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

Figure 1 depicts some of the steps of protein synthesis in eukaryotes.

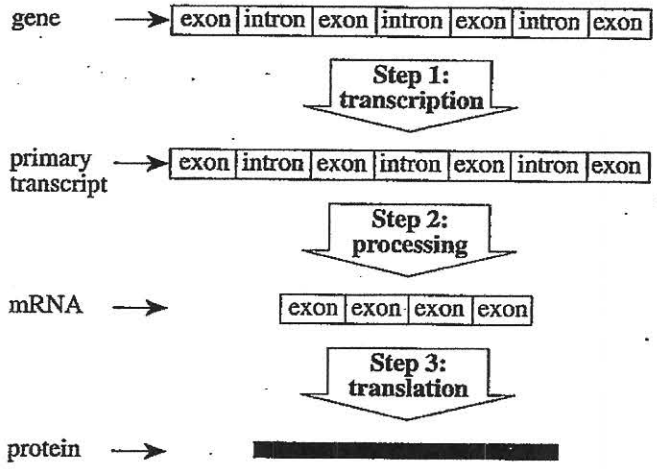


Figure 1

In yeast, the genes that are expressed at a given time depend on environmental conditions, such as the glucose concentration in the environment.

Saccharomyces cerevisiae, a type of yeast, was grown for 12 hours on a growth medium containing glucose. The transcription rates of 4 genes (Genes 1–4) were determined. The *relative transcription rate* (*RTR*) of each gene was then calculated using the following formula:

$$RTR = \frac{\text{the gene's transcription rate at a given time}}{\text{the gene's transcription rate at time} = 0 \text{ hr}}$$

The results appear in Figure 2.

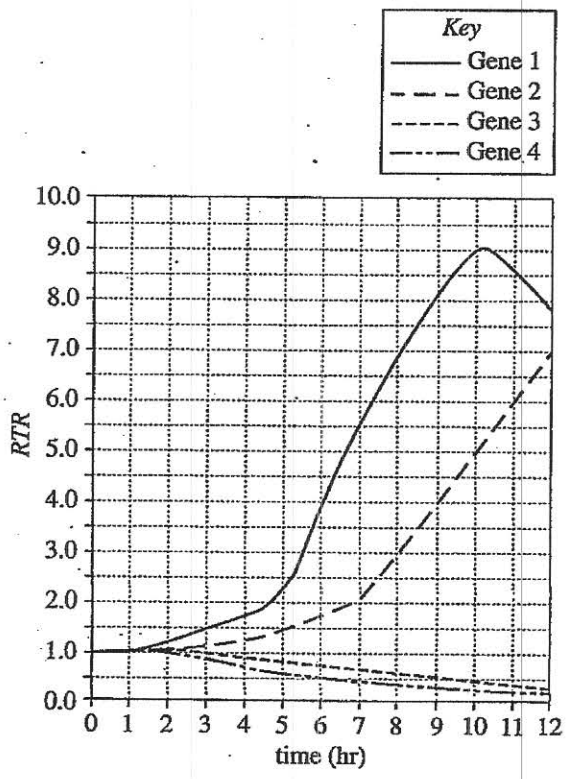


Figure 2

Figure 3 shows the glucose concentration of the medium during the experiment.

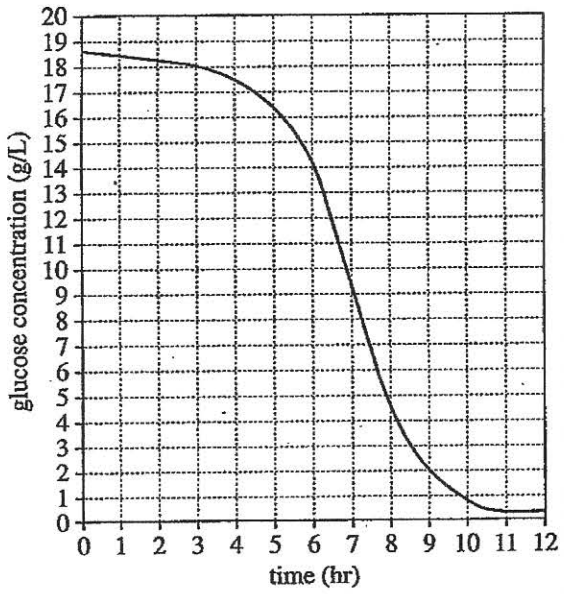


Figure 3

Figures 2 and 3 adapted from Joseph L. DeRisi, Vishwanath R. Iyer, and Patrick O. Brown, "Exploring the Metabolic and Genetic Control of Gene Expression on a Genomic Scale." ©1997 by the American Association for the Advancement of Science.

1. At which of the following times was the transcription rate of Gene 2 the greatest?

   A. Time = 0 hr
   B. Time = 2 hr
   C. Time = 4 hr
   D. Time = 6 hr

2. At which of the following times was the transcription rate of Gene 2 closest to 2 times the transcription rate of Gene 2 at time = 0 hr ?

