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

X-ray spectroscopy is a way of analyzing a mineral's composition. When an electron beam is directed onto a mineral, each element in the mineral emits characteristic X-rays having a narrow range of energies. The *intensity* of all X-rays emitted by the elements is measured. The greater the *maximum* intensity of the X-rays emitted by an element, the greater the relative concentration of the element in the mineral.

Figures 1 and 2 show X-ray spectroscopy results for Mineral 1 and Mineral 2, respectively, under identical conditions. Energy is given in kiloelectron volts (keV); intensity is given in counts per second (sec).

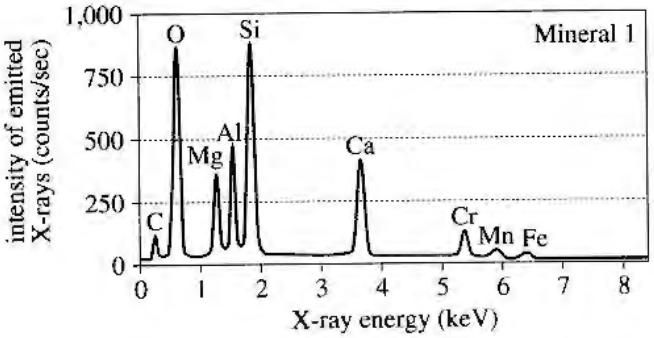


Figure 1

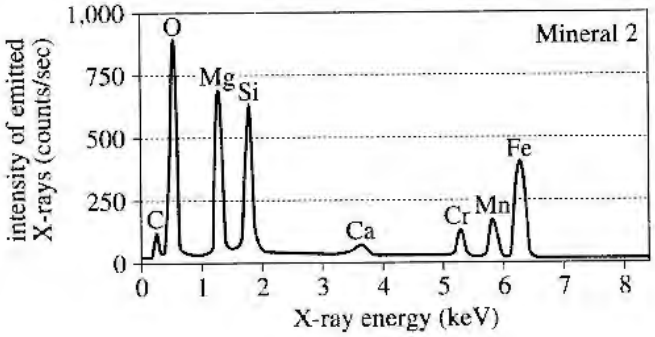


Figure 2

1. Which of the following elements emitted X-rays that had the same maximum intensity in both minerals?

   A. Ca
   B. Cr
   C. Fe
   D. Si

2. According to Figure 2 and additional information provided, what is the order of C, Ca, Mn, and Fe, from the element with the lowest relative concentration in Mineral 2 to the element with the highest relative concentration in Mineral 2 ?

   F. Ca, Mn, C, Fe
   G. Ca, C, Mn, Fe
   H. Fe, Mn, C, Ca
   J. Fe, C, Ca, Mn

3. The energy of the most intense X-rays emitted by an element is directly related to the element's atomic number. The atomic numbers of several of the elements are shown in the table below.

Element	Atomic number
Si	14
Ca	20
Cr	24

If an element with an atomic number of 22 had been present in Mineral 1, the energy of the most intense X-rays emitted by this element would most likely have been:

A. less than 3.5 keV.
B. between 3.5 keV and 5.5 keV.
C. between 5.5 keV and 7.5 keV.
D. greater than 7.5 keV.

4. According to Figure 1, the maximum intensity of the X-rays emitted by the Mg in Mineral 1 is less than half the maximum intensity of the X-rays emitted by which of the following other elements in Mineral 1 ?

F. Al
G. Ca
H. Cr
J. Si

5. Suppose that another mineral, Mineral 3, has the chemical formula $MnSiO_3$. Based on Figures 1 and 2, X-ray spectroscopy of this mineral would produce 3 maximum intensity peaks closest to which of the following energies?

A. 0.5 keV, 1.9 keV, and 5.9 keV
B. 0.5 keV, 3.7 keV, and 5.9 keV
C. 1.9 keV, 3.7 keV, and 5.3 keV
D. 1.9 keV, 5.3 keV, and 6.3 keV

Passage II

In red blood cells (RBCs), the protein *hemoglobin* (Hb) carries oxygen. Each Hb molecule contains 4 globin polypeptides—a pair of P-type globins and a pair of Q-type globins. The possible combinations of the P-type globin and the Q-type globin for the 3 variants of human Hb are shown in Table 1. For each combination, the notation is of the form $(\text{P-type})_2(\text{Q-type})_2$.

Table 1

Human Hb variant		
Hb1	Hb2	Hb3
$\zeta_2\varepsilon_2$ $\zeta_2\gamma_2$ $\alpha_2\varepsilon_2$	$\alpha_2\gamma_2$	$\alpha_2\beta_2$ $\alpha_2\delta_2$

Note: ζ, ε, γ, α, β, and δ are 6 different globin polypeptides. Each of them is either a P-type globin or a Q-type globin. For example, in each molecule of Hb2, α_2 is the P-type globin pair and γ_2 is the Q-type globin pair.

