Mission 2: Deciphering the “yikes”

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

The freezing point of an aqueous solution (T_f), in °C, can be calculated using the equation

$$T_f = -1.86 \times m \times i$$

where m is the concentration of the solute in moles of solute per kilogram of H_2O (mol/kg H_2O) and i is the average number of particles produced by 1 formula unit of the solute when the formula unit dissolves in H_2O. The *theoretical i value* of a solute is the total number of particles produced when 1 formula unit of the solute dissolves in H_2O. Table 1 gives, for 4 ionic compounds, the chemical formula and the theoretical i value. Table 2 shows how the *observed i value* at 25°C for these compounds changes with solute concentration.

Table 1

Name	Chemical formula	Theoretical i value
Sodium chloride	NaCl	2
Potassium chloride	KCl	2
Magnesium chloride	$MgCl_2$	3
Ammonium sulfate	$(NH_4)_2SO_4$	3

Table 2

Concentration of aqueous solution (mol/kg H_2O)	Observed i value at 25°C for:			
	NaCl	KCl	$MgCl_2$	$(NH_4)_2SO_4$
0.1	1.87	1.85	2.58	2.30
0.2	1.85	1.83	2.63	2.19
0.3	1.84	1.81	2.68	2.12
0.4	1.84	1.80	2.76	2.07
0.5	1.84	1.80	2.84	2.03
0.6	1.85	1.80	2.92	2.00
0.7	1.85	1.79	3.01	1.97
0.8	1.86	1.79	3.11	1.96
0.9	1.86	1.79	3.21	1.94
1.0	1.87	1.80	3.32	1.92
2.0	1.97	1.83	4.57	1.87

Table 2 adapted from B. A. Kunkel, "Comments on 'A Generalized Equation for the Solution Effect in Droplet Growth.'" ©1969 by American Meteorological Society.

GO ON TO THE NEXT PAGE.

Secret word

6. Sucrose ($C_{12}H_{22}O_{11}$) is a molecular compound and remains intact when it dissolves in water. Based on this information and the passage, would the theoretical *i* value for $C_{12}H_{22}O_{11}$ more likely be less than that of KCl or greater than that of KCl ?

   F. Less; the theoretical *i* value for $C_{12}H_{22}O_{11}$ is most likely 1.
   G. Less; the theoretical *i* value for $C_{12}H_{22}O_{11}$ is most likely 4 or greater.
   H. Greater; the theoretical *i* value for $C_{12}H_{22}O_{11}$ is most likely 1.
   J. Greater; the theoretical *i* value for $C_{12}H_{22}O_{11}$ is most likely 4 or greater.

GO ON TO THE NEXT PAGE.

Passage II

Some mutations in *Escherichia coli* allow the bacteria to survive exposure to an antibiotic. These antibiotic-resistant bacteria may have a different *relative fitness* (a measure of survival and reproductive success) than *E. coli* without mutations. Scientists conducted a study to determine the relative fitness of 5 *E. coli* strains—1 nonmutated (Strain U) and 4 mutated (Strains W, X, Y, and Z)—when the strains were exposed for 24 hr to each of 5 different concentrations of the antibiotic *streptomycin* (see Table 1). The effect of the mutation in each of Strains W–Z is listed in Table 2.

Table 1

Strain	Relative fitness of *E. coli* exposed for 24 hr to a streptomycin concentration (in μg/mL*) of:				
	0	2	4	6	8
U	1.0	0.5	0.0	0.0	0.0
W	1.2	0.3	0.1	0.0	0.0
X	0.9	0.8	0.5	0.2	0.0
Y	0.7	0.8	0.7	0.5	0.3
Z	1.0	0.1	0.9	0.8	1.5

*micrograms per milliliter

Note: A relative fitness of 0.0 indicates no surviving bacteria.

Table 1 adapted from Viktória Lázár et al., "Bacterial Evolution of Antibiotic Hypersensitivity." ©2013 by EMBO and Macmillan Publishers Limited.

Table 2

Strain	Effect of mutation
W	Increased rate of cell division
X	Increased rate of streptomycin removal from the cell
Y	Decreased rate of streptomycin entry into the cell
Z	Decreased rate of DNA damage repair

Secret word

9. According to Table 2, which of the following statements best describes the effect of the mutation in Strain X cells? Compared to nonmutated *E. coli* cells, Strain X cells move streptomycin:

   A. into the cell at a decreased rate.
   B. into the cell at an increased rate.
   C. out of the cell at a decreased rate.
   D. out of the cell at an increased rate.

