SCIENCE TEST

40 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

Green anoles and brown anoles (2 species of reptiles) behave differently when the species are together in a habitat than when the species are in separate habitats. Table 1 lists the anole species present in each of 3 habitats (Habitats X, Y, and Z).

Table 1

Habitat	Anole species present:
X	green only
Y	green and brown
Z	brown only

Figure 1 shows, for each anole species, the average perching height in a habitat.

Figure 1

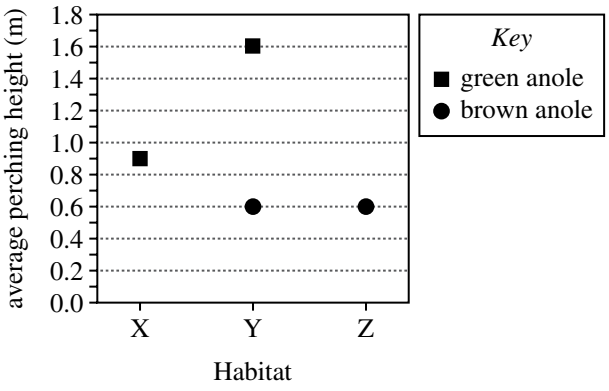

Table 2 lists the number of times each of Behaviors 1–4 was displayed by the anoles in a habitat. Green anoles display Behaviors 1–3 only; brown anoles display Behavior 4 only.

Table 2

Behavior	Number of times behavior was displayed in Habitat:		
	X	Y	Z
1	4	5	N.A.
2	3	6	N.A.
3	24	13	N.A.
4	N.A.	5	17

Note: N.A. indicates the behavior was not displayed in the habitat.

Table 3 lists, for the anole species in a habitat, the average display time for Behavior 5.

Table 3

Anole species	Habitat	Average display time for Behavior 5 (s)
Green	X	23.1
Green	Y	23.7
Brown	Y	49.6
Brown	Z	33.1

Figure 1 and Tables 2 and 3 adapted from Jessica R. Edwards and Simon P. Lailvaux, "Display Behavior and Habitat Use in Single and Mixed Populations of *Anolis carolinensis* and *Anolis sagrei* Lizards." ©2012 by Blackwell Verlag GmbH.

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1. Based on Table 2, which of the following ratios best represents the number of times Behavior 2 was displayed in Habitat X compared to the number of times Behavior 2 was displayed in Habitat Y?

A. 1:2
B. 1:8
C. 4:5
D. 5:6

2. Which of the following observations for brown anoles was(were) the same in both Habitats Y and Z?

1. Average perching height
2. The number of times Behavior 4 was displayed
3. Average display time for Behavior 5

F. 1 only
G. 3 only
H. 1 and 2 only
J. 2 and 3 only

3. Based on Table 3, how many display times were measured for Behavior 5 in Habitat Z?

A. 2
B. 4
C. 12
D. Cannot be determined from the given information

4. Based on Figure 1, for green anoles, the difference in average perching height between Habitat X and Habitat Y was closest to which of the following?

F. 0.0 m
G. 0.3 m
H. 0.7 m
J. 1.0 m

5. A student claimed that anoles are endotherms. Which of the following explains why this claim is incorrect? Anoles are:

A. amphibians and primarily generate heat from internal metabolic processes to maintain body temperature.
B. amphibians and primarily absorb heat from the surrounding environment to maintain body temperature.
C. reptiles and primarily generate heat from internal metabolic processes to maintain body temperature.
D. reptiles and primarily absorb heat from the surrounding environment to maintain body temperature.

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Passage II

The coastline of Antarctica consists of many ice shelves (floating 100–1,000 m thick sheets of ice that extend from a landmass). Many of these ice shelves are melting, causing them to calve (break off) large pieces known as icebergs. Four students each explain iceberg calving.