Figure 1 shows the sites of RBC production during early human development (gestation through 48 weeks after birth). The figure also shows, over that time period, what percent of the total number of globin polypeptides produced are ζ, ε, γ, α, β, or δ globin polypeptides.

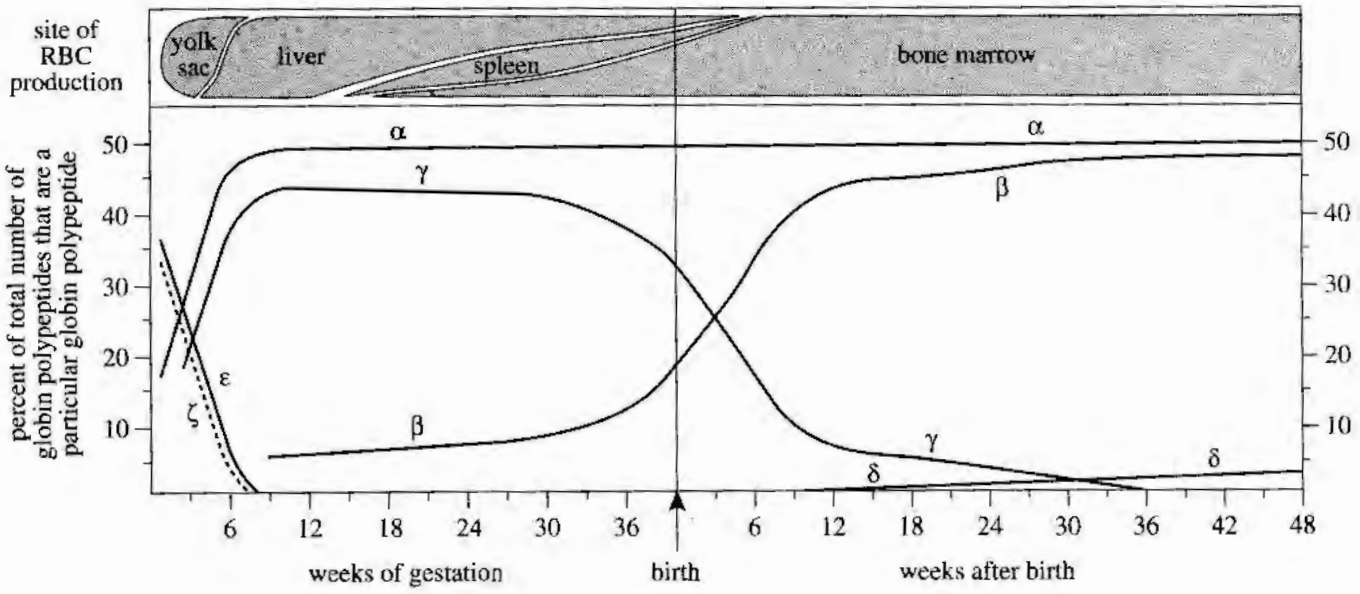


Figure 1

Table and figure adapted from Robert L. Nussbaum, Roderick R. McInnes, and Huntington F. Willard, *Thompson & Thompson Genetics in Medicine*, 6th edition. ©2004 by Elsevier.

6. According to Figure 1, ζ globin is found in RBCs that are produced at which 2 sites in the human body?

   F. Yolk sac and liver
   G. Liver and spleen
   H. Liver and bone marrow
   J. Spleen and bone marrow

7. According to Figure 1, approximately what percent of the total number of globin polypeptides produced in the RBCs of a human at birth are α globins?

   A. 13%
   B. 21%
   C. 30%
   D. 50%

8. The percent of any particular globin polypeptide produced in the RBCs of a human does not change significantly after the first 48 weeks of age. Based on this information and the information provided in the passage, the most abundant Hb variant in a healthy 2-year-old child would most likely have what globin polypeptide combination?

   F. $\alpha_2\beta_2$
   G. $\alpha_2\delta_2$
   H. $\alpha_2\gamma_2$
   J. $\alpha_2\varepsilon_2$

9. According to the information given, which Hb variant, Hb2 or Hb3, is more abundant in RBCs from 12 weeks to 24 weeks of gestation?

   A. Hb2, because the percent of β globin produced is greater than the percent of γ globin produced.
   B. Hb2, because the percent of γ globin produced is greater than the percent of β globin produced.
   C. Hb3, because the percent of β globin produced is greater than the percent of γ globin produced.
   D. Hb3, because the percent of γ globin produced is greater than the percent of β globin produced.

10. Based on Table 1, how many different P-type globins and how many different Q-type globins, respectively, are found among the 3 hnman Hb variants?