10. Suppose an equal number of Strain W cells and Strain X cells were exposed for 24 hr to a streptomycin concentration of 2 μg/mL. Based on Table 1, which of Strain W or Strain X would more likely have the greater number of cells survive and reproduce?

    F. Strain W; Strain W had a relative fitness of 0.3, and Strain X had a relative fitness of 0.8.
    G. Strain W; Strain W had a relative fitness of 1.2, and Strain X had a relative fitness of 0.9.
    H. Strain X; Strain X had a relative fitness of 0.8, and Strain W had a relative fitness of 0.3.
    J. Strain X; Strain X had a relative fitness of 0.9, and Strain W had a relative fitness of 1.2.

Secret word

Secret word

12. In the study, the relative fitness of a nonmutated strain that was grown for 24 hr in the absence of an antibiotic was set to 1.0. Was this strain more likely Strain U or Strain Z, and was this strain grown for 24 hr at a streptomycin concentration of 0 µg/mL or at a streptomycin concentration of 8 µg/mL ?

F. Strain U; 0 µg/mL
G. Strain U; 8 µg/mL
H. Strain Z; 0 µg/mL
J. Strain Z; 8 µg/mL

GO ON TO THE NEXT PAGE.

Passage IV

Introduction

During the *early Earth period* (the first 2 billion years after Earth formed), the Sun produced only about 70% of the light and heat that it does today. Consequently, if early Earth's atmosphere had been identical to Earth's atmosphere today, the average surface temperature would have been well below the freezing point of water. However, geologic evidence indicates that a large amount of liquid water was present on the surface. Two hypotheses were proposed to explain how 3 heat-absorbing greenhouse gases—carbon dioxide (CO_2), ammonia (NH_3), and methane (CH_4)—in early Earth's atmosphere contributed to the presence of liquid water on the surface.

Hypothesis 1

During the early Earth period, volcanic eruptions released both CO_2 and NH_3 into the atmosphere. In addition, microbes produced CH_4 by metabolizing hydrogen (H_2) gas. Compared with atmospheric greenhouse gas concentrations at present day, those on early Earth were considerably greater: the CO_2 concentration was about 100 times as great, the NH_3 concentration was about 20 times as great, and the CH_4 concentration was about 1,000 times as great. These higher-than-present atmospheric concentrations of CO_2, NH_3, and CH_4 absorbed enough heat to maintain an average surface temperature that allowed for liquid water.

Hypothesis 2

The only source of atmospheric CO_2, NH_3, and CH_4 on early Earth was volcanic eruptions. Compared with atmospheric CO_2 and NH_3 concentrations at present day, those on early Earth were somewhat greater: the CO_2 concentration was about 40 times as great and the NH_3 concentration was about 10 times as great. The CH_4 concentration was about the same as its present value. At those concentrations, the 3 gases by themselves would not have absorbed enough heat to raise the average surface temperature above freezing. However, atmospheric concentrations of both nitrogen (N_2) and H_2 were approximately twice what they are today. These higher-than-present concentrations of N_2 and H_2 greatly enhanced the heat-absorbing effects of the 3 greenhouse gases, maintaining an average surface temperature that allowed for liquid water.

20. A supporter of Hypothesis 1 and a supporter of Hypothesis 2 would be likely to agree that, during the early Earth period, magma from beneath Earth's crust contained:

- **F.** carbon compounds but not nitrogen compounds.
- **G.** nitrogen compounds but not carbon compounds.
- **H.** both carbon compounds and nitrogen compounds.
- **J.** neither carbon compounds nor nitrogen compounds.

Secret Word

23. In regard to the source of CH_4 in early Earth's atmosphere, which of the following statements describes a difference between Hypothesis 1 and Hypothesis 2 ? According to Hypothesis 1, CH_4 was:

- **A.** released from volcanic eruptions, whereas according to Hypothesis 2, CH_4 was produced by microbial metabolism.
- **B.** released from volcanic eruptions, whereas according to Hypothesis 2, CH_4 was produced by chemical reactions between CO_2 and H_2O.
- **C.** produced by microbial metabolism, whereas according to Hypothesis 2, CH_4 was released from volcanic eruptions.
- **D.** produced by microbial metabolism, whereas according to Hypothesis 2, CH_4 was produced by chemical reactions between CO_2 and H_2O.

