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

Table 1 lists the name, chemical formula, *molecular mass* (the mass of 1 molecule in atomic mass units, amu), and BP (the boiling point at 1 atmosphere of pressure) of various compounds. The first compound listed is composed of the elements carbon (C) and hydrogen (H). Each of the other compounds is composed of C, H, and either fluorine (F), chlorine (Cl), bromine (Br), or iodine (I). The elements F, Cl, Br, and I belong to the *halogen* family.

Table 1

Name	Chemical formula	Molecular mass (amu)	BP (°C)
Methane	CH_4	16	−162
Fluoromethane	CH_3F	34	−78
Difluoromethane	CH_2F_2	52	−52
Trifluoromethane	CHF_3	70	−82
Chloromethane	CH_3Cl	51	−24
Dichloromethane	CH_2Cl_2	85	40
Trichloromethane	$CHCl_3$	119	61
Bromomethane	CH_3Br	95	4
Dibromomethane	CH_2Br_2	174	97
Tribromomethane	$CHBr_3$	253	149
Iodomethane	CH_3I	142	42
Diiodomethane	CH_2I_2	268	182
Triiodomethane	CHI_3	394	218

Table 1 adapted from W. M. Haynes, ed., *CRC Handbook of Chemistry and Physics on CD-ROM*, Version 2011. ©2011 by CRC Press, LLC.

Figure 1 shows a plot of BP versus molecular mass for 3 groups of compounds (Groups 1–3). Each compound in each group is composed of C and 1 or more halogens.

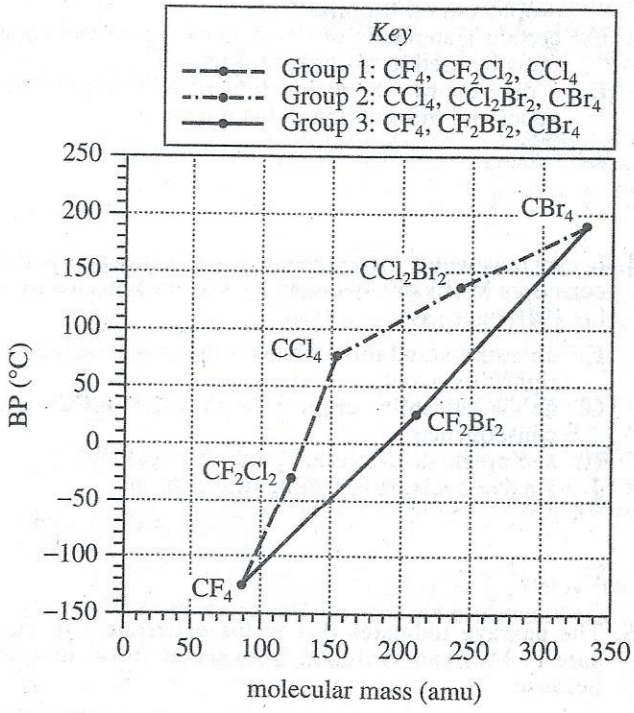


Figure 1

Figure 1 adapted from Michael Laing, "Boiling Points of the Family of Small Molecules, $CH_wF_xCl_yBr_z$: How Are They Related to Molecular Mass?" ©2001 by Division of Chemical Education, Inc., American Chemical Society.

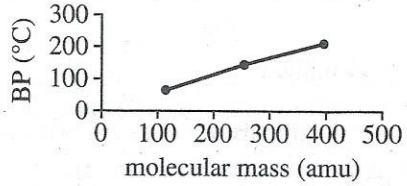
1. The compound represented in Figure 1 that has a BP of −30°C has a molecular mass of about:

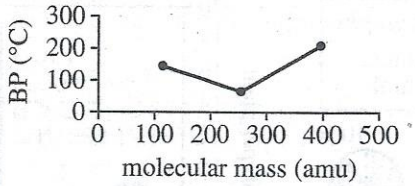
   A. 90 amu.
   B. 120 amu.
   C. 150 amu.
   D. 210 amu.

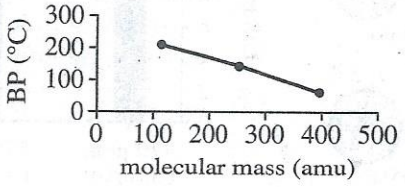
2. According to Figure 1, of the following compounds, which one has the highest BP ?

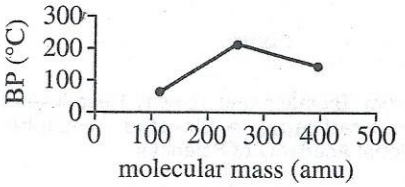
   F. CF_4
   G. CF_2Cl_2
   H. CF_2Br_2
   J. CCl_4

3. According to Table 1, the relationship between molecular mass and BP among the compounds $CHCl_3$, $CHBr_3$, and CHI_3 is best represented by which of the following graphs?