   F. Time = 5 hr
   G. Time = 7 hr
   H. Time = 9 hr
   J. Time = 10 hr

3. Which of the following cellular components is most directly involved in Step 3 in Figure 1 ?

   A. Cell membrane
   B. Chloroplasts
   C. Lysosomes
   D. Ribosomes

4. Based on Figure 1, which of the following best describes what happens to introns during gene expression?

   F. Introns are transcribed and then translated.
   G. Introns are translated and then transcribed.
   H. Introns are transcribed, but not translated.
   J. Introns are translated, but not transcribed.

5. According to Figures 2 and 3, when the glucose concentration of the medium was 12 g/L, the *RTR* of Gene 4 was closest to which of the following?

   A. 0.1
   B. 0.5
   C. 0.9
   D. 1.3

Passage II

Some students experimentally determined g, the acceleration due to gravity.

In each trial, the students suspended a spring from a stand and measured the spring's length, L. They attached a mass to the suspended spring, allowed the spring-mass system to come to rest, and measured the length, y, of the extended spring (see Figure 1).

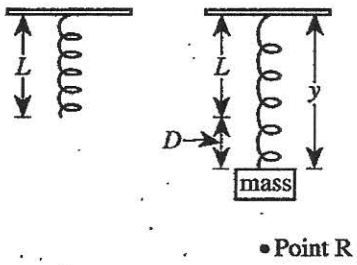


Figure 1

Then they calculated the distance $D = y - L$.

Next, they pulled the mass down to the release point, R, and released it, allowing the mass and spring to oscillate. Using a sensor and a computer, they plotted the distance of the mass from Point R over time (see Figure 2).

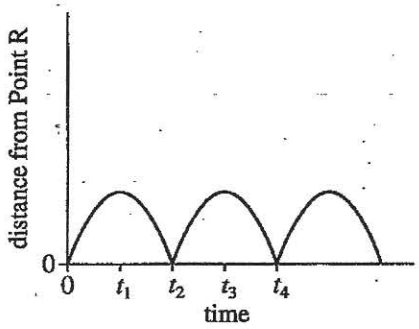


Figure 2

The measured period, P, of the spring-mass system equaled the time that elapsed from the moment the mass left Point R until the moment the mass returned to Point R. Finally, the students used D and P to calculate g.

Study 1

In Trial 1, the students tested Spring 1 with a 0.50 kg mass. (Spring 1 had a *spring constant* [stiffness], k, of 100 newtons/meter, N/m.) In Trials 2 and 3, the students replaced the 0.50 kg mass with a 1.00 kg mass and a 1.50 kg mass, respectively. The results are shown in Table 1.

Table 1

Trial	Mass (kg)	D (m)	P (sec)	g (m/sec^2)
1	0.50	0.049	0.444	9.8
2	1.00	0.098	0.628	9.8
3	1.50	0.146	0.767	9.8

Study 2

The students followed the procedure from Study 1, except that they substituted Spring 2 (k = 200 N/m) for Spring 1. The results are shown in Table 2.

Table 2

Trial	Mass (kg)	D (m)	P (sec)	g (m/sec^2)
4	0.50	0.025	0.315	9.9
5	1.00	0.049	0.444	9.8
6	1.50	0.073	0.544	9.7

Study 3

The students followed the procedure from Study 1, except that they substituted Spring 3 (k = 300 N/m) for Spring 1. The results are shown in Table 3.

Table 3

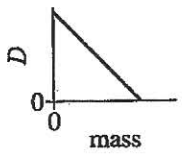
Trial	Mass (kg)	D (m)	P (sec)	g (m/sec^2)
7	0.50	0.016	0.257	9.6
8	1.00	0.033	0.363	9.9
9	1.50	0.049	0.443	9.9

6. According to Figure 2, each mass was at Point R at which of the following 2 times?

F. t_1 and t_2
G. t_1 and t_3
H. t_2 and t_3
J. t_2 and t_4

7. Based on Trials 7–9, which of the following graphs best represents the relationship between mass and D ?

A.



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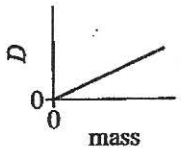
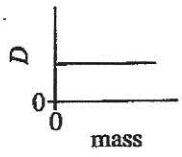
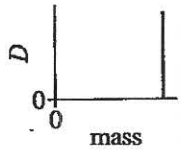


B.



D.



8. If, in Study 1, an additional trial had been conducted with a mass of 0.75 kg, P would most likely have been:

F. less than 0.444 sec.
G. between 0.444 sec and 0.628 sec.
H. between 0.628 sec and 0.767 sec.
J. greater than 0.767 sec.

9. Based on the introductory information, when D was equal to 0, what was the relationship between y and L ?

A. $y = L$

B. $y = 2 \times L$

C. $y = \frac{L}{2}$

D. $y = \frac{L}{4}$

10. In each trial, 2 forces acted on the mass: the force due to gravity and the force due to the spring. At the moment the spring was released at Point R, which of these forces must have been stronger?

F. The force due to gravity, because the mass moved upward from Point R.
G. The force due to gravity, because the mass moved downward from Point R.
H. The force due to the spring, because the mass moved upward from Point R.
J. The force due to the spring, because the mass moved downward from Point R.