	P-type globins	Q-type globins
F.	1	3
G.	2	4
H.	2	5
J.	4	6

Passage III

Prey can use visual cues and/or chemical cues to identify predators. Students conducted 2 experiments to determine if visual cues and/or chemical cues affected how guppies (a prey fish) responded to cichlids (a guppy predator).

Experiment 1

Four identical tanks (Tanks 1–4) were filled with water. A barrier was placed in each tank to divide each tank into 2 equal halves, the predator half and the prey half. The type of barrier was different for each tank (see Table 1). Three regions (Regions X–Z), each 10 cm wide, were designated in the prey half of each tank (see diagram).

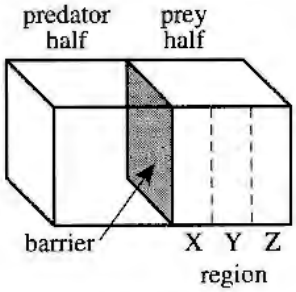


diagram of tank

Table 1

Tank	Barrier	Cue(s) transmitted through the barrier
1	opaque withont perforations	none
2	transparent without perforations	visual only
3	opaque with perforations	chemical only
4	transparent with perforations	visual and chemical

A guppy was added to the prey half of each tank, and a cichlid was added to the predator half of each tank. The guppy in each tank was observed every 15 sec for the next 5 min, and the region in which the guppy was located at the time of each observation was recorded. Then, the percent of observations recorded for each region was determined (see Figure 1).

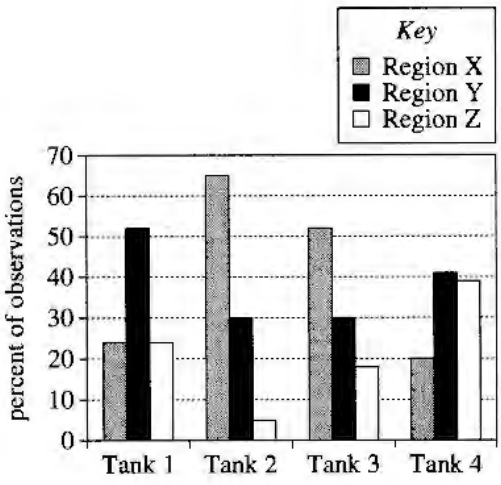


Figure 1

Experiment 2

Tanks 1–4 were emptied. Then, Experiment 1 was repeated in every respect but the following: 4 guppies were added to the prey half of each tank, and the location of each of the guppies was recorded at the time of each observation (see Figure 2).

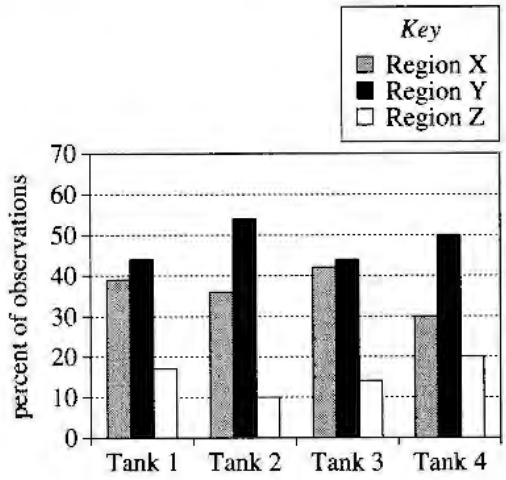


Figure 2

Figures 1 and 2 adapted from Jason Jones et al., "Senses & Sensibility: Predator-Prey Experiments Reveal How Fish Perceive & Respond to Threats." ©2008 by the American Biology Teacher.

11. In Experiment 1, in which of the tanks was the guppy able to see the cichlid?

    A. Tank 1 only
    B. Tanks 2 and 4 only
    C. Tanks 3 and 4 only
    D. Tanks 2, 3, and 4 only

12. Experiment 1 differed from Experiment 2 in which of the following ways?

    F. More cichlids were observed in Experiment 1 than in Experiment 2.
    G. More cichlids were observed in Experiment 2 than in Experiment 1.
    H. More guppies were observed in Experiment 1 than in Experiment 2.
    J. More guppies were observed in Experiment 2 than in Experiment 1.

13. A student hypothesized that when no cues were transmitted through the barrier, the percent of observations in Region Y would be the same regardless of the number of guppies in the tank. Are the results of Experiments 1 and 2 consistent with this hypothesis?

    A. Yes; the percent of observations in Region Y was the same for Tank 1 in Experiment 1 and Tank 1 in Experiment 2.
    B. Yes; the percent of observations in Region Y was the same for Tank 1 in Experiment 1 and Tank 3 in Experiment 2.
    C. No; the percent of observations in Region Y was uot the same for Tank 1 in Experiment 1 and Tank 1 in Experiment 2.
    D. No; the percent of observations in Region Y was not the same for Tauk 1 in Experiment 1 and Tank 3 iu Experiment 2.