Student 1

Antarctic ice shelves melt due to the warming of the air above the surface of the ice during the summer. When the air temperature increases, the surface ice melts and water pools. The meltwater moves downward into the ice shelf, causing fractures to form. The accumulation of many fractures in the ice over many summers gradually leads to icebergs calving from an ice shelf.

Student 2

Student 1 is correct that an increase in air temperature during the summer leads to surface ice melting and water pooling, causing fractures to form in the ice. However, the action of the meltwater alone is insufficient to produce fractures deep enough to cause calving. When the air temperature lowers at the beginning of winter, falling snow accumulates in the fractures, increasing the pressure on the ice, eventually causing calving. After a large snowfall, calving can occur within a few days.

Student 3

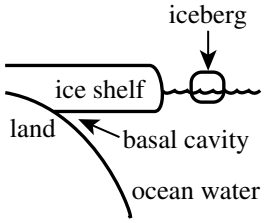
Antarctic ice shelves melt only from below. During the summer, ocean currents circulate water that is just above freezing into and out of the basal cavity (the area underneath an ice shelf), causing the ice within the cavity to melt. For every 0.1°C that the ocean water is above freezing, the water melts a thickness of 10 m of ice from the bottom per year. When the ice shelf thickness has been reduced by at least 50 m, calving occurs.

Student 4

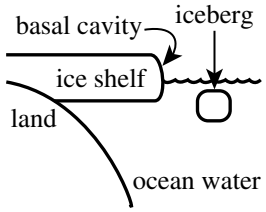
The warmer water circulated by ocean currents melts the ice shelf as described by Student 3. However, calving cannot occur from this process alone. Snow accumulates on the surface of the ice each winter, but each following summer, warm air leads to the melting and compaction of the snow. The compaction lowers the surface of the ice shelf, pushing the ice down into the basal cavity, where it is melted by the ocean water. After several winter-summer cycles, the ice shelf becomes top-heavy due to the snow and the melting from below, and calving occurs.

6. Which of the following diagrams best shows the location of the basal cavity as described by Student 3?

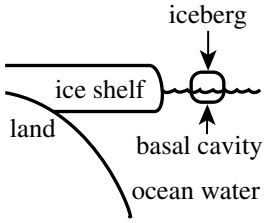
F.



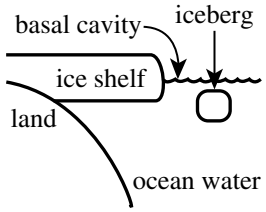
H.



G.



J.



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7. Suppose that the air temperature along the Antarctic coastline is never warmer than −10°C and that the atmospheric pressure is always 1.0 atmosphere. Does this information support the description given by Student 1?

A. Yes, because ice cannot melt at those temperatures.
B. Yes, because ice can melt at those temperatures.
C. No, because ice cannot melt at those temperatures.
D. No, because ice can melt at those temperatures.

8. Based on the description of the icebergs that are calved along the coastline of Antarctica, do the icebergs sink or float?

F. Sink; they are more dense than ocean water.
G. Sink; they are less dense than ocean water.
H. Float; they are more dense than ocean water.
J. Float; they are less dense than ocean water.

9. Which of Students 1 and 4, if either, implied that the processes involved in iceberg calving will take more than one year to result in the formation of an iceberg?

A. Student 1 only
B. Student 4 only
C. Both Student 1 and Student 4
D. Neither Student 1 nor Student 4

10. In regard to the season(s) involved in iceberg calving, how does Student 2's description differ from Student 3's description? Student 2 indicated that:

F. summer and winter are involved in calving, whereas Student 3 indicated that only summer is involved in calving.
G. summer and winter are involved in calving, whereas Student 3 indicated that only winter is involved in calving.
H. only summer is involved in calving, whereas Student 3 indicated that summer and winter are involved in calving.
J. only winter is involved in calving, whereas Student 3 indicated that only summer is involved in calving.