11. Based on the 3 studies, if the students had suspended a 1.50 kg mass from a spring with $k = 400$ N/m, D would most likely have been:

A. less than 0.049 m.
B. between 0.049 m and 0.073 m.
C. between 0.073 m and 0.146 m.
D. greater than 0.146 m.

Passage III

As human life expectancy increases, people are becoming more familiar with the complex signs of aging; however, scientists still do not completely understand what causes aging at the molecular level.

Three scientists propose models to explain the human aging process.

Scientist 1

Aging is caused by the shortening of *telomeres*, specialized DNA sequences at the ends of chromosomes. Telomeres play an important role in protecting and replicating chromosome ends. Each time a cell replicates its DNA and divides, its telomeres become shorter. Eventually, the telomeres become too short to perform their necessary roles, and the cell is no longer able to divide, ultimately causing defects in cell structure and function that result in aging.

Scientist 2

Aging is caused by random DNA damage that accumulates over the lifetime of *somatic* (nonreproductive) cells. As humans age, the DNA in their somatic cells accumulates damage that is not repaired. This results in mutations that cause defects in proteins and in gene expression, leading to aging. Most DNA damage is caused by *free oxygen radicals* (oxygen species containing oxygen atoms with unpaired electrons) formed during metabolic processes. Thus, the accumulation of DNA damage can be slowed by decreasing the rate of metabolism. Although telomeres do become shorter each time a cell divides, this occurs too slowly to affect the aging process.

Scientist 3

Aging is caused by mutations present in each human at birth that usually produce defects after an individual is too old to reproduce. Because individuals with these mutations reproduce, the mutations can be passed on to the next generation and maintained in the population. Thus, aging is caused by the mutations that humans inherit from their parents. This is why closely related individuals tend to have similar life expectancies. Telomere shortening occurs too slowly to affect the aging process, and DNA damage from free oxygen radicals is easily repaired.

12. Based on the passage, would Scientist 1 or Scientist 3 be more likely to argue that the process of cell division contributes directly to aging, and why?
    - F. Scientist 1, because according to Scientist 1, telomeres become shorter each time a cell divides.
    - G. Scientist 1, because according to Scientist 1, telomeres become longer each time a cell divides.
    - H. Scientist 3, because according to Scientist 3, telomeres become shorter each time a cell divides.
    - J. Scientist 3, because according to Scientist 3, telomeres become longer each time a cell divides.

13. How does Scientist 2's model differ from Scientist 3's model? Scientist 2 claims that the mutations that cause aging:
    - A. are due to telomere shortening, whereas Scientist 3 claims that the mutations that cause aging are present at birth.
    - B. accumulate throughout a human's life span, whereas Scientist 3 claims that the mutations that cause aging are due to telomere shortening.
    - C. accumulate throughout a human's life span, whereas Scientist 3 claims that the mutations that cause aging are present at birth.
    - D. are present at birth, whereas Scientist 3 claims that the mutations that cause aging accumulate throughout a human's life span.

14. Scientist 1's model would be most weakened if which of the following observations were made?
    - F. Telomeres are the same length in both young cells and old cells.
    - G. The telomeres in a baby's cells are longer than the telomeres in an adult's cells.
    - H. More free oxygen radicals are produced by young cells than by old cells.
    - J. More free oxygen radicals are produced by old cells than by young cells.

15. All 3 scientists would most likely agree with which of the following statements about telomeres?
    - A. Telomeres become shorter as a human ages.
    - B. Telomeres remain the same length throughout a human's life span.
    - C. Telomeres become longer as a human ages.
    - D. Changes in telomere length are responsible for aging.

16. Scientist 3 proposes that the mutations that eventually cause aging are:

F. produced when telomeres shorten.
G. produced by metabolic products.
H. present only in old cells.
J. present in both young cells and old cells.

17. Scientist 2's model would be best supported by which of the following observations?

A. There are fewer mutations in old cells than in young cells.
B. There are fewer mutations in young cells than in old cells.
C. Free oxygen radicals do not cause DNA damage.
D. Telomere shortening influences the aging process.

18. Suppose studies show that consuming fewer calories can slow the aging process. How would Scientist 2 explain this result? Scientist 2 would most likely argue that consuming fewer calories:

F. increases the rate of metabolism and increases the production of free oxygen radicals.
G. increases the rate of metabolism and decreases the production of free oxygen radicals.
H. decreases the rate of metabolism and increases the production of free oxygen radicals.
J. decreases the rate of metabolism and decreases the production of free oxygen radicals.

Passage IV

A river's *discharge* is the volume of river water flowing past a location in the river in a given amount of time. Discharge is affected by several factors, including the area of the river's *drainage basin* (the land surface that delivers the rainwater that falls on it into the river) and the spatial relationship of the river to other rivers.

Two studies examined the discharge in 3 rivers—the North River, the Jones River, and the Calm River—following a rainfall event. As shown in Figure 1, the drainage basin of the North River and the drainage basin of the Jones River are within the drainage basin of the Calm River. The area of each river's drainage basin is given in kilometers^2.