14. Consider the results of Experiment 2 for the tank with the barrier through which both visual cues and chemical cues were transmitted. What is the order of the regions of the tank, from the region with the largest percent of observations to the region with the smallest percent of observations?

    F. Region Y, Region X, Region Z
    G. Region Y, Region Z, Region X
    H. Region Z, Region X, Region Y
    J. Region Z, Region Y, Region X

15. A student hypothesized that any guppy receiving visual cues would stay as far away from a predator as possible. Are the results of Experiment 1 consistent with this hypothesis?

    A. Yes; in Experiment 1, neither the guppy in Tank 2 nor the guppy in Tank 4 was observed in Region X.
    B. Yes; in Experiment 1, neither the guppy in Tank 1 nor the guppy in Tank 3 was observed in Region Z.
    C. No; in Experiment 1, both the guppy in Tank 2 and the guppy in Tank 4 were observed in Region X.
    D. No; in Experiment 1, both the guppy in Tank 1 and the guppy in Tank 3 were observed iu Region Z.

16. The students conducting the experiments made which of the following assumptions about chemical cues?

    F. Chemical cues were not produced by the cichlids when a barrier was present.
    G. Chemical cues were not produced by the cichlids when a barrier was absent.
    H. Chemical cues could diffuse through the barriers without perforations.
    J. Chemical cues could not diffuse through the barriers without perforations.

Passage IV

Using the equipment shown in Figure 1, a group of students performed 3 experiments involving pendulums in motion. Each pendulum consisted of a bob of mass M suspended from a rigid support by a string of length L.

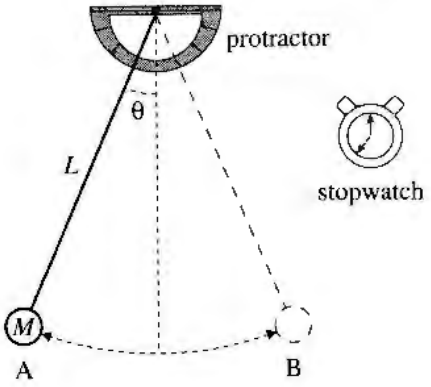


Figure 1

At the start of each trial, the students displaced the bob to a selected angle, θ, measured from the vertical, using a protractor fastened to the support. The students then released the bob from rest, allowing it to swing back and forth. They used a stopwatch to measure the *period*, T, of the pendulum, defined as the time required for the bob to complete 1 *full swing* (from Point A to Point B and back to Point A).

Before each experiment, the students derived an equation, based on the laws of physics, to predict T for each trial of that experiment. Then, after obtaining their measurements, the students graphed their predicted T data and their measured T data.

Experiment 1

A pendulum with $M = 100$ g and $L = 100$ cm was released from rest at various values of θ, in degrees. The pendulum was timed for 10 full swings and the measured time was then divided by 10 to obtain a measured average T, in seconds (sec), for each θ (see Figure 2).

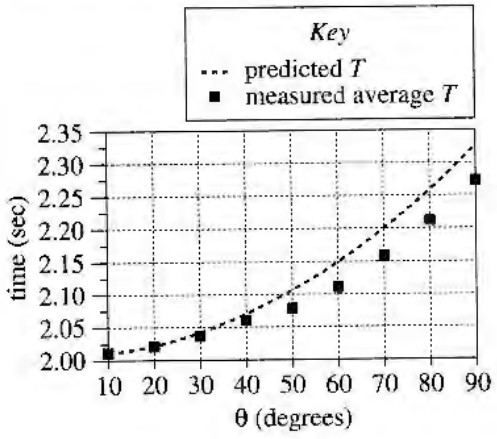


Figure 2

Experiment 2

Pendulums with $M = 100$ g but various values of L were released from rest at $\theta = 10°$. The measured average T for each pendulum was obtained as in Experiment 1 (see Figure 3).

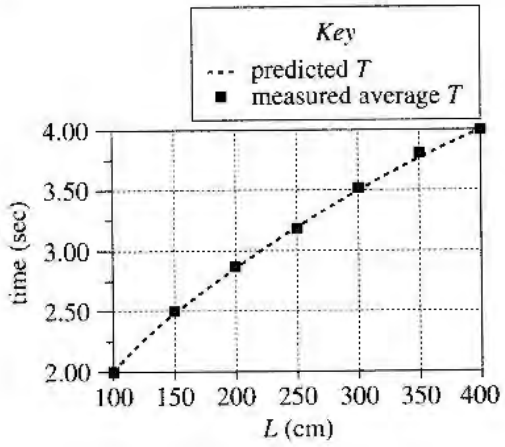


Figure 3

Experiment 3

Pendulums with $L = 100$ cm but various values of M were released from rest at $\theta = 10°$. The measured average T for each pendulum was obtained as in Experiment 1 (see Figure 4).