11. Which of Students 2, 3, and 4 agree(s) with Student 1 that some form of melting occurs on the ice shelf surface?

A. Student 2 only
B. Students 2 and 3 only
C. Students 2 and 4 only
D. Students 3 and 4 only

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Passage III

Amphiprion percula, a species of clownfish, are kept in many home aquariums. Two experiments were conducted to determine how diet and stocking density (number of fish per liter of seawater, fish/L) affect the specific growth rate (SGR; percent increase in length per day, percent/day) in *A. percula*.

Experiment 1

Each of 12 identical 15 L tanks received 10 L of seawater having a salinity of 33 parts per thousand (ppt), a temperature of 27°C, and a pH of 8.2. Salinity, temperature, and pH were kept constant over the course of the experiment. *A. percula* of similar lengths were selected, and their lengths were measured, in cm, with a ruler. Then they were equally distributed among the tanks at a stocking density of 1 fish/L. The tanks were then divided equally into 4 groups.

For 4 months, each group was fed a different diet (Diets Q–T). Each group was fed the same mass of food 3 times daily. At the end of 4 months, the length of each fish was measured, in cm, with a ruler, and the SGR of each fish was calculated. The average SGR was then determined for each group (see Table 1).

Table 1

Diet	Average SGR (percent/day)
Q	0.30
R	0.40
S	0.50
T	0.35

Experiment 2

The procedures for Experiment 1 were repeated except that each group was kept at a different stocking density, 0.5 fish/L, 1 fish/L, 2 fish/L, or 3 fish/L, and all fish were fed Diet T. At the end of 4 months, the average SGR was determined for each group (see Table 2).

Table 2

Stocking density (fish/L)	Average SGR (percent/day)
0.5	0.50
1	0.35
2	0.25
3	0.20

Tables adapted from João Chambel et al., "Effect of Stocking Density and Different Diets on Growth of Percula Clownfish, *Amphiprion percula* (Lacepede, 1802)." ©2015 by Springer.

12. Which of the following statements about the relationship between the number of *A. percula* per tank and the average SGR is consistent with the results of Experiment 2? On average, as the number of *A. percula* per tank increased, the average SGR:

F. increased only.
G. decreased only.
H. remained the same.
J. varied with no general trend.

13. The following table gives the percent protein in each of the 4 diets.

Diet	Percent protein
Q	52.5
R	48.0
S	41.1
T	38.1

Which of the following statements about the percent protein in each diet and the average SGR is consistent with the data shown in the table and the results of Experiment 1? The diet that resulted in the:

A. highest average SGR also had the highest percent protein.
B. highest average SGR had the lowest percent protein.
C. lowest average SGR had the highest percent protein.
D. lowest average SGR also had the lowest percent protein.

14. Based on the results of Experiment 1, if Experiment 2 were repeated except that all the *A. percula* were fed Diet R, would the average SGRs more likely have been lower or higher for each group?

F. Lower; on average, *A. percula* fed Diet R had an SGR 0.05 percent/day less than those fed Diet T.
G. Lower; on average, *A. percula* fed Diet R had an SGR 0.10 percent/day less than those fed Diet T.
H. Higher; on average, *A. percula* fed Diet R had an SGR 0.05 percent/day greater than those fed Diet T.
J. Higher; on average, *A. percula* fed Diet R had an SGR 0.10 percent/day greater than those fed Diet T.

15. Suppose that, in the experiments, 1 g of food were added to each tank at each feeding. A total of how many grams of food would have been placed into an individual tank each day?

A. 1 g
B. 3 g
C. 12 g
D. 36 g

16. How many *A. percula* were placed in each of the tanks in Experiment 1?

F. 1
G. 4
H. 10
J. 12

17. Which of the following was a dependent variable in Experiment 1?

A. Volume of seawater in each tank
B. Specific growth rate
C. Diet fed to the *A. percula*
D. Stocking density of the *A. percula*

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Passage IV

Scientists hypothesized that heating tomatoes affects the concentration of nutrients such as vitamin C and lycopene (a red pigment) in the tomatoes. They conducted 2 experiments to test their hypothesis.