   A.
   

   B.
   

   C.
   

   D.
   

4. At 1 atmosphere of pressure, the temperature at which CH_2I_2 boils is how much greater than the temperature at which CH_4 boils?

   F. 162°C
   G. 268°C
   H. 344°C
   J. 430°C

5. According to Table 1 and Figure 1, the molecular mass of CF_4 is closest to the molecular mass of which of the following compounds?

   A. Dichloromethane
   B. Trichloromethane
   C. Iodomethane
   D. Dibromomethane

6. The *atomic mass* (the mass of 1 atom, in amu) of C is 12 amu. Based on the molecular mass of CBr_4 shown in Figure 1, the atomic mass of Br is closest to which of the following?

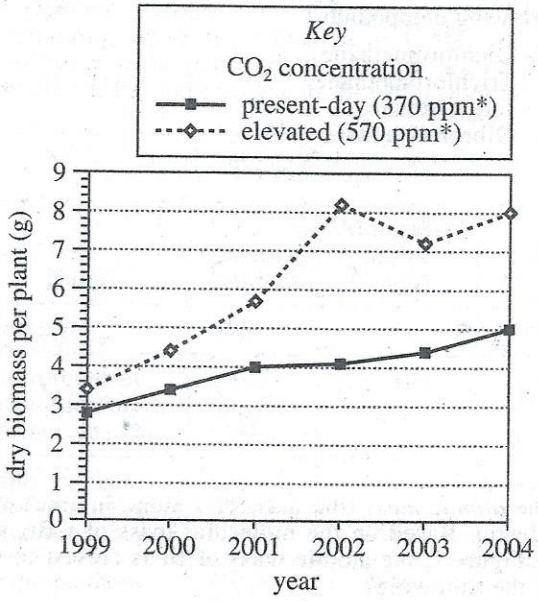
   F. 20 amu
   G. 35 amu
   H. 80 amu
   J. 127 amu

Passage II

Urushiols are the oils in poison ivy that cause allergic reactions in humans. The higher the *U:S ratio*—the ratio of unsaturated (U) urushiols to saturated (S) urushiols—the more severe the reaction.

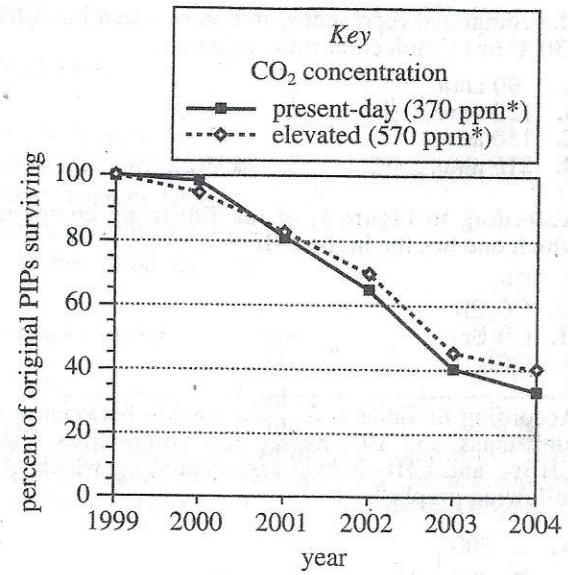
From 1999 to 2004, poison ivy plants (PIPs) were grown in 2 identical outdoor plots under identical conditions except for the atmospheric CO_2 concentration.

Figure 1 shows, for each plot, the yearly dry biomass per plant. Figure 2 shows the yearly percent of original PIPs surviving in each plot. Figure 3 shows, for each plot in 2004, the percent of U urushiols per plant, the percent of S urushiols per plant, and the U:S ratio per plant.



*ppm = parts per million

Figure 1



*ppm = parts per million

Figure 2

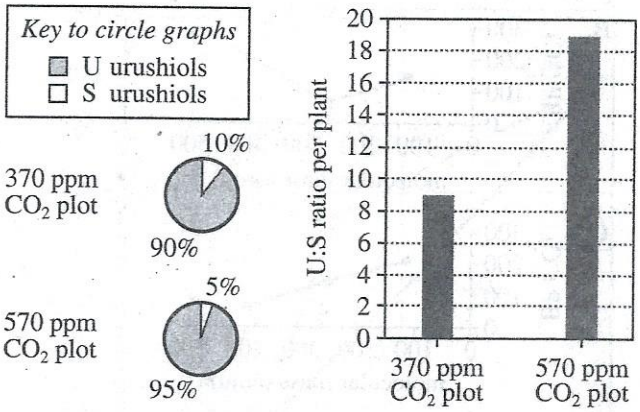


Figure 3

Figures adapted from "Biomass and Toxicity Responses of Poison Ivy (*Toxicodendron radicans*) to Elevated Atmospheric CO_2." ©2006 by the National Academy of Sciences.