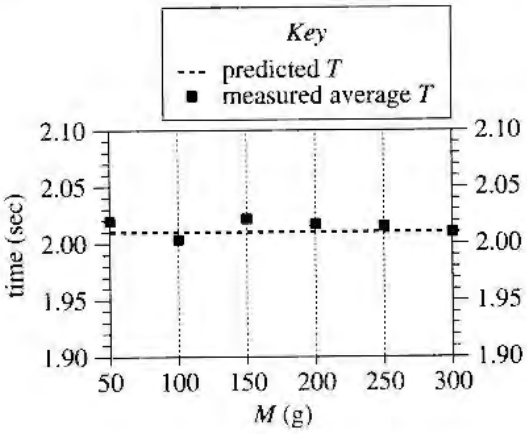


Figure 4

17. In Experiment 1, the gravitational potential energy of the pendulum bob was greatest when the bob was released from which selected value of θ ?

A. 10°
B. 30°
C. 70°
D. 90°

18. Suppose a trial had been performed in Experiment 2 using a pendulum with $L = 175$ cm. The measured average T for this pendulum would most likely have been between:

F. 1.50 sec and 2.00 sec.
G. 2.00 sec and 2.50 sec.
H. 2.50 sec and 3.00 sec.
J. 3.00 sec and 3.50 sec.

19. According to the results of Experiment 1, for $\theta = 70°$, the measured average T was how many seconds less than, or how many seconds greater than, the predicted T ?

A. 0.04 sec less
B. 2.16 sec less
C. 0.04 sec greater
D. 2.16 sec greater

20. How did the procedure followed in Experiment 1 differ from the procedure followed in Experiment 2 ? In Experiment 1:

F. θ was varied while M and L were held constant, but in Experiment 2, L was varied while M and θ were held constant.
G. θ was varied while M and L were held constant, but in Experiment 2, M was varied while L and θ were held constant.
H. L was varied while θ and M were held constant, but in Experiment 2, θ was varied while L and M were held constant.
J. L was varied while θ and M were held constant, but in Experiment 2, M was varied while L and θ were held constant.

21. Based on the results of Experiments 1 and 2, which of the following changes in θ or in L would most likely yield the greatest change in the measured average T for a pendulum with $M = 100$ g ?

A. Increasing θ from 10° to 70°
B. Increasing θ from 20° to 90°
C. Increasing L from 100 cm to 200 cm
D. Increasing L from 200 cm to 250 cm

22. Suppose Experiment 3 had been repeated, except that each pendulum had a string length of 200 cm. Based on the results of Experiments 2 and 3, the graph of predicted T versus M for the pendulums would most likely have been a:

F. straight horizontal line crossing both vertical axes at approximately 2.01 sec.
G. straight horizontal line crossing both vertical axes at approximately 2.85 sec.
H. curve crossing the left vertical axis at approximately 2.01 sec, increasing as M increases.
J. curve crossing the left vertical axis at approximately 2.85 sec, increasing as M increases.

Passage V

When *vinegar* (a solution of acetic acid, CH_3COOH, in H_2O) is mixed with *baking soda* (sodium bicarbonate, $NaHCO_3$), the following reaction occurs:

$$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$$

A teacher constructed the apparatus shown in Figure 1 for a demonstration. First, 30 mL of vinegar was poured into a bottle. Then, 5 g of baking soda was placed in a balloon. The balloon was affixed to the top of the bottle with wire to form an airtight seal.

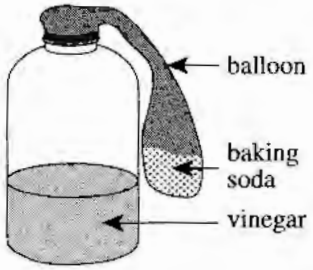


Figure 1

The apparatus was placed on a balance, and the mass reading was 68.7 g. The balloon was then lifted up so that all the baking soda fell into the bottle. As bubbles formed in the bottle, the balloon inflated and the mass reading on the balance steadily *decreased*. When the reaction was finished, the mass reading was 68.1 g (see Figure 2).