Experiment 1

Two kilograms of a particular variety of raw tomatoes were sliced and then blended in a food processor until a homogeneous (uniform) tomato mixture was produced. The mixture was divided into 4 equal samples (Samples 1–4). Each sample was placed in a separate plastic bag, and the bags were sealed. The bag containing Sample 1 was immediately frozen at −40°C. The bags containing Samples 2–4 were each incubated in a water bath at 88°C for a different period of time (see Table 1) and then frozen at −40°C.

Table 1

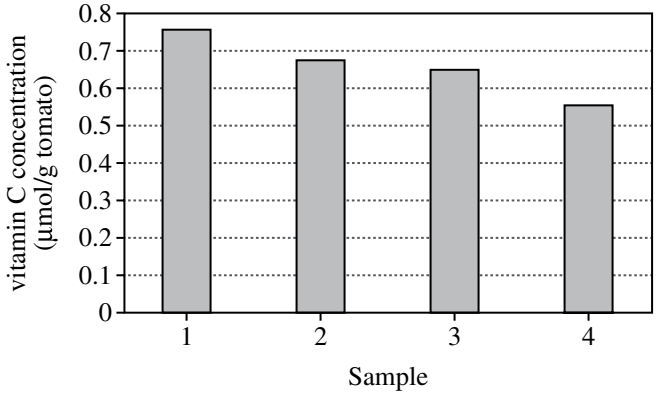
Sample	Incubation time at 88°C (min)
1	0
2	2
3	15
4	30

Then, 2 days later, Steps 1–3 were performed for each sample.

1. The sample was thawed, and then 100 g of the sample was placed in a beaker containing 200 mL of Solvent A.
2. The contents of the beaker were mixed for 5 min at 25°C and then filtered using a paper filter. The filtered liquid was collected.
3. The filtered liquid was analyzed to determine the vitamin C concentration in micromoles per gram of tomato (μmol/g tomato).

The results for each sample are shown in Figure 1.

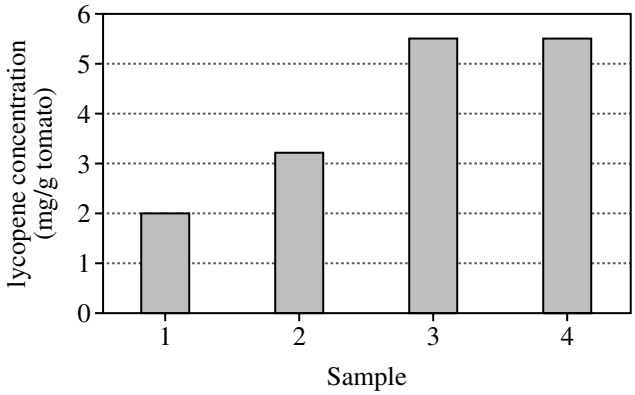
Figure 1



Experiment 2

Experiment 1 was repeated except that in Step 3 the filtered liquid was analyzed to determine the lycopene concentration in milligrams per gram of tomato (mg/g tomato). The results for each sample are shown in Figure 2.

Figure 2



Figures 1 and 2 adapted from Veronica Dewanto et al., "Thermal Processing Enhances the Nutritional Value of Tomatoes by Increasing Total Antioxidant Activity." ©2002 by American Chemical Society.

18. Which of the samples in Experiment 1 was most likely intended as a control for the concentration of vitamin C present in the unheated tomatoes?

F. Sample 1
G. Sample 2
H. Sample 3
J. Sample 4

19. Based on the results of Experiment 2, which of the following incubation times would most likely have produced a tomato mixture with a lycopene concentration between 5 mg/g tomato and 6 mg/g tomato?