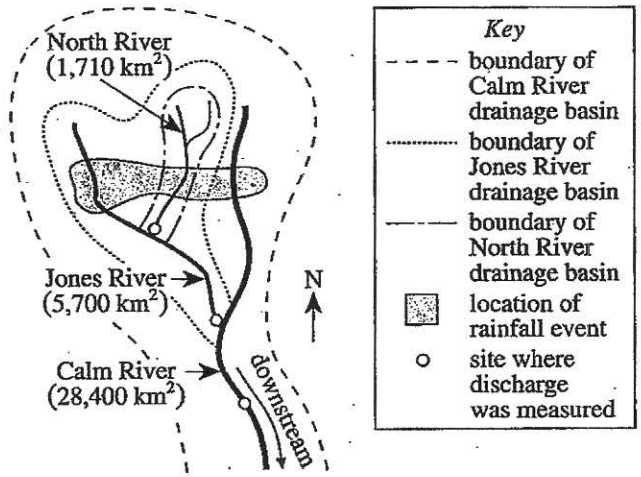


Figure 1

Study 1

The rainfall event produced 25 mm of rain. As rainwater drained into the 3 rivers, the discharges of the rivers increased. The maximum discharge measured immediately after a rainfall event is called a *flood*.

Over the 12 days following the rainfall event, as the flood caused by the rainfall moved downstream, the discharge was continuously measured, in m^3/sec, at the 3 sites shown in Figure 1. The results are shown in Figure 2. (Note: No rainfall event occurred in the Calm River drainage basin during those 12 days.)

Study 2

The *normalized discharge* over the 12 days following the rainfall event was calculated for each of the 3 rivers. The normalized discharge values allowed the flood to be studied as if the 3 rivers had identical drainage basin areas of 1 km^2. Each normalized discharge value was calculated using the following equation:

$$\text{normalized discharge} = \frac{\text{river discharge (m}^3\text{/sec)}}{\text{river drainage basin area (km}^2\text{)}}$$

The value of the numerator, the river discharge, was obtained from Figure 2. The results are shown in Figure 3.

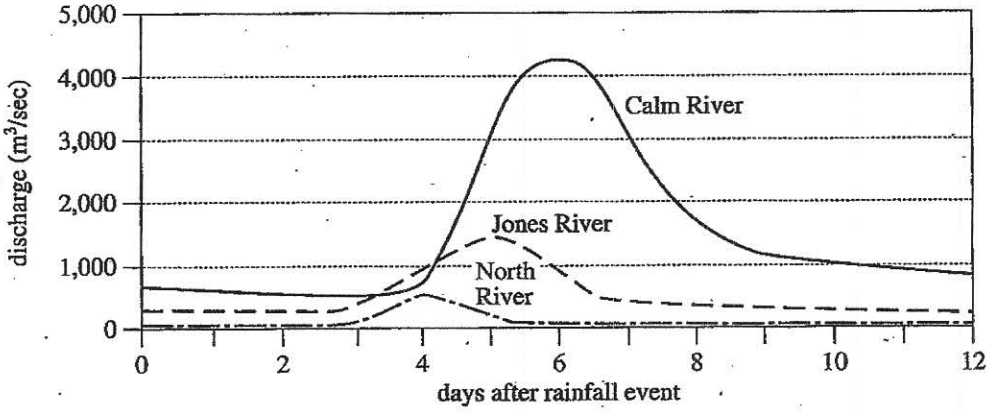


Figure 2

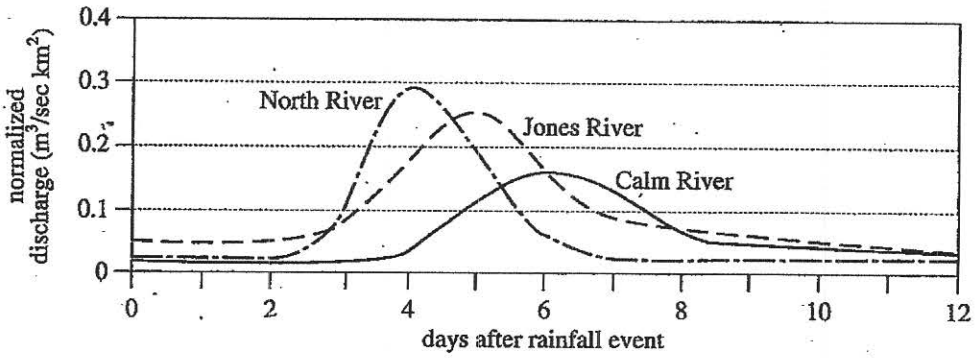


Figure 3

Figures 2 and 3 adapted from George Hornberger et al., *Elements of Physical Hydrology*. ©1998 by The Johns Hopkins University Press.

19. According to Figure 2, the maximum discharge in the Jones River after the rainfall event was closest to which of the following?

- **A.** 500 m^3/sec
- **B.** 1,000 m^3/sec
- **C.** 1,500 m^3/sec
- **D.** 2,000 m^3/sec

20. According to Study 1, the Jones River and Calm River discharges were closest to the same value at which of the following times after the rainfall event?