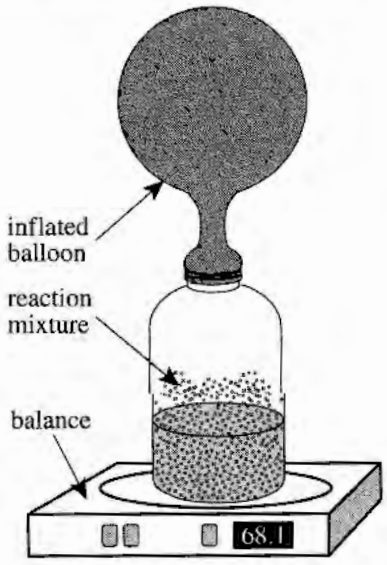


Figure 2

The teacher asked 3 students to explain what occurred in the demonstration. The students agreed that the balloon inflated because bubbles of CO_2 formed and then exited the reaction mixture. They disagreed about why the mass reading on the balance decreased.

Student 1

No gas exited the apparatus because it was airtight. Gases, however, have no mass, so as CO_2 was produced, the mass of the apparatus decreased.

Student 2

Gases have mass, so the mass of the apparatus should not have changed. A balloon, however, will deflate over time because there are tiny pores in its surface. Due to the rapid pressure increase in the apparatus, a measurable mass of CO_2 exited through the pores in the quickly expanding balloon, which caused the mass of the apparatns to decrease.

Student 3

Gases have mass, and although there are tiny pores in a balloon's surface, there was not enough time for a measurable mass of gases to have exited the balloon. The air exerted an upward *buoyant force* on the apparatus that was equal to the weight of the volume of air that was displaced by the apparatus. As the balloon inflated, the volume of the apparatus increased, causing it to displace a greater volume of air. Thus, the buoyant force increased, which caused the mass reading on the balance to decrease. The actual mass of the apparatus did not measurably change.

23. The explanation given by which student, if any, is *inconsistent* with the law of conservation of mass?

A. Student 1
B. Student 2
C. Student 3
D. None of the students

24. Suppose that while the balloon was inflating, a probe located near the balloon had detected a significant increase in the concentration of CO_2 in the air surrounding the balloon. Which of the students gave an explanation that would be supported by this finding?

F. Student 1 only
G. Student 2 only
H. Students 1 and 2 only
J. Students 1, 2, and 3

25. As the balloon inflated, did the mass of acetic acid in the bottle increase or decrease?

A. Increase, because acetic acid was being consumed.
B. Increase, because acetic acid was being produced.
C. Decrease, because acetic acid was being consumed.
D. Decrease, because acetic acid was being produced.

26. When empty, a particnlar balloon has a mass of 2.0 g. After the balloon is completely inflated with CO_2 and sealed, the mass of the inflated balloon and its contents is 3.0 g. The mass 24 hr later is still 3.0 g. These observations are most consistent with the explanation given by which, if any, student?

F. Student 1
G. Student 2
H. Student 3
J. The observations are equally consistent with the explanations given by all 3 students.

27. Based on Student 3's explanation, the mass of air that was displaced by the inflated balloon was approximately:

A. 0.6 g.
B. 5.0 g.
C. 68.1 g.
D. 68.7 g.

28. Suppose that the apparatus had been fitted with a rigid, airtight cap instead of the balloon, and that the baking soda had been contained in a chamber below the cap. If the baking soda in the chamber had been released by remote control into the vinegar, which of the students would have been likely to predict that the mass reading on the balance would *decrease* ?

F. Student 1 only
G. Students 1 and 3 only
H. Stndents 2 and 3 only
J. Stndents 1, 2, and 3

29. Which of the students wonld agree that the actual mass of the apparatus decreased by more than 0.1 g during the demonstration?

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

Passage VI

A *parallel-plate capacitor* (PPC) stores electric charge on 2 separated plates when a voltage is applied across the plates. Figure 1 shows a PPC before (left) and after (right) it was filled with a *dielectric* (insulating material). The capacitance of an empty PPC, C_0, is the amount of charge stored per unit of applied voltage. The capacitance of a filled PPC, C_κ, equals C_0 multiplied by the *dielectric constant*, κ, of the filling material. Table 1 gives κ for 12 materials. Table 2 gives the *dielectric strength*, S (the maximum electric field strength at which a dielectric remains an insulator), for 7 of the materials.

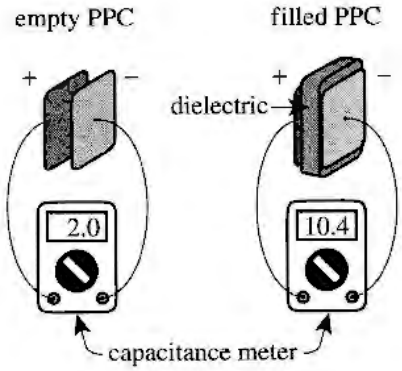


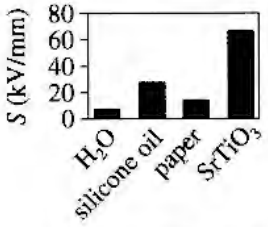
Figure 1

Table 1		
Material		κ
Gases	oxygen	1.00048
	nitrogen	1.00052
	air	1.00053
	CO_2	1.00092
Liquids	silicone oil	2.5
	ethanol	25.3
	glycerol	46.5
	H_2O	80.1
Solids	polystyrene	2.6
	paper	3.7
	Pyrex glass	5.2
	$SrTiO_3$*	332.1
*strontium titanate		