7. According to Figure 3, for the present-day CO_2 concentration plot, the percent of U urushiols per plant in 2004 was:

   A. 10%.
   B. 20%.
   C. 50%.
   D. 90%.

8. According to Figure 2, which plot had the higher percent of original PIPs surviving at the end of the study?

   F. The present-day CO_2 plot, by a difference of 1%
   G. The present-day CO_2 plot, by a difference of 7%
   H. The elevated CO_2 plot, by a difference of 1%
   J. The elevated CO_2 plot, by a difference of 7%

9. Based on the passage, which of the factors listed below was(were) the same for the 2 plots?

   I. Atmospheric CO_2 concentration in each plot
   II. Soil type in each plot
   III. Amount of water applied to each plot

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

10. According to Figure 1, from 1999 to 2004, how did the dry biomasses per plant for the 2 plots compare? The dry biomass per plant grown in a CO_2 concentration of 370 ppm was:

    F. always the same as the dry biomass per plant grown in a CO_2 concentration of 570 ppm.
    G. always greater than the dry biomass per plant grown in a CO_2 concentration of 570 ppm.
    H. always less than the dry biomass per plant grown in a CO_2 concentration of 570 ppm.
    J. in some years greater than, but in other years less than, the dry biomass per plant grown in a CO_2 concentration of 570 ppm.

11. Based on Figure 2, what percent of PIPs grown in the plot with a CO_2 concentration of 370 ppm had *died* by the year 2003 ?

    A. 40%
    B. 45%
    C. 55%
    D. 60%

12. According to Figure 3, which plot produced a higher percent of S urushiols per plant?

    F. The present-day CO_2 concentration plot; 10% of the urushiols produced per plant were saturated.
    G. The present-day CO_2 concentration plot; 90% of the urushiols produced per plant were saturated.
    H. The elevated CO_2 concentration plot; 5% of the urushiols produced per plant were saturated.
    J. The elevated CO_2 concentration plot; 95% of the urushiols produced per plant were saturated.

Passage III

When the ozone (O_3) in air is mixed with an acidic solution of iodide ion (I^-), the O_3 reacts to form triiodide ion (I_3^-), O_2, and H_2O.

$$O_3 + 3I^- + 2H^+ \rightarrow I_3^- + O_2 + H_2O$$

Students performed an experiment to determine the concentration of O_3 in samples of air. Figure 1 shows the relationship between the concentration of I_3^-, in µmol/L, and the concentration of O_3, in parts per billion (ppb), under the conditions of the experiment.

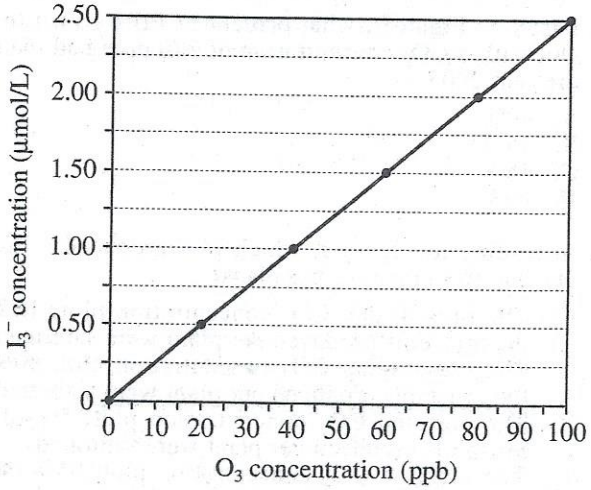


Figure 1

Experiment

At each of 4 outdoor sites, the students assembled the apparatus shown in Figure 2. First, they attached a long piece of tubing to a stand so that one end of the tubing was 1.5 m above the ground. Then, they placed the other end of the tubing into one hole of a 2-holed stopper. Next, they placed one end of a shorter piece of tubing into the second hole of the 2-holed stopper and attached the other end of the shorter tubing to a vacuum pump.

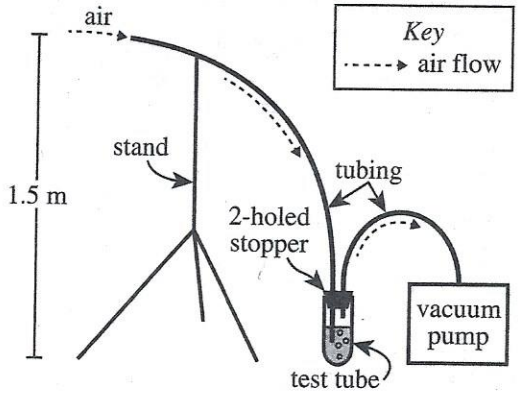


Figure 2

At each site, the students performed the following 2 steps every half hour from 12:30 p.m. to 5:30 p.m. on a particular day:

1. A 10.0 mL volume of an aqueous acidic solution having a 10 mg/mL concentration of I^- was placed into a clean, empty test tube that was then sealed with the 2-holed stopper.