A. 0 min
B. 0.2 min
C. 2 min
D. 20 min

20. A student claimed that heating tomatoes decreases the concentration of nutrients present. This claim is consistent with the results shown for which of vitamin C and lycopene, if either?

F. Vitamin C only
G. Lycopene only
H. Both vitamin C and lycopene
J. Neither vitamin C nor lycopene

21. Assume that, in the experiments, the water bath contained pure water at standard atmospheric pressure (1 atmosphere; atm). While the bags containing the samples were being incubated, was the water in the water bath most likely boiling?

A. Yes; the incubation temperature was less than the boiling point of water at 1 atm.
B. Yes; the incubation temperature was greater than the boiling point of water at 1 atm.
C. No; the incubation temperature was less than the boiling point of water at 1 atm.
D. No; the incubation temperature was greater than the boiling point of water at 1 atm.

22. In Experiment 1, how many of the samples had a vitamin C concentration of less than 1.0 μmol/g tomato?

F. 0
G. 1
H. 3
J. 4

23. Consider the following procedures performed in Experiment 2 for Sample 2.

1. The sample was frozen.
2. The sample was incubated in the water bath.
3. The sample and solvent mixture was filtered.

These procedures were performed in what order?

A. 1, 2, 3
B. 1, 3, 2
C. 2, 1, 3
D. 2, 3, 1

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Passage V

A molten alloy (a mixture of 2 or more metallic elements) can be poured into a cylindrical mold and cooled to form an ingot. Crystals form inside the ingot as it cools. The average crystal length, L, in micrometers (μm), determines how brittle the ingot will be. A method for reducing L using rotating magnetic fields was applied to Alloy Q as it cooled in the molds. Table 1 shows the elemental composition of Alloy Q. Figure 1 shows the effect of the relative magnetic stirring force, F, on L for ingots formed from molten Alloy Q that had an initial temperature of either 280°C or 550°C.

Table 1

Element	Symbol	Percent by mass in Alloy Q
Aluminum	Al	88.7
Silicon	Si	10.8
Manganese	Mn	0.28
Magnesium	Mg	0.22

Figure 1

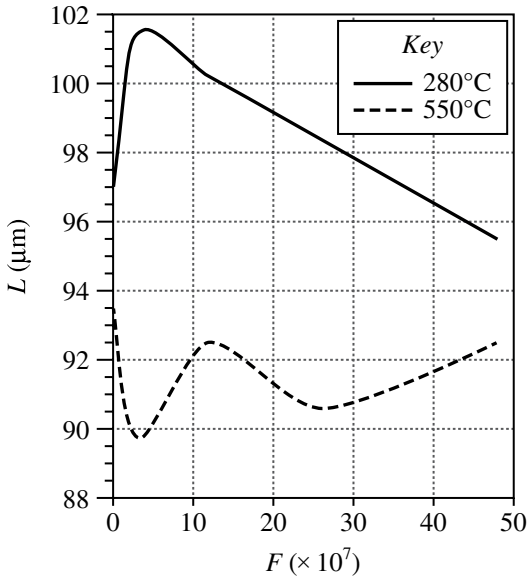

Figure 1 is adapted from S. Denisov, et al., "The Effect of Traveling and Rotating Magnetic Fields on the Structure of Aluminum Alloy During Its Crystallization in a Cylindrical Crucible." ©2014 by Institute of Physics, University of Latvia.

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24. A linear region of a graph is a range of data that can be approximated with a straight line. Based on Figure 1, for Alloy Q initially at a temperature of 550°C, which of the following ranges of F best represents a linear region?

F. Between 0 and 10×10^7
G. Between 10×10^7 and 20×10^7
H. Between 20×10^7 and 30×10^7
J. Between 30×10^7 and 40×10^7

25. Consider the 2 trends shown for Alloy Q initially at the temperatures of 280°C and 550°C, from $F = 40 \times 10^7$ through $F = 48 \times 10^7$. If these lines were to continue along the same trend, at which of the following values of F would the average crystal lengths most likely be the same?