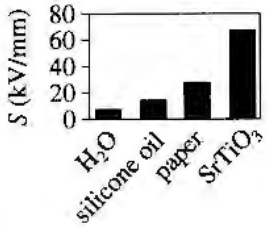
Table 2	
Material	S (kV/mm*)
Oxygen	2.97
Nitrogen	3.23
Air	3.13
Silicone oil	15.0
H_2O	67.5
Paper	28.7
$SrTiO_3$	8.0
*kilovolts per millimeter of material thickness	

30. Based on Table 2, which of the following graphs best represents S for H_2O, silicone oil, paper, and $SrTiO_3$?

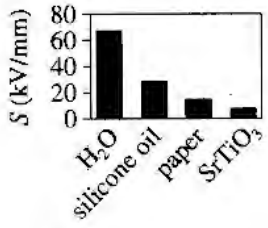
F.



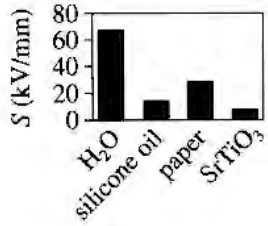
G.



H.



J.



31. For many substances, κ depends on temperature. The table below gives κ for H_2O at several temperatures.

Temperature (°C)	κ
0.0	87.9
30.0	76.6
60.0	66.7
90.0	58.1

The κ for H_2O given in Table 1 was most likely measured at a temperature closest to which of the following?

A. 20°C
B. 40°C
C. 80°C
D. 100°C

32. Based on Table 1, the dielectric that fills the PPC shown in Fignre 1 is most likely which material?

F. Polystyrene
G. Paper
H. Pyrex glass
J. $SrTiO_3$

33. Based on Table 2, when exposed to an electric field of 3.00 kV/mm, which of the gases listed below remain(s) an insulator?

I. Oxygen
II. Nitrogen
III. Air

A. I only
B. III only
C. I and II only
D. II and III only

34. Lightning strikes can occur when air between the ground and the base of a storm cloud is exposed to an electric field stronger than S for air. Suppose a certain storm cloud's base is 300 m above the ground. Based on Table 2, approximately what minimum voltage would be present between the storm cloud's base and the ground immediately before a bolt of lightning from this storm cloud strikes the ground?

F. 300,000 mm × 3.13 kV/mm
G. 300,000 m × 3.13 kV/mm
H. $\frac{300\text{ mm}}{3.13\text{ kV/mm}}$
J. $\frac{300\text{ m}}{3.13\text{ kV/mm}}$

Passage VII

In a particular *estuary* (an inlet where ocean water and river water mix), the sediment contains the radioactive isotopes lead-210 (^{210}Pb) and cesium-137 (^{137}Cs). The isotopes are components of particles that fall from the air into the estuary. Unlike ^{210}Pb, ^{137}Cs is prodnced only by human activities. It has been detectable in the estuary sediment since 1954, the year it was first found in Earth's atmosphere. In 2003, 2 studies examined ^{210}Pb and ^{137}Cs concentrations in the estuary sediment.

At each of 2 sites (Site 1 and Site 2), 4 cylindrical vertical cores of the sediment, each 5.0 cm in diameter and 40 cm in length, were collected. Each core's sediment was sampled at the top and then every 2 cm down the core's length. The Site 1 samples from the same depth in each core were combined, and the Site 2 samples from the same depth in each core were combined.

Study 1

A portion of each combined sample was analyzed to determine the ^{210}Pb concentration in *becquerels* per kilogram of sediment (Bq/kg). (One becquerel is equivalent to 1 nnclear decay per second.) The results are shown in Figure 1.

