J.** $z > y > x$

Passage V

Two studies of 6 trials each were performed with several projectiles, blocks, and springs.

In each trial, the following occurred: First, a spring having a *spring constant* of k (a measure of the spring's stiffness) was attached to a block of mass M_b. Next, the block was placed on a frictionless horizontal surface such that the spring was neither stretched nor compressed. Then, a projectile of mass m_p was launched toward the block with a velocity v. Upon impact, the projectile became stuck in the block. The force of the impact compressed the spring by a maximum distance x. Figure 1 illustrates the sequence of events beginning with the launch.

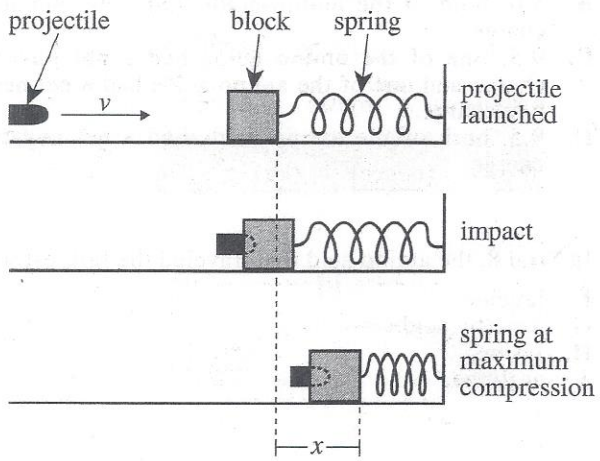


Figure 1

The values of m_p and v were used to calculate KE, the projectile's kinetic energy prior to impact. The values of k and x were used to calculate PE, the elastic potential energy that was stored in the spring when it was at maximum compression.

Study 1

In Trials 1–6, various combinations of m_p and v were tested while M_b equaled 2.0 kg and k equaled 3.0 newtons per meter (N/m). Table 1 shows the value of x, and the values of KE and PE (in millijoules, mJ), for each trial.

Table 1

Trial	m_p (kg)	v (m/sec)	x (m)	KE (mJ)	PE (mJ)
1	0.010	5	0.020	125	0.6
2	0.020	5	0.041	250	2.5
3	0.030	5	0.061	375	5.5
4	0.010	10	0.041	500	2.5
5	0.010	15	0.061	1,125	5.6
6	0.010	20	0.081	2,000	10.0

Study 2

In Trials 7–12, various combinations of M_b and k were tested while m_p equaled 0.010 kg and v equaled 15 m/sec. See Table 2.

Table 2

Trial	M_b (kg)	k (N/m)	x (m)	KE (mJ)	PE (mJ)
7	1.0	3.0	0.086	1,125	11.1
8	2.0	3.0	0.061	1,125	5.6
9	3.0	3.0	0.050	1,125	3.7
10	1.0	5.0	0.067	1,125	11.1
11	1.0	7.0	0.056	1,125	11.1
12	1.0	9.0	0.050	1,125	11.1

27. A *controlled variable* is a variable that is held constant. What were the 3 controlled variables in Trials 4–6 ?

A. m_p, M_b, and k
B. m_p, M_b, and x
C. v, M_b, and k
D. v, k, and x

28. Assume that each projectile and each block could only be tested once. Upon completion of the studies, how many projectile/block pairs had been tested?

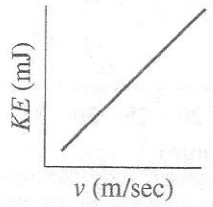
F. 6
G. 12
H. 24
J. 48

29. Was the momentum of the projectile in Trial 3, before impact, the same as the momentum of the projectile in Trial 1, before impact?

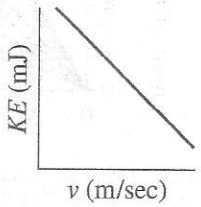
A. No, because the projectiles had different velocities.
B. No, because the projectiles had different masses.
C. Yes, because the projectiles had the same velocity.
D. Yes, because the projectiles had the same mass.