2. The vacuum pump was turned on for 25 min to collect an air sample. Then, the pump was turned off and the concentration of I_3^-, in micromoles/liter (µmol/L), in the solution was measured.

The results are shown in Figure 3.

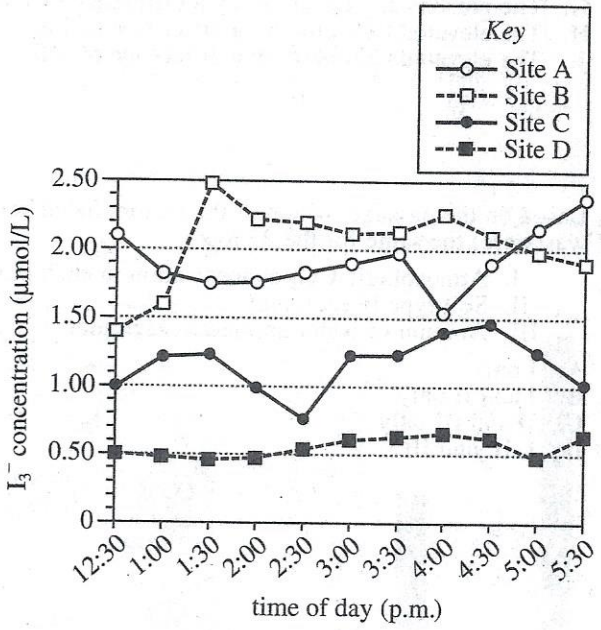


Figure 3

Figures adapted from J. V. Seeley et al., "A Simple Method for Measuring Ground-Level Ozone in the Atmosphere." ©2005 by the Division of Chemical Education, Inc., American Chemical Society.

13. Based on Figures 1 and 3, the air sample collected at which of the following combinations of time and location had the *lowest* O_3 concentration?

	time	location
A.	2:30 p.m.	Site B
B.	2:30 p.m.	Site C
C.	4:00 p.m.	Site B
D.	4:00 p.m.	Site C

14. Consider the air samples that were collected at the 4 sites at 2:00 p.m. Based on Figures 1 and 3, what is the order of those samples from lowest O_3 concentration to highest O_3 concentration?

F. Site A, Site B, Site C, Site D
G. Site C, Site B, Site A, Site D
H. Site D, Site C, Site A, Site B
J. Site D, Site A, Site C, Site B

15. Based on Figures 1 and 3, which site had the highest overall average O_3 concentration across all the air samples?

A. Site A
B. Site B
C. Site C
D. Site D

16. Based on Figures 1 and 3, the O_3 concentration at 5:00 p.m. at Site B was approximately how many times as great as the O_3 concentration at 2:00 p.m. at Site C ?

F. 0.5
G. 2
H. 3
J. 4

17. At Site A, was the O_3 concentration highest at 4:00 p.m. or at 5:30 p.m. ?

A. 4:00 p.m.; the I_3^- concentration was highest at 4:00 p.m., and the higher the I_3^- concentration, the higher the O_3 concentration.
B. 4:00 p.m.; the I_3^- concentration was lowest at 4:00 p.m., and the lower the I_3^- concentration, the higher the O_3 concentration.
C. 5:30 p.m.; the I_3^- concentration was highest at 5:30 p.m., and the higher the I_3^- concentration, the higher the O_3 concentration.
D. 5:30 p.m.; the I_3^- concentration was lowest at 5:30 p.m., and the lower the I_3^- concentration, the higher the O_3 concentration.

18. When a vacuum pump was operating during Step 2, it drew air through the solution in the test tube. Assuming that the pump drew air at a rate of 200 mL/min, how many milliliters of air were drawn through the solution in the test tube each time Step 2 was performed?

F. 200 mL
G. 550 mL
H. 2,500 mL
J. 5,000 mL

19. Suppose that the actual O_3 concentration at 12:30 p.m. at Site C was 43 ppb. Based on Figures 1 and 3, which of the following expressions would give the percent error for the value of the O_3 concentration that was determined at 12:30 p.m. at Site C ?

A. $\frac{|40 \text{ ppb} - 43 \text{ ppb}|}{43 \text{ ppb}} \times 100\%$
B. $\frac{|40 \text{ ppb} - 43 \text{ ppb}|}{40 \text{ ppb}} \times 100\%$
C. $\frac{|100 \text{ ppb} - 43 \text{ ppb}|}{43 \text{ ppb}} \times 100\%$
D. $\frac{|100 \text{ ppb} - 43 \text{ ppb}|}{40 \text{ ppb}} \times 100\%$

Passage IV

When waves of laser light pass through a narrow slit and onto a screen, they form a pattern of light and dark bands on the screen, as shown in Figure 1.