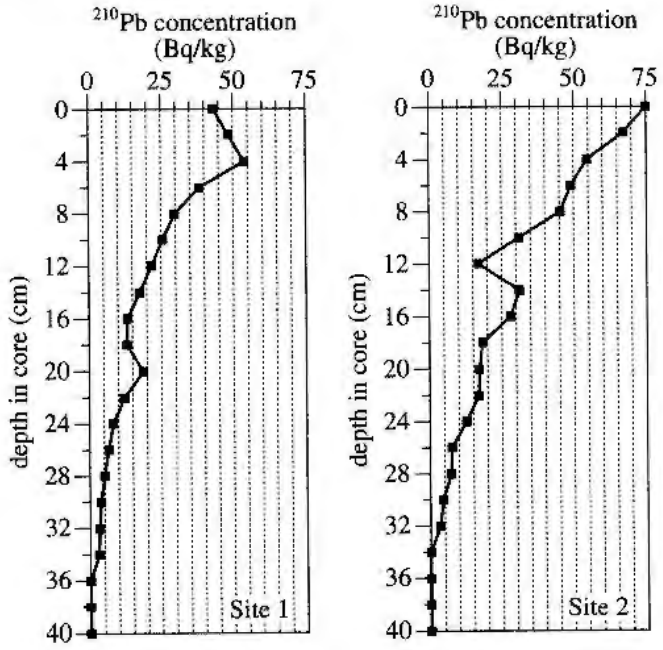


Figure 1

Study 2

Another portion of each combined sample was analyzed to determine the ^{137}Cs concentration (see Figure 2). The ^{137}Cs data indicated the total thickness of sediment that had been deposited at each site from 1954 to 2003. Then, the average sediment accumulation rate over that period was calculated for each site. The Site 1 rate was 0.41 cm/yr; the Site 2 rate was 0.37 cm/yr.

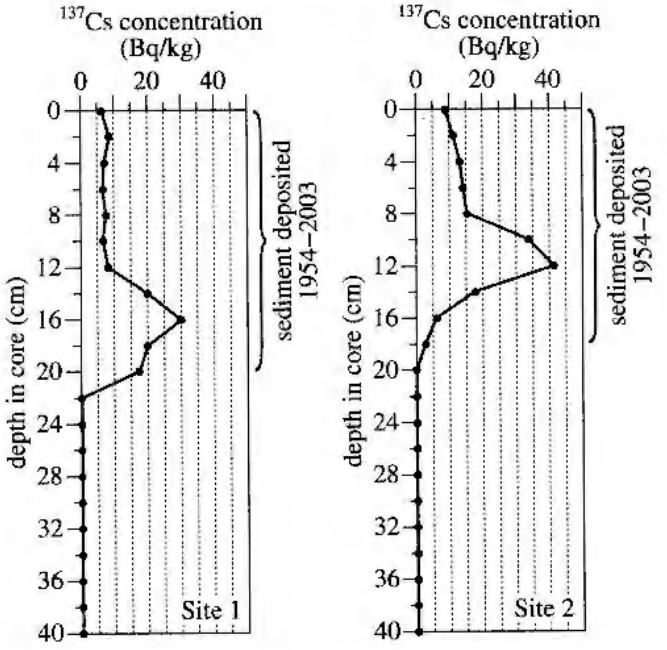


Figure 2

Figures adapted from M. C. Freitas et al., "Anthropogenic Influence in the Sado Estuary (Portugal): A Geochemical Approach." ©2008 by Journal of Iberien Geology.

35. According to the results of Study 1, at Site 1, what was the maximum concentration of ^{210}Pb in a combined sediment sample and from what depth was that sample?

	^{210}Pb concentration (Bq/kg)	depth in core (cm)
A.	54	0
B.	54	4
C.	75	0
D.	75	4

36. At the average sediment accumulation rate calculated for Site 1 in Study 2, the time it would take to accumulate a 40 cm thickness of sediment would be closest to which of the following?

F. 40 yr
G. 100 yr
H. 400 yr
J. 1,000 yr

37. Suppose equal masses of the combined sediment samples from a depth of 8 cm at Site 1 and of the combined sediment samples from a depth of 8 cm at Site 2 had been thoroughly mixed and then analyzed for ^{210}Pb. Based on the results of Study 1, the ^{210}Pb concentration would most likely have been:

A. less than 30 Bq/kg.
B. between 30 Bq/kg and 45 Bq/kg.
C. between 45 Bq/kg and 60 Bq/kg.
D. greater than 60 Bq/kg.

38. According to the results of Study 1, at Site 2, the concentration of ^{210}Pb in the sample of surface sediment was how many times as great as the concentration of ^{210}Pb in the sample from a depth of 10 cm ?

F. Less than 0.5
G. 0.5
H. 2.0
J. More than 2.0

39. Based on the information provided, why was no ^{137}Cs present in the Site 1 and Site 2 sediments at a depth of 30 cm ?

A. All the ^{137}Cs in the sediments had decayed.
B. All the ^{137}Cs in the sediments had reacted with other elements.
C. The sediments at that depth were deposited before 1954.
D. The sediments at that depth were deposited after 1954.

40. In Study 2, the average sediment accumulation rate for Site 2 was calculated using which of the following expressions?

F. 18 cm ÷ 49 yr
G. 49 yr ÷ 18 cm
H. 40 cm ÷ 49 yr
J. 49 yr ÷ 40 cm

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.