- **F.** 0.5 day
- **G.** 2 days
- **H.** 3.5 days
- **J.** 5 days

21. The *tributary* (a smaller stream flowing into a larger stream) of the North River shown in Figure 1 would most likely have a drainage basin area of:

- **A.** less than 1,710 km^2.
- **B.** between 1,710 km^2 and 5,700 km^2.
- **C.** between 5,700 km^2 and 28,400 km^2.
- **D.** greater than 28,400 km^2.

22. A student predicted that the river with the greatest maximum discharge would also have the greatest maximum normalized discharge. Based on Figures 2 and 3, is the student's prediction correct?

- **F.** Yes, because the North River had both the greatest maximum discharge and the greatest maximum normalized discharge.
- **G.** Yes, because the Calm River had both the greatest maximum discharge and the greatest maximum normalized discharge.
- **H.** No, because the North River had the greatest maximum discharge but the Calm River had the greatest maximum normalized discharge.
- **J.** No, because the Calm River had the greatest maximum discharge but the North River had the greatest maximum normalized discharge.

23. Based on Figures 1 and 2 and the description of Study 2, the normalized discharge of the Calm River 5 days after the rainfall event was most likely calculated using which of the following expressions?

- **A.** 3,000 km^2 ÷ 28,400 m^3/sec
- **B.** 3,000 m^3/sec ÷ 28,400 km^2
- **C.** 28,400 km^2 ÷ 3,000 m^3/sec
- **D.** 28,400 m^3/sec ÷ 3,000 km^2

24. Suppose that discharge in the Jones River had been measured at a site north of the area where the rainfall event occurred, instead of at the site indicated in Figure 1. How would the discharge data recorded after the rainfall event have differed from that shown in Figure 2 ?

- **F.** No flood would have been recorded in the data for the North River.
- **G.** No flood would have been recorded in the data for the Jones River.
- **H.** The flood recorded in the data for the North River would have been greater than 700 m^3/sec.
- **J.** The flood recorded in the data for the Jones River would have been greater than 1,500 m^3/sec.

Passage V

A *binary phase diagram* (BPD) shows how the phases of a mixture of 2 chemicals vary with temperature and composition at 1 atmosphere (atm) of pressure. The phases include the solid (s) phase of each chemical and the liquid (l) solution phase of the 2 chemicals. The *eutectic* is the point where all 4 regions of the BPD intersect. It indicates the conditions at which all the phases represented in the 4 regions exist in equilibrium. When a mixture is at equilibrium, no net phase change occurs. Figure 1 is a BPD for durene and biphenyl. Figure 2 is a BPD for durene and naphthalene.

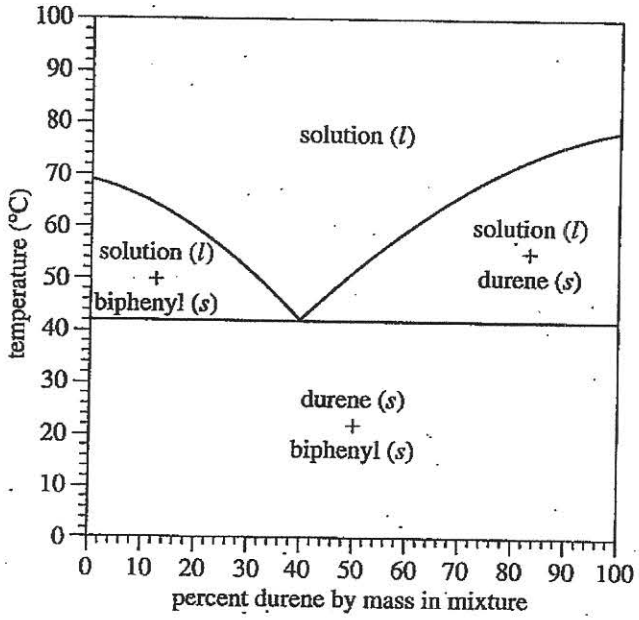


Figure 1

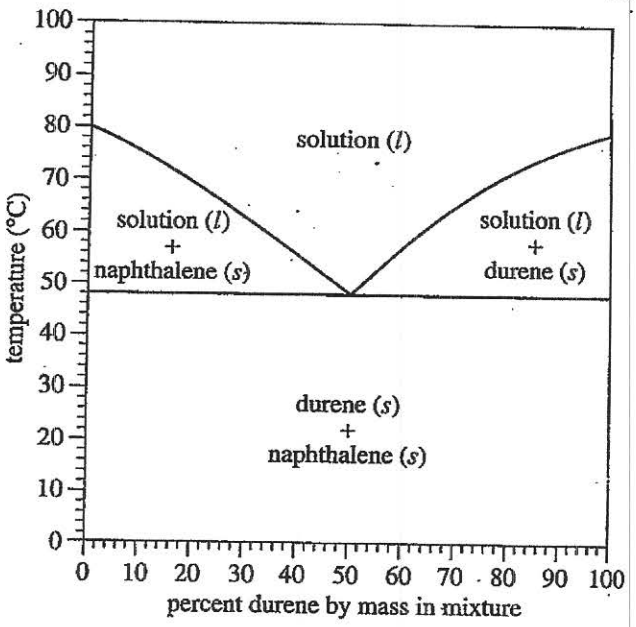


Figure 2

Figures adapted from Jürgen Gallus et al., "Binary Solid-Liquid Phase Diagrams of Selected Organic Compounds." ©2001 by Division of Chemical Education, Inc., American Chemical Society.