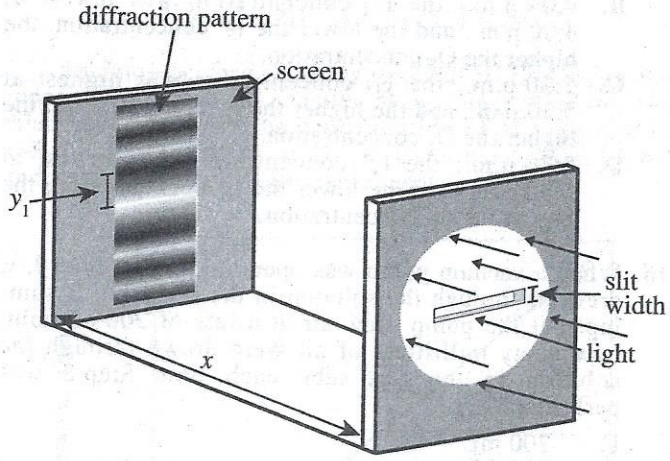


Figure 1

Figure 1 adapted from Francis Sears and Mark Zemanski, *College Physics*. ©1960 by Addison Wesley Publishing Co., Inc.

This phenomenon is called *diffraction*, and the pattern is called a *diffraction pattern*.

In each of the following studies of diffraction, students directed laser light through a slit, forming a diffraction pattern on a screen. They measured y_1, the distance from the center of the brightest band in the pattern to the center of one of the 2 adjacent dark bands. In each study, x was the distance between the slit and the screen.

Study 1

In Trials 1–4, the slit width was varied, the wavelength of the laser light was fixed, and x was 6.00 m. The results are shown in Table 1.

Table 1

Trial	Slit width (mm)	y_1 (mm)
1	0.12	30.0
2	0.24	15.0
3	0.36	10.0
4	0.48	7.5

Study 2

In Trials 5–8, the slit width was 0.24 mm, the wavelength (color) of the laser light was varied, and x was 6.00 m. The results are shown in Table 2.

Table 2

Trial	Wavelength (nm)	y_1 (mm)
5	400 (violet)	10.0
6	500 (green)	12.5
7	600 (yellow)	15.0
8	700 (red)	17.5

Study 3

In Trials 9–12, the slit width was 0.24 mm, the wavelength was the same as in Study 1, and x was varied. The results are shown in Table 3.

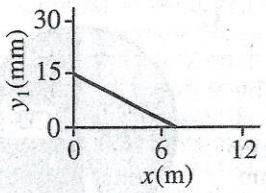
Table 3

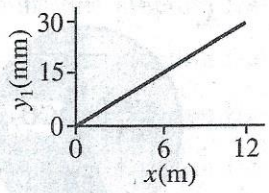
Trial	x (m)	y_1 (mm)
9	3.00	7.5
10	6.00	15.0
11	9.00	22.5
12	12.00	30.0

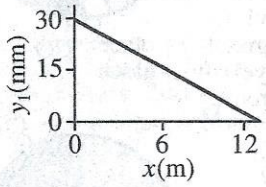
20. In Study 2, y_1 would most likely have been less than 10.0 mm if the students had used a laser emitting light having which of the following wavelengths?

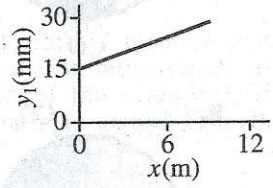
F. 300 nm
G. 500 nm
H. 700 nm
J. 900 nm

21. For fixed values of wavelength and slit width, which of the following graphs best represents the relationship between y_1 and x ?

A.


C.


B.


D.


22. Suppose that the procedure performed in Trial 2 was repeated, except that x was 9.00 m. Based on the results of Studies 1 and 3, would y_1 more likely have been greater than 15.0 mm or less than 15.0 mm ?

F. Greater, because y_1 increased as x increased.
G. Greater, because y_1 increased as x decreased.
H. Less, because y_1 decreased as x increased.
J. Less, because y_1 decreased as x decreased.

23. During the 3 studies, the students did NOT examine the relationship between y_1 and the:

A. width of the slit.
B. wavelength of laser light.
C. distance between the slit and the screen.
D. distance between the slit and the laser.

24. As the wavelength of light increases, the energy of a *photon* (particle of light) decreases. In which of the following trials of Study 2 was the energy of a photon greatest?

F. Trial 5
G. Trial 6
H. Trial 7
J. Trial 8

25. For fixed values of wavelength and x, when the slit width was doubled, the distance from the center of the brightest band in the pattern to the center of one of the 2 adjacent dark bands:

A. was doubled.
B. was halved.
C. remained unchanged.
D. varied with no general trend.

26. What is the result of Trial 7 expressed in *meters* (m) ?

F. 0.00150 m
G. 0.0150 m
H. 0.150 m
J. 1.50 m

Passage V

Unlike most volcanoes, *hot spot volcanoes* (HSVs) develop far from tectonic plate boundaries. Two scientists discuss the origin and properties of HSVs.