30. Based on the results of Study 1, which of the following graphs best represents the relationship between *KE* and v ?

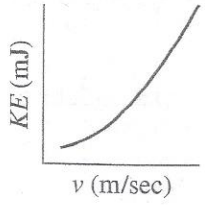
F.



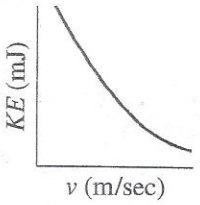
H.



G.



J.



31. Prior to impact, the *mechanical energy* of a projectile/block/spring system equaled *KE*. After impact, when the spring was at maximum compression, the mechanical energy of the system equaled *PE*. Based on the results of the studies, did the system more likely gain mechanical energy or lose mechanical energy as a result of the impact?

A. Gain; in any trial, *KE* was greater than *PE*.
B. Gain; in any trial, *KE* was less than *PE*.
C. Lose; in any trial, *KE* was greater than *PE*.
D. Lose; in any trial, *KE* was less than *PE*.

32. Based on the results of Studies 1 and 2, which of the following combinations of m_p, v, M_b, and k would yield the greatest value of x ?

	m_p (kg)	v (m/sec)	M_b (kg)	k (N/m)
F.	0.010	5	3.0	9.0
G.	0.010	20	1.0	7.0
H.	0.030	5	3.0	5.0
J.	0.030	20	1.0	3.0

33. To best determine the mathematical relationship between k and x, the data obtained in which trials should be considered?

A. Trials 1–3 only, because k was the independent variable in those trials.
B. Trial 1 and Trials 4–6 only, because k was the independent variable in those trials.
C. Trials 7–9 only, because k was the independent variable in those trials.
D. Trial 7 and Trials 10–12 only, because k was the independent variable in those trials.

Passage VI

When sucrose is dissolved in an aqueous solution, it can *hydrolyze* (react with H_2O to break down) to form glucose and fructose. The compound *imidazole* catalyzes the hydrolysis:

$$1 \text{ sucrose} + 1 \text{ } H_2O \xrightarrow{\text{imidazole}} 1 \text{ glucose} + 1 \text{ fructose}$$

To study this reaction, chemists prepared several *buffer solutions*. (A buffer solution is a solution that maintains a stable pH.) Each buffer solution had a different pH.

Experiment 1

In each trial, Steps 1–4 were followed:

1. A certain mass of imidazole (or no imidazole) was dissolved in a certain volume of a buffer solution having a pH of 5.24.
2. A test tube containing 8.0 mL of this imidazole solution (or of the buffer solution only) and a test tube containing 2.0 mL of a 500.0 g/L sucrose solution were each partially submerged in a water bath maintained at 85°C.
3. After 30 min, the reaction solution was formed by adding the 8.0 mL of imidazole solution (or of the buffer solution only) to the test tube containing the 2.0 mL of sucrose solution.
4. The concentration of sucrose in the reaction solution was monitored over the next 35 min while the solution was kept at 85°C.

In no two trials was the same mass of imidazole added to the buffer solution.

The measured values of sucrose concentration were then used to calculate values of the total mass of sucrose that was hydrolyzed. Figure 1 shows how the total mass of sucrose that was hydrolyzed varied over time for reaction solutions having 6 different imidazole concentrations.