Secret word

ecret
word

25. Hypothesis 1 would be best supported by which of the following findings involving CO_2 or CH_4 ?

A. Evidence that 4 billion years ago the concentration of CO_2 was 20 times the present concentration
B. Evidence that 4 billion years ago the concentration of CH_4 was 20 times the present concentration
C. 3.5-billion-year-old rock samples containing evidence of CO_2 produced by microbes
D. 3.5-billion-year-old rock samples containing evidence of CH_4 produced by microbes

Passage V

Viscous fluid flow occurs when various parts of a fluid interact with each other to produce forces that inhibit flow and generate heat. Students performed 3 studies of viscous fluid flow using the experimental setup shown in Figure 1 below.

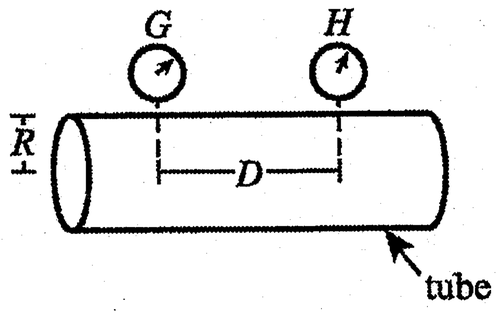

Figure 1

In each trial of the studies, the students sent a fluid through a tube such that the fluid completely filled the tube. The fluid had a viscosity η; the tube had a radius R and was fitted with 2 pressure gauges, Gauge G and Gauge H, that were a distance D apart. The pressure of the fluid at Gauge G minus the pressure of the fluid at Gauge H always equaled 5 kilopascals. (A *kilopascal*, kPa, is a unit of pressure, which is defined as force per unit area.) Using a flow meter, the students measured the fluid's flow rate through the tube, F, in milliliters per second (mL/sec).

Study 1

The students measured F for various fluids, each having a different η, that flowed, one at a time, through a tube having an R of 5.00 mm and a D of 1.00 m (see Table 1).

Table 1

η (10^{-3} Pa·sec*)	F (mL/sec)
1.00	1,230
2.00	615
3.00	410
4.00	307
5.00	246

*pascal second

Study 2

The students measured F for a fluid having an η of 1.0×10^{-3} Pa·sec that flowed through each of various tubes having the same D, 1.00 m, but different R (see Table 2).

Table 2

R (mm)	F (mL/sec)
1.00	1.97
2.00	31.5
3.00	159
4.00	504
5.00	1,230

Study 3

The students measured F for a fluid having an η of 1.0×10^{-3} Pa·sec that flowed through each of various tubes having the same R, 5.00 mm, but different D (see Table 3).

Table 3

D (m)	F (mL/sec)
0.50	2,460
1.00	1,230
1.50	820
2.00	615
2.50	492

Secret Word

30. Based on the information given, in what direction was the fluid flowing?

F. From Gauge G toward Gauge H, because the pressure at Gauge G was greater than the pressure at Gauge H.

G. From Gauge G toward Gauge H, because the pressure at Gauge G was less than the pressure at Gauge H.

H. From Gauge H toward Gauge G, because the pressure at Gauge H was greater than the pressure at Gauge G.

J. From Gauge H toward Gauge G, because the pressure at Gauge H was less than the pressure at Gauge G.

Passage VI

Wheat growth is negatively affected by higher-than-normal salt (NaCl) concentrations in the soil. Scientists investigated whether the negative effects are countered by adding to the soil either a species of bacteria (Species R) or a mixture of proteins from marine algae (PMA).

Study 1

First, 240 identical 2 L pots were each filled with 1.5 kg of a certain soil. Next, 5 wheat seeds were planted in each pot, and the pots were divided equally into 4 groups (Groups 1–4). Then, all the pots in each group received 1 of 4 treatments (see Table 1).

Table 1

Group	Treatment
1	0.5 L of H_2O
2	0.5 L of H_2O containing 9.3 g/L of NaCl
3	0.5 L of H_2O containing Species R and 9.3 g/L of NaCl
4	0.5 L of H_2O containing PMA and 9.3 g/L of NaCl

Note: The addition of 9.3 g/L of NaCl to the pots in Groups 2–4 resulted in a higher-than-normal NaCl concentration in the soil in those pots.