Scientist 1

In the mantle beneath an HSV, at depths between 200 km and 400 km, hot magma rises toward Earth's surface in one large column called a *mantle plume*. The ascending magma causes earthquakes and creates networks of large fractures in crustal rocks. Propagation of these fracture networks enables magma to reach the surface more easily, which is why the frequency of eruptions at an HSV typically increases over time. Magma that does not breach Earth's surface will cool and eventually sink back down into the mantle.

HSVs erupt iron-rich lavas that are chemically similar to mantle rocks. Olivine and pyroxenes are the most abundant minerals in mantle rocks and in the lavas erupted at HSVs. The lavas at HSVs also retain a lot of water from the mantle. By weight, water vapor accounts for 75% of the total gas output at HSVs, while CO_2 accounts for only 10%–15%. All other gases combined never account for more than 10%–15% of the total gas output. Kilauea Caldera, in Hawaii, erupts this way.

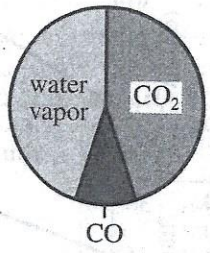
Scientist 2

In certain places near the top of the mantle, at depths of less than 100 km, a high concentration of dissolved CO_2 allows mantle rocks to melt at lower temperatures than they normally would. This is how the magma that fuels an HSV forms. The magma then rises toward Earth's surface in small isolated bodies that melt through the entire thickness of the crust, sometimes causing small fractures (less than 1 km long) in crustal rocks. Each eruption at an HSV depletes some of the excess CO_2, which is why eruption frequency at an HSV will typically slow down over time.

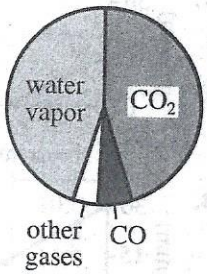
HSVs erupt lavas in which feldspar is the most abundant mineral. These aluminum-rich lavas contain much less water than most mantle rocks. By weight, CO_2 and water vapor each account for 45% of the total gas output at HSVs. Carbon monoxide (CO) accounts for 6% of the total gas output, and all other gases combined account for only 4%. Mt. Erebus, in Antarctica, erupts this way.

27. Which of the following pie charts is most consistent with Scientist 2's description of the total gas output at HSVs ?

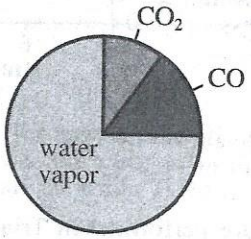
A.



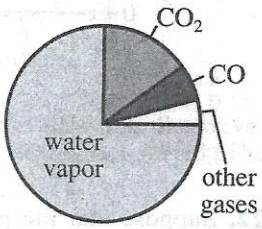
C.



B.



D.



28. Which of the scientists, if either, state(s) that ascending magma causes earthquakes?

F. Scientist 1 only
G. Scientist 2 only
H. Both Scientist 1 and Scientist 2
J. Neither Scientist 1 nor Scientist 2

29. *Basalt* is a volcanic rock that contains abundant iron and is less than 10% feldspar by volume. In contrast, the volcanic rock *phonolite* is mostly feldspar by volume. Based on the passage, which of these 2 types of rock would each scientist more likely expect to see at an HSV ?

	Scientist 1	Scientist 2
A.	basalt	basalt
B.	basalt	phonolite
C.	phonolite	basalt
D.	phonolite	phonolite

30. Suppose it were discovered that older HSVs erupt more frequently than younger HSVs. This discovery would better support the viewpoint of which scientist?

F. Scientist 1; Scientist 1 claims that eruption frequency decreases over time.
G. Scientist 1; Scientist 1 claims that eruption frequency increases over time.
H. Scientist 2; Scientist 2 claims that eruption frequency decreases over time.
J. Scientist 2; Scientist 2 claims that eruption frequency increases over time.

31. The *lithosphere* is a zone of Earth's interior that extends from the surface to a maximum depth of approximately 200 km. Which of the scientists, if either, discuss(es) a process that may extend *beneath* the lithosphere?

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

32. Suppose that another scientist claims that most mantle rocks contain water. Which of the scientists, if either, would be likely to agree with this claim?

F. Scientist 1 only
G. Scientist 2 only
H. Both Scientist 1 and Scientist 2
J. Neither Scientist 1 nor Scientist 2

33. A material that lowers the melting point of rocks is called a *flux*. The melting of rocks due to the presence of a flux is called *flux melting*. Flux melting is a feature of which scientist's discussion, and based on that scientist's discussion, what material is acting as the flux?