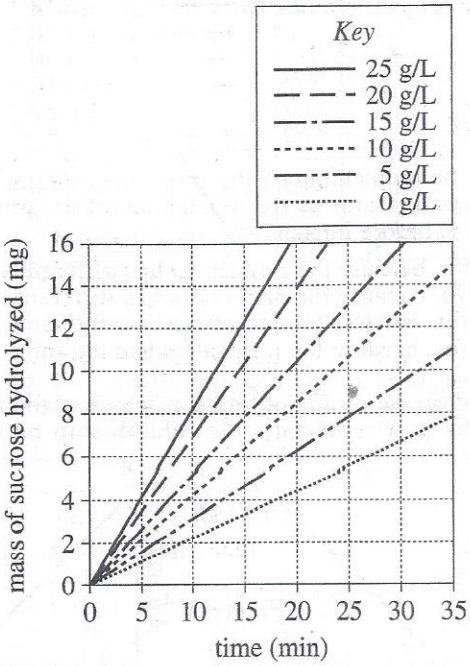


Figure 1

Experiment 2

Experiment 1 was repeated except that, from trial to trial, the pH of the buffer solution was varied and the mass of imidazole added to the buffer solution remained constant (see Figure 2).

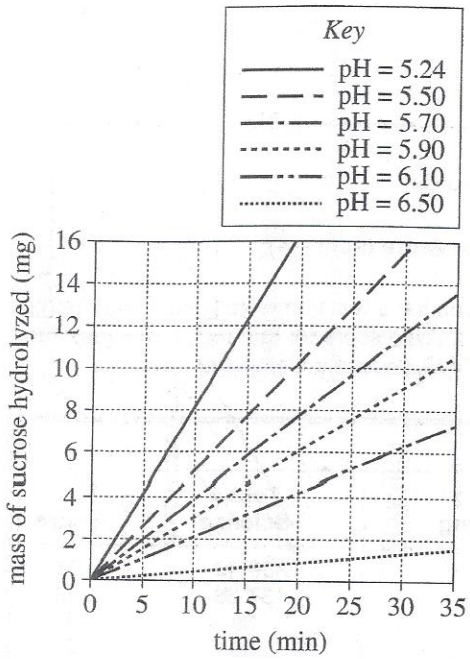


Figure 2

Figures adapted from George W. Farr and James R. Heitz, "Imidazole Catalysis of Sucrose Hydrolysis." ©1974 by International & American Associations for Dental Research.

34. In the trial of Experiment 2 that was done at a pH of 5.50, the mass of sucrose hydrolyzed by 35 min was most likely:

F. less than 13 mg.
G. between 13 mg and 17 mg.
H. between 17 mg and 21 mg.
J. greater than 21 mg.

35. During each trial of the experiments, as the mass of sucrose that was hydrolyzed increased, the concentration of fructose:

A. increased only.
B. decreased only.
C. increased, then remained constant.
D. decreased, then remained constant.

36. Suppose a trial had been done in Experiment 2 at a pH of 6.00. The mass of sucrose hydrolyzed by 20 min would most likely have been:

F. less than 4 mg.
G. between 4 mg and 6 mg.
H. between 6 mg and 8 mg.
J. greater than 8 mg.

37. Based on the results of Experiment 1, the imidazole concentration of the reaction solution in the trial of Experiment 2 done at a pH of 5.24 was most likely:

A. 0 g/L.
B. 5 g/L.
C. 20 g/L.
D. 25 g/L.

38. Which of the following factors was the same in every trial of Experiment 2, but was varied across trials in Experiment 1 ?

F. The temperature at which the reaction was carried out
G. The time over which the glucose concentration was monitored
H. The initial concentration of sucrose in the reaction solution
J. The concentration of imidazole in the reaction solution

39. How many of the 6 buffer solutions tested in Experiment 2 were acidic, and how many were basic?

	acidic	basic
A.	0	6
B.	6	0
C.	2	4
D.	4	2

40. A student claimed that imidazole must be present for the hydrolysis of sucrose to occur. Do the results of Experiment 1 *contradict* this claim?

F. Yes; the line in Figure 1 for 0 g/L has a positive slope.
G. Yes; the line in Figure 1 for 25 g/L has a positive slope.
H. No; the line in Figure 1 for 0 g/L has a positive slope.
J. No; the line in Figure 1 for 25 g/L has a positive slope.

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.