A. $F = 50 \times 10^7$
B. $F = 60 \times 10^7$
C. $F = 70 \times 10^7$
D. $F = 80 \times 10^7$

26. Based on Figure 1, which of the following combinations of values for initial temperature and F would produce the shortest average crystal length in an ingot of Alloy Q? The smallest L would be produced with a temperature of:

F. 280°C and $F = 10 \times 10^7$.
G. 280°C and $F = 40 \times 10^7$.
H. 550°C and $F = 10 \times 10^7$.
J. 550°C and $F = 40 \times 10^7$.

27. The following table lists the mass of silicon in 50 g samples of 4 different alloys, one of which is Alloy Q.

Sample	Mass of Si (g)
W	0.11
X	0.14
Y	2.7
Z	5.4

Given the composition of Alloy Q, which sample is most likely Alloy Q?

A. Sample W
B. Sample X
C. Sample Y
D. Sample Z

28. Based on Table 1, if an ingot of Alloy Q had a mass of 200 g, that ingot would contain what mass of Mg?

F. 0.22 g
G. 0.44 g
H. 2.2 g
J. 4.4 g

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Passage VI

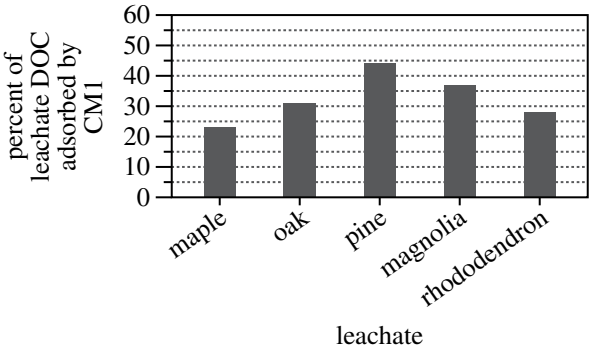
In a lake, water leaches (dissolves out) soluble organic compounds from decaying tree leaves, producing dissolved organic carbon (DOC). DOC is subsequently removed from the water if it is adsorbed by (becomes adhered to the surface of) clay mineral particles that are suspended in the water. Three studies done at a lake examined DOC adsorption by 3 clay minerals—CM1, CM2, and CM3—found in the lake's sediment.

Green leaves were collected from 5 types of trees around the lake (maple, oak, pine, magnolia, and rhododendron). A 5 L volume of lake water was filtered to remove all solid particles. The following procedures were performed for each type of leaf: A 100 g sample of the leaves was mixed with a 1 L volume of the filtered lake water. The mixture was then placed in the dark for 10 weeks at 4°C while leaching occurred. At 10 weeks, the mixture was filtered to remove all solid particles. The resulting liquid (the leachate) was analyzed for DOC.

Study 1

The following procedures were performed for each leachate: A 100 mL volume of the leachate was mixed with 10 g of CM1. The mixture was stirred continuously for 2 hr, then filtered to remove all solid particles. The resulting liquid (the filtrate) was analyzed for DOC. The percent of the leachate DOC that had been adsorbed by CM1 was calculated (see Figure 1).

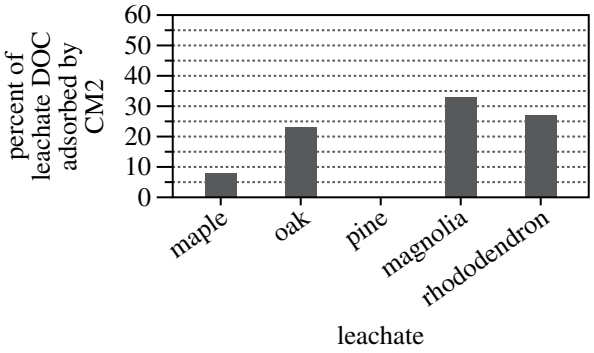
Figure 1



Study 2

Study 1 was repeated, substituting CM2 for CM1 (see Figure 2).