A. Scientist 1; iron
B. Scientist 2; iron
C. Scientist 1; CO_2
D. Scientist 2; CO_2

Passage VI

Gene expression in eukaryotes is controlled by *regulatory DNA sequences* (RSs). RSs determine whether, for a particular type of cell, the expression of a gene is turned on or turned off.

Figure 1 shows the coding region of Gene X and shows 3 RSs (RS1–RS3) that are thought to be associated with Gene X. Figure 1 also shows the known expression pattern of Gene X across 6 types of mammalian cells (cell types A–F).

Scientists did 2 experiments to study how RS1, RS2, and RS3 control the expression of Gene X in each of cell types A–F. In each experiment, they prepared *GFP reporter genes*. GFP is a protein that emits green light when viewed with a certain microscope. Reporter genes are DNA molecules that contain RSs of interest and the coding region for an easily detectable protein.

Experiment 1

GFP reporter genes that contained RS1–RS3 and the coding region for GFP were prepared (see Figure 2). The reporter genes were then *transfected* (delivered) into cells of each of cell types A–F. Then, 48 hr after transfection, the cells were viewed with the microscope to determine if the GFP reporter genes were expressed. Figure 2 also shows the expression pattern of the GFP reporter gene across cell types A–F.

Experiment 2

Experiment 1 was repeated except that 5 types of GFP reporter genes were prepared. Each type of reporter gene contained either 0, 1, or 2 of the RSs and the coding region for GFP (see Figure 3). Figure 3 also shows the expression patterns of the 5 types of GFP reporter genes across cell types A–F.