25. According to Figure 2, at 1 atm, solid will NOT be present in a durene-naphthalene mixture at 55°C that contains which of the following percents durene by mass?

A. 30%
B. 50%
C. 70%
D. 90%

26. According to Figure 1, at 1 atm, a durene-biphenyl mixture that is 70% durene by mass at 50°C will be a:

F. liquid solution only.
G. mixture of a liquid solution and solid biphenyl.
H. mixture of a liquid solution and solid durene.
J. mixture of solid durene and solid biphenyl.

27. Consider a durene-biphenyl mixture at 1 atm that is 40% durene by mass. According to Figure 1, solid durene, solid biphenyl, and a liquid solution will all be present in equilibrium at a temperature closest to which of the following?

A. 42°C
B. 52°C
C. 69°C
D. 79°C

28. A durene-biphenyl mixture that is 60% durene by mass at 90°C was slowly cooled to 20°C, then slowly heated to 70°C (all at 1 atm). Based on Figure 1, at the end of this procedure the mixture consisted of:

F. liquid solution only.
G. liquid solution and solid biphenyl.
H. liquid solution and solid durene.
J. solid durene and solid biphenyl.

29. Based on Figures 1 and 2, the melting point of durene is closest to which of the following?

A. 19°C
B. 39°C
C. 59°C
D. 79°C

Passage VI

Students studied the rates at which various heated, solid aluminum spheres cooled in air.

Experiment 1

The students tested 3 solid aluminum spheres, A, B, and C, having different radii. The volume, V, in cm^3, and the ratio of surface area to volume, $\frac{S}{V}$, in cm^{-1}, for each sphere are shown in Table 1.

Table 1

Sphere	V (cm^3)	$\frac{S}{V}$ (cm^{-1})
A	3.9	3.1
B	31	1.5
C	490	0.6

Each of the spheres was fitted with a thermocouple to measure the *central temperature* (the temperature at the center) of the sphere. Then the 3 spheres were simultaneously heated. Once the temperature throughout each sphere was 100°C, the 3 spheres were immediately suspended at time = 0 min in air that was at a temperature of 20°C (see Figure 1).

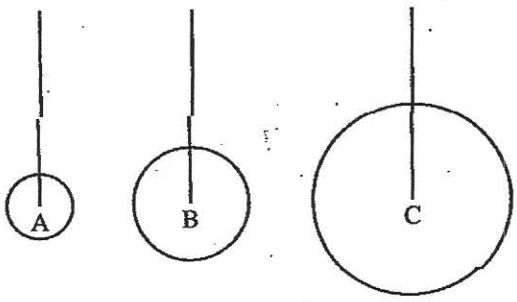


Figure 1

The spheres were allowed to cool over the next 30 min while the temperature of the air was kept constant at 20°C. A graph of the central temperature of each sphere versus time over the 30 min cooling period is shown in Figure 2. For each sphere, the *cooling rate* at a given time equals the graph's slope at that time.

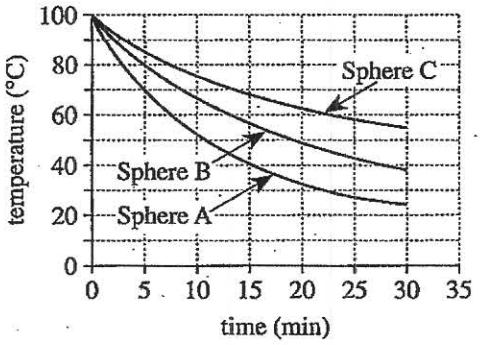


Figure 2

Experiment 2

The students tested 2 solid aluminum spheres, X and Y, that were identical in size. Sphere X was painted with Coating X, and Sphere Y was painted with Coating Y. Each of the spheres was fitted with a thermocouple as in Experiment 1, and then the 2 spheres were simultaneously heated. Once the temperature throughout each sphere was 120°C, the 2 spheres were immediately suspended at time = 0 min in air that was at a temperature of 20°C. The spheres were allowed to cool over the next 55 min while the temperature of the air was kept constant at 20°C. A plot of the central temperature of each sphere versus time over the 55 min cooling period is shown in Figure 3.

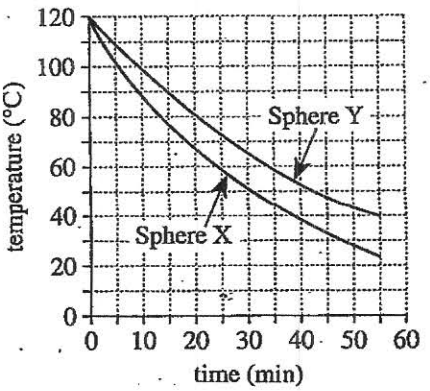


Figure 3

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30. A student stated that spheres that are the same in size but that are made of different metals will cool at different rates. Do the results of Experiment 1 verify this statement?