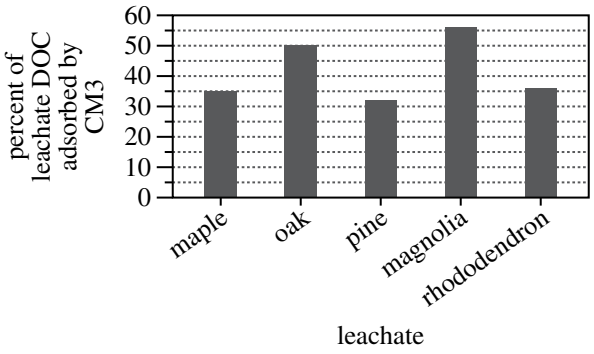
Figure 2



Study 3

Study 1 was repeated, substituting CM3 for CM1 (see Figure 3).

Figure 3



Figures and table adapted from Todd Tietjen, Anssi Vähätalo, and Robert Wetzel, "Effects of Clay Mineral Turbidity on Dissolved Organic Carbon and Bacterial Production." ©2005 by the Swiss Federal Institute for Environmental Science and Technology.

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29. Based on the results of the studies, from which of the 5 leachates was the greatest percent of DOC adsorbed by CM1, CM2, and CM3, respectively?

A. CM1: maple
CM2: maple
CM3: rhododendron

B. CM1: oak
CM2: pine
CM3: magnolia

C. CM1: pine
CM2: magnolia
CM3: rhododendron

D. CM1: pine
CM2: magnolia
CM3: magnolia

30. Based on the results of Study 3, the percent of leachate DOC adsorbed by CM3, averaged across the 5 types of leaves, is closest to which of the following?

F. 10%
G. 20%
H. 30%
J. 40%

31. Is the statement "CM2 adsorbed a greater percent of the DOC in the maple leachate than did CM3" supported by the results of Studies 2 and 3?

A. Yes; CM2 adsorbed 35% of the leachate DOC, whereas CM3 adsorbed 7%.
B. Yes; CM2 adsorbed 55% of the leachate DOC, whereas CM3 adsorbed 17%.
C. No; CM2 adsorbed 7% of the leachate DOC, whereas CM3 adsorbed 35%.
D. No; CM2 adsorbed 17% of the leachate DOC, whereas CM3 adsorbed 55%.

32. Based on the results of the studies, which of the 3 clay minerals, if any, reduced the DOC in the oak leachate by more than 50%?

F. CM1 only
G. CM2 only
H. CM1 and CM3 only
J. None of the 3 clay minerals

33. Is a mixture of any one of the leachates and any one of the clay minerals properly considered a solution?

A. Yes, because the clay mineral particles are dissolved in the leachate.
B. Yes, because the clay mineral particles are not dissolved in the leachate.
C. No, because the clay mineral particles are dissolved in the leachate.
D. No, because the clay mineral particles are not dissolved in the leachate.

34. In lake water, DOC is broken down into simpler compounds by electromagnetic energy in the visible wavelength range. What action was taken in the studies to prevent this process from occurring?

F. Each mixture of leaves and filtered lake water was placed in the dark.
G. Each mixture of filtrate and clay mineral was placed in the dark.
H. Each mixture of leaves and lake water was filtered.
J. Each mixture of leachate and clay mineral was filtered.