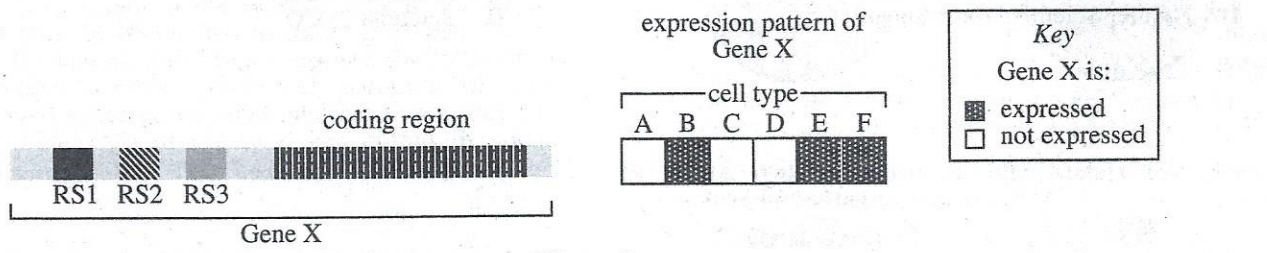


Figure 1

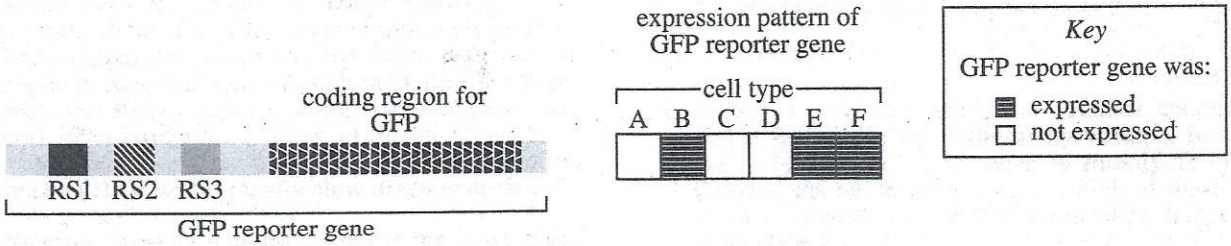


Figure 2

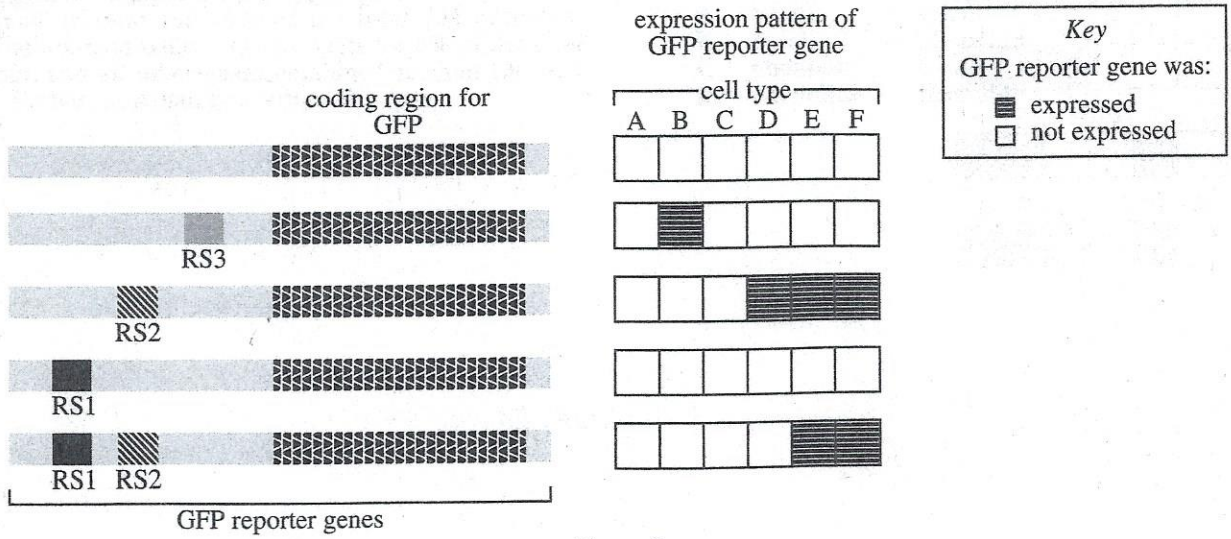


Figure 3

Figures adapted from Bruce Alberts et al., *Molecular Biology of the Cell*, 5th ed. ©2008 by Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter.

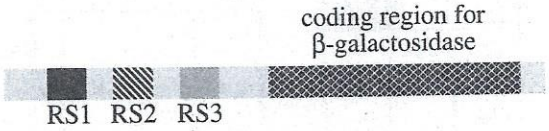
34. Based on the results of Experiment 2, RS2 turns on the expression of the GFP reporter gene in which of the cell types?

- **F.** Cell type B only
- **G.** Cell types E and F only
- **H.** Cell types A, B, and C only
- **J.** Cell types D, E, and F only

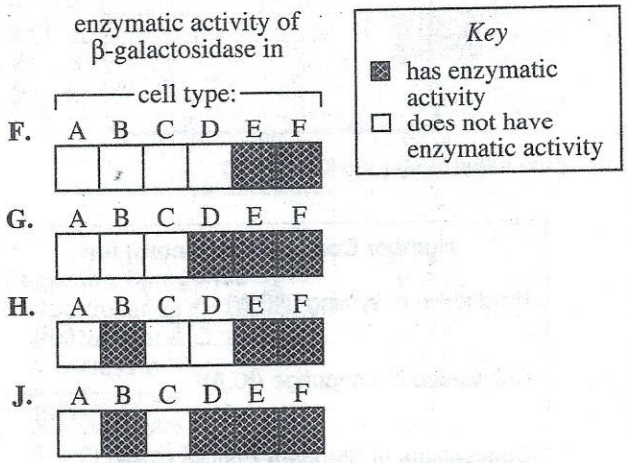
35. According to the results of Experiments 1 and 2, when the cells were viewed with the microscope, green light was NEVER observed for which of the cell types?

- **A.** Cell type A only
- **B.** Cell type C only
- **C.** Cell types A and C only
- **D.** Cell types A, C, and D only

36. The gene that codes for the enzyme *β-galactosidase* is a common reporter gene. Consider the combination of RSs in the reporter gene shown below.



Which of the following patterns of β-galactosidase enzymatic activity would most likely result from transfecting the cells of cell types A–F with the above reporter gene?



37. Based on the results of Experiment 2, the expression of the GFP reporter genes in cell type F was turned on by which of the 3 RSs ?

- **A.** RS1 only
- **B.** RS2 only
- **C.** RS3 only
- **D.** RS1 and RS2 only

38. What is the most likely reason that reporter genes were used in Experiments 1 and 2 ?

- **F.** The protein product of Gene X could be more easily observed than could the protein product of the reporter genes.
- **G.** The protein product of the reporter genes could be more easily observed than could the protein product of Gene X.
- **H.** RS1–RS3 cannot control the expression of Gene X in the cell types studied.
- **J.** RS1–RS3 cannot control the expression of the reporter genes in the cell types studied.

39. Consider the expression pattern of the GFP reporter gene in Experiment 2 that contained only RS1 and RS2. What is the most likely reason that the GFP reporter gene was NOT expressed in cell type D ? In cell type D, gene expression was turned:

- **A.** on by RS1.
- **B.** on by RS2.
- **C.** off by RS1.
- **D.** off by RS2.

40. Do the results of Experiments 1 and 2 indicate that the expression of Gene X is controlled by each of RS1–RS3 ?

- **F.** No; only 1 of the 3 RSs appeared to affect the expression of the GFP reporter gene in all of the cell types.
- **G.** No; only 2 of the 3 RSs appeared to affect the expression of the GFP reporter gene in all of the cell types.
- **H.** Yes; each of the 3 RSs appeared to affect the expression of the GFP reporter gene in all of the cell types.
- **J.** Yes; each of the 3 RSs appeared to affect the expression of the GFP reporter gene in at least 1, but not all, of the cell types.

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.