After treatment, each pot was irrigated once every 3 days with either 0.5 L of H_2O only (Group 1) or 0.5 L of H_2O containing 9.3 g/L of NaCl (Groups 2–4). The average number of seeds germinated per pot was then determined for each group at 3, 5, 7, and 9 days after treatment (see Table 2).

Table 2

Days after treatment	Average number of seeds germinated per pot			
	Group 1	Group 2	Group 3	Group 4
3	4.8	0.0	1.1	2.8
5	5.0	0.0	4.3	4.0
7	5.0	0.2	5.0	4.6
9	5.0	0.4	5.0	4.8

Study 2

An additional 240 of the 2 L pots were prepared, treated, and irrigated as in Study 1. Nine days after treatment, all but 1 seedling were removed from each of the pots that had multiple seedlings. Each pot was then irrigated as in Study 1 for an additional 75 days. The average plant height was then determined for each group (see Figure 1).

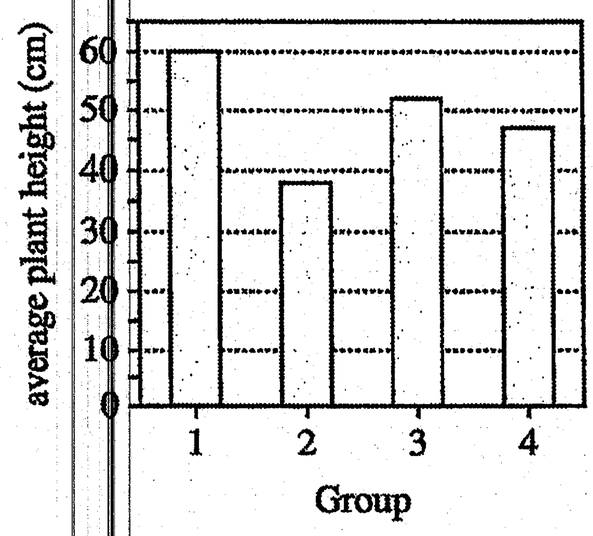

Figure 1

Table 2 and Figure 1 adapted from Elhafid Nabti et al., "Restoration of Growth of Durum Wheat (*Triticum durum* var. waha) Under Saline Conditions Due to Inoculation with the Rhizosphere Bacterium *Azospirillum brasilense* NH and Extracts of the Marine Alga *Ulva lactuca*." ©2010 by Springer Science and Business Media, LLC.

GO ON TO THE NEXT PAGE.

Secret word

37. Consider the claim "The average height of the plants in a group was affected by the number of days that the pots in that group were irrigated." Can this claim be evaluated on the basis of the results of Study 2 ?

A. Yes, because the number of days of irrigation was the same for all the groups.
B. Yes, because the number of days of irrigation was different for each group.
C. No, because the number of days of irrigation was the same for all the groups.
D. No, because the number of days of irrigation was different for each group.

38. Consider the statement "Treatment with Species R was more effective at promoting seed germination in soil with a higher-than-normal NaCl concentration than was treatment with PMA." Are the results of Study 1 for 5, 7, and 9 days after treatment consistent with this statement?

F. Yes; on each of those days, the average number of seeds germinated per pot was greater for Group 3 than for Group 4.
G. Yes; on each of those days, the average number of seeds germinated per pot was greater for Group 4 than for Group 3.
H. No; on each of those days, the average number of seeds germinated per pot was greater for Group 3 than for Group 4.
J. No; on each of those days, the average number of seeds germinated per pot was greater for Group 4 than for Group 3.

Secret word

40. Consider the statement "On average, plant height was greater for the plants treated with H_2O containing PMA and NaCl than it was for the plants treated with either H_2O containing NaCl only or H_2O containing Species R and NaCl." Do the results of Study 2 support this statement?

F. Yes; the average plant height in Group 3 was greater than the average plant height in Groups 2 and 4.
G. Yes; the average plant height in Group 4 was greater than the average plant height in Groups 2 and 3.
H. No; the average plant height in Group 3 was greater than that in Group 2 but less than that in Group 4.
J. No; the average plant height in Group 4 was greater than that in Group 2 but less than that in Group 3.

Secret word