F. Yes, because all the spheres tested in Experiment 1 were made of the same metal.
G. Yes, because all the spheres tested in Experiment 1 were made of different metals.
H. No, because all the spheres tested in Experiment 1 were made of the same metal.
J. No, because all the spheres tested in Experiment 1 were made of different metals.

31. Based on Figures 2 and 3, the unit of measurement for the cooling rate was which of the following?

A. °C/min
B. °C/cm^3
C. min/°C
D. cm^3/°C

32. Suppose that Sphere A had been allowed to continue cooling until the central temperature of the sphere stopped decreasing with the passage of time. Based on the information given, once the temperature stopped decreasing, the central temperature of the sphere would most likely have been:

F. 15°C.
G. 20°C.
H. 22°C.
J. 30°C.

33. Based on the results of Experiment 1, a solid aluminum cylinder having which of the following values for $\frac{S}{V}$ will cool the fastest?

A. 0.5 cm^{-1}
B. 1.0 cm^{-1}
C. 1.5 cm^{-1}
D. 2.0 cm^{-1}

34. In Experiment 1, to adjust the temperature throughout each sphere before the 3 spheres were suspended and allowed to begin cooling, the students most likely immersed the spheres in:

F. air at 20°C.
G. boiling water.
H. dry ice.
J. molten aluminum.

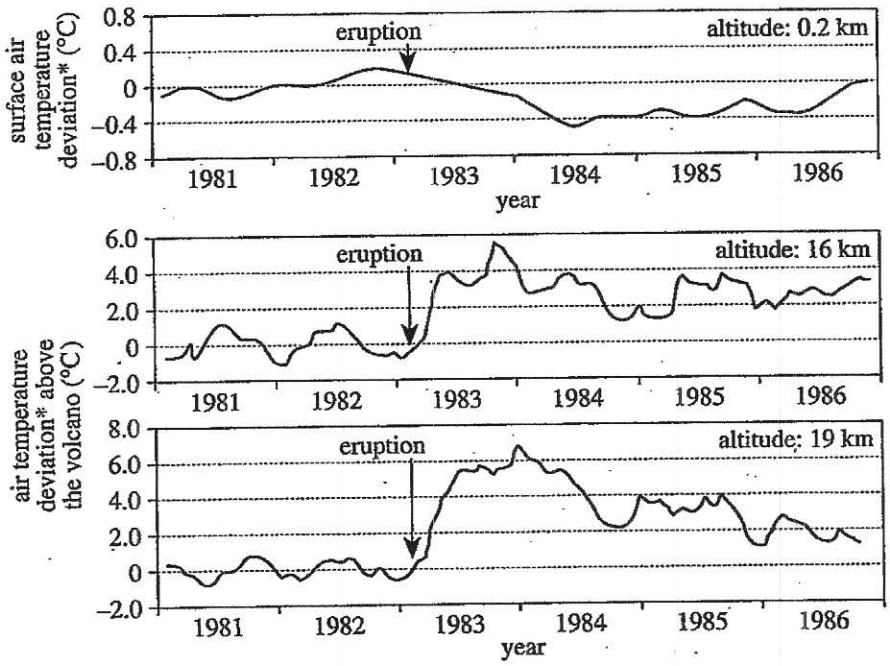
35. During the 55 min cooling period of Experiment 2, the central temperature of Sphere Y reached 40°C how much sooner or later than the central temperature of Sphere X reached 40°C ?

A. 13 min sooner
B. 13 min later
C. 17 min sooner
D. 17 min later

Passage VII

Volcanoes put sulfur into the troposphere and the stratosphere, where the sulfur reacts to form sulfate *aerosols* (liquid droplets suspended in air). For locations at 50°N latitude, aerosols present at altitudes below 11 km scatter incoming solar energy, resulting in cooler air, while aerosols present at higher altitudes absorb incoming solar energy, warming the air.

Figure 1 shows the air temperature deviation at the surface of, and at 2 different altitudes above, a particular volcano (located at 50°N latitude), before and after it erupted. Figure 2 shows the maximum surface air temperature deviation associated with the specific mass of sulfate aerosols formed in the stratosphere after each of 8 volcanoes erupted.