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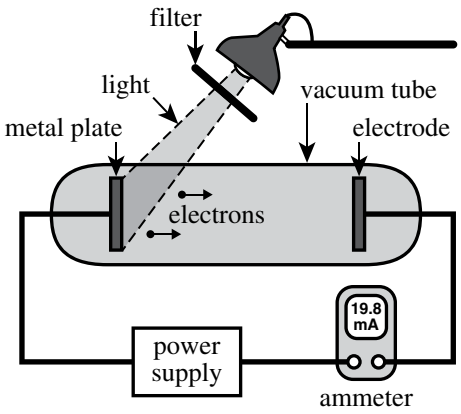
Passage VII

When light shines on a metal plate, electrons can be ejected from the plate. An electron will be ejected if the energy, E, of a photon (particle of light) striking the plate is greater than the minimum energy, M, required for the electron to be removed from the plate. The maximum kinetic energy of the ejected electron, K, is the difference between E and M as shown in the equation:

$K = E - M$

Students conducted 2 experiments to examine how differences in the light striking a metal plate affect K. The setup included a light source, a removable filter, a circuit with an ammeter to measure current, a power supply that could be adjusted to measure K, and a vacuum tube containing a metal plate and an electrode (see Figure 1).

Figure 1



Experiment 1

A filter was placed between the metal plate and the light source, and the K of the ejected electrons was measured. This procedure was repeated with each of 4 additional filters. Each filter transmitted light of only one frequency. Table 1 lists the following:

- color of light transmitted by the filter
- frequency of light in hertz, Hz
- E in electron volts, eV
- K in electron volts

Table 1

Color	Frequency ($\times 10^{14}$ Hz)	E (eV)	K (eV)
Red	4.4	1.81	N.A.*
Yellow	5.2	2.14	N.A.*
Green	5.6	2.31	0.11
Blue	6.3	2.60	0.40
Violet	7.5	3.10	0.90

*N.A.—Not available; no electrons were ejected.

Experiment 2

With the same setup as in Experiment 1 except without a filter, the current, in milliamperes (mA), and K were measured as the intensity of the light was varied. Table 2 shows the current and K for 4 different relative light intensities, each given as a percent of maximum intensity.

Table 2

Relative intensity	Current (mA)	K (eV)
100%	40.0	0.90
50%	19.8	0.90
25%	9.8	0.90
12.5%	4.8	0.90

35. Consider the current shown on the ammeter in Figure 1. Based on the results of Experiment 2, when this current was measured, what was the relative intensity of the light?

A. 100%
B. 50%
C. 25%
D. 12.5%

36. What aspect of the experimental setup was held constant in Experiment 2 but not in Experiment 1?

F. Color of light
G. Light source
H. Type of metal plate
J. Distance between metal plate and electrode

37. Based on Figure 1, are the particles ejected from the metal plate moving toward the electrode or away from the electrode, and are those particles positively charged or negatively charged?

A. Toward; positively charged
B. Toward; negatively charged
C. Away from; positively charged
D. Away from; negatively charged

38. Based on the equation in the passage and the results of Experiment 1, what was the value of M for the metal plate used in the setup?

F. 2.14 eV
G. 2.20 eV
H. 2.31 eV
J. 2.42 eV

39. The *cutoff frequency* for a particular metal is the lowest frequency of light at which electrons are ejected from the metal. Based on the results of Experiment 1, the cutoff frequency for the metal plate was:

A. less than 4.4×10^{14} Hz.
B. between 4.4×10^{14} Hz and 5.2×10^{14} Hz.
C. between 5.2×10^{14} Hz and 5.6×10^{14} Hz.
D. greater than 5.6×10^{14} Hz.

40. The relationship between E and the frequency of light is given by the equation:

$E = hf$

where h is Planck's constant and f is the frequency of light. Based on the data for green light in Table 1, which of the following expressions could be used to determine the value of h?

F. $\frac{5.6 \times 10^{14}\ \text{Hz}}{0.11\ \text{eV}}$

G. $\frac{0.11\ \text{eV}}{5.6 \times 10^{14}\ \text{Hz}}$

H. $\frac{5.6 \times 10^{14}\ \text{Hz}}{2.31\ \text{eV}}$

J. $\frac{2.31\ \text{eV}}{5.6 \times 10^{14}\ \text{Hz}}$

END OF TEST 4

STOP! DO NOT RETURN TO ANY OTHER TEST.