Note: A tick mark on the x-axis indicates Jan. 1 of a given year.

$$\text{*air temperature deviation at a given altitude} = \left[\begin{array}{c}\text{measured air temperature}\\ \text{at the given altitude}\end{array}\right] - \left[\begin{array}{c}\text{average air temperature}\\ \text{at the given altitude}\end{array}\right]$$

Figure 1

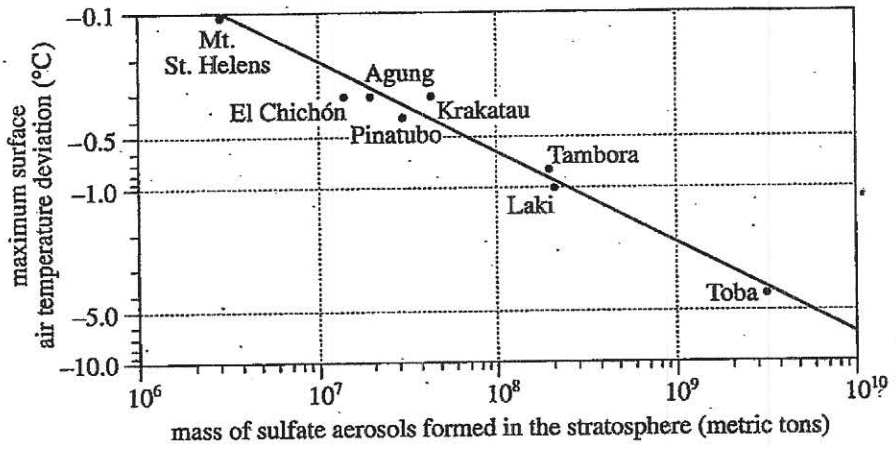


Figure 2

Figure 1 adapted from Haraldur Sigurdsson, "Evidence of Volcanic Loading of the Atmosphere and Climate Response." ©1990 by Elsevier Science Publishers.

Figure 2 adapted from Michael Rampino, "Supereruptions as a Threat to Civilizations on Earth-like Planets." ©2002 by Elsevier Science (USA).

36. According to Figure 1, after the eruption, the greatest air temperature deviation at an altitude of 19 km was closest to which of the following?

F. 5°C
G. 6°C
H. 7°C
J. 8°C

37. Consider the equation provided in Figure 1 and the data point for Toba in Figure 2. After Toba erupted, the surface air temperature, when at its most extreme, was approximately:

A. 4°C above average.
B. 4°C below average.
C. 10°C above average.
D. 10°C below average.

38. According to Figure 1, after the eruption, the air temperature at 16 km altitude stayed more than 1°C above average for:

F. less than 1 year.
G. between 1 year and 2 years.
H. between 2 years and 3 years.
J. more than 3 years.

39. Consider the volcano whose data are shown in Figure 1. Suppose that the average air temperature 16 km above that volcano is −60.0°C. Based on Figure 1, on January 1, 1984, the measured air temperature 16 km above that same volcano would have been closest to which of the following?

A. −64.0°C
B. −60.0°C
C. −56.0°C
D. −4.0°C

40. In Figure 1, a value of zero for the air temperature deviation at a given altitude indicates that the measured air temperature at that altitude equaled the:

F. maximum air temperature deviation at that altitude.
G. average air temperature deviation at that altitude.
H. maximum air temperature at that altitude.
J. average air temperature at that altitude.

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.

ITEM	1	1111111112	2222222223	3333333334	4444444445	5555555556	6666666667	77777	
NUMBER	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	1234567890	12345	
ENGLISH									
CORRECT ANSWER	DFBHCHDGCG	CFAGCJAHAF	CGAHBFDGCJ	CFDHBJBJCG	AGDJAJCGAJ	CFBGCJDFCG	AJBGCJDFBG	DHAJC	
YOUR ANSWER	[redacted]								
SUBSCORE	URURURURRU	RUURRRRUUR	URRUUURRUR	UUURURURUU	UURUUURRUU	RRUURRURUR	RRURUUURRR	UUUUR	
MATHEMATICS									
CORRECT ANSWER	DGCFAJCJBG	BFDJDKBGCK	EHBFCHBGEJ	CJEHCKBGEJ	EJAFEKDHEH	BFDFDFAKCF			
YOUR ANSWER	[redacted]								
SUBSCORE	AAAAATGAAA	TAGTAGAAAG	AAAGTGTGAA	TTTGTAATGT	GTAATGATGT	TGGTGGTGAG			
READING									
CORRECT ANSWER	BHAJCJBHBG	AJCJCHBFDF	CFCGDJBFCF	BJDJBJAHBH					
YOUR ANSWER	[redacted]								
SUBSCORE	LLLLLLLLLL	SSSSSSSSSS	LLLLLLLLLL	SSSSSSSSSS					
SCIENCE									
CORRECT ANSWER	DGDHBJCGAH	AFCFAJBJCH	AJBGBHAFDH	AGDGDHBJCJ					
YOUR ANSWER	[redacted]								

Form 16N
ACT® Writing Test Prompt
(April 2011)

Some students debate whether teachers should express their personal opinions about political and social issues in the classroom. Some students believe teachers should express personal opinions in the classroom because they think teachers can use their experience and knowledge to raise student awareness about important political and social issues. Other students do not believe teachers should express personal opinions in the classroom because they think students may be reluctant to participate in class discussions if they do not agree with their teacher's beliefs. In your opinion, should teachers express their personal opinions about political and social issues in the classroom?

In your essay, take a position on this question. You may write about either one of the two points of view given, or you may present a different point of view on this question. Use specific reasons and examples to support your position.