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SECTION 4: SCIENCE TEST

35 Minutes—40 Items

DIRECTIONS: Each passage below is followed by several items. After reading a passage, choose the best answer for each item. Fill in the corresponding oval on your bubble sheet. You may refer to the passage as often as necessary. You are NOT permitted the use of a calculator on this test. Answers are on page 692.

Passage I

The chart below shows several physical properties of compounds called alkanes, which are long "chains" of carbons to which hydrogen atoms are attached. As an example, the compound propane, which has three carbons, has the structural formula:

$$CH_3—CH_2—CH_3$$

Physical Properties of Straight-Chain Alkanes

Name	# of Carbons	Boiling Point (°C)	Melting Point (°C)	Density
methane	1	–162	–183	0.47
ethane	2	–89	–183	0.57
propane	3	–42	–188	0.50
butane	4	0	–138	0.58
pentane	5	36	–130	0.56
hexane	6	69	–95	0.66
heptane	7	98	–91	0.68
octane	8	126	–57	0.70
nonane	9	151	–54	0.72
decane	10	174	–30	0.74

1. The general trends shown in the chart are:

   A. as the number of carbons increases, all properties increase in value (with occasional exceptions).
   B. as the number of carbons increases, boiling points and melting points decrease, while density increases.
   C. as the number of carbons increases, density decreases and other properties increase.
   D. as the number of carbons increases, all properties decrease.

2. The change in boiling point is greatest:

   F. from methane to ethane.
   G. from propane to butane.
   H. from butane to pentane.
   J. from nonane to decane.

3. For alkanes with more than one carbon, the change in melting point from one alkane to the next:

   A. tends to be greater from an even number of carbons to the next odd number.
   B. tends to be greater from an odd number of carbons to the next even number.
   C. is similar, whether from an even number of carbons to the next odd number, or from an odd number of carbons to the next even number.
   D. Cannot be determined from the given information

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4. Considering the alkane properties listed, if alkane X has a higher boiling point than alkane Y, then without exception, it must also have a:

F. higher melting point.
G. higher density.
H. higher number of carbons.
J. longer name.

5. The greatest percentage increase in density occurs from:

A. ethane to propane.
B. propane to butane.
C. pentane to hexane.
D. hexane to heptane.

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Passage II

A student performs a set of physics laboratory experiments, in which objects of different masses glide "frictionlessly" along a smooth surface, collide, and then continue to glide. The momentum of each object is defined as its "mass • velocity." The momentum of a system of objects is the sum of the individual momentums.

Experiment 1

The light mass moves toward the stationary, heavy mass, and both stick together and continue to move. Table 1 shows the relevant information.

Table 1

	Object 1	Object 2
Mass	2 kg	5 kg
Initial velocity	4 m/sec	0 m/sec
Final velocity	1.14 m/sec	1.14 m/sec

Experiment 2

The student performs a similar experiment in which the objects do not stick together, but collide "elastically"—that is, rebound from each other with no loss in energy. Table 2 shows the results.

Table 2

	Object 1	Object 2
Mass	2 kg	5 kg
Initial velocity	4 m/sec	0 m/sec
Final velocity	−1.71 m/sec	2.29 m/sec

(Note that positive velocities indicate motion to the right, negative velocities indicate motion to the left.)

6. In Experiment 1, the momentum of Object 1 before the collision is:

F. 0 kg • m/sec.
G. 2 kg • m/sec.
H. 4 kg • m/sec.
J. 8 kg • m/sec.

7. After the collision in Experiment 1, the momentum of the combined masses is:

A. much less than the initial total momentum of the two masses.
B. about equal to the initial total momentum of the two masses.
C. much greater than the initial total momentum of the two masses.
D. Cannot be determined from the given information

8. After the collision in Experiment 2:

F. both objects are moving to the right.
G. both objects are moving to the left.
H. Object 1 is moving to the left and Object 2 to the right.
J. Object 1 is moving to the right and Object 2 to the left.

9. In Experiment 2, if Object 2 were replaced by another object that was far more massive than Object 1, its final velocity would be closest to:

A. 4.0 m/sec.
B. 2.3 m/sec.
C. −1.7 m/sec.
D. 0 m/sec.

10. Under the conditions described in the previous item, the final velocity of Object 1 would be closest to:

F. −2 m/sec.
G. −1.7 m/sec.
H. 0 m/sec.
J. 2 m/sec.

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11. Kinetic energy is defined as $\frac{mv^2}{2}$. During the collision described in Experiment 1, the kinetic energy of Object 1:

A. increases.
B. remains the same.
C. decreases.
D. Cannot be determined from the given information

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Passage III

The table below shows how an increase (+) or a decrease (−) in one or more plant hormones and environmental factors can affect various plant activities. The activities listed on the left occur when the combinations of conditions to the right exist at the same time. Hormones (H) are numbered; e.g., H_1, H_2, etc.

Activities	H_1	H_2	H_3	H_4	H_5	Day Length	Temperature
Plant growth	++		++				
No plant growth (1)	++		++	++			
No plant growth (2)	++		++		++		
Seed germination			++				
Flowering			++		++	(++ *or* − −)*	++
Flower drop-off	− −	++					
Fruit drop-off	− −	++					
Leaf drop-off	− −	++					− −

*Different species of plants require different combinations of light and darkness to stimulate flowering.

12. Based on the information in the table, a drop in temperature will help cause:

F. flowering.
G. loss of leaves, fruit, and flowers.
H. loss of leaves only.
J. seed germination.

13. The hormones that can inhibit (prevent) plant growth are:

A. 1 and 3.
B. 1, 3, and 4.
C. 1, 3, and 5.
D. 4 and 5.

14. Which conclusion is correct about the various factors affecting plant activities?

F. Hormone 3 influences more plant activities than any other factor.
G. Seed germination is influenced by the fewest factors, whereas flowering is influenced by the most.
H. For Hormone 1 to have an effect on any plant activity, it must be changing in the opposite direction of at least one other hormone.
J. Temperature changes can affect all plant activities.

15. Which activity would most likely be affected by changing a houseplant's growing conditions from 12 hours of light per 12 hours of darkness to constant light?

I. Plant growth
II. Loss of leaves
III. Flowering

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

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16. Which statement best describes the relationship between Hormone 1 and Hormone 2?

F. Hormone 2 must change in the opposite direction of Hormone 1 for plant growth to occur.
G. When Hormone 1 and Hormone 2 affect a plant activity together, no other factors influence that activity.
H. As Hormone 1 increases, Hormone 2 always decreases; and as Hormone 1 decreases, Hormone 2 always increases.
J. Hormone 2 only affects plant activities when Hormone 1 is also involved.

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Passage IV

In order to examine the factors that affect the flow of substances across cell membranes, three experiments were carried out. In each experiment, semi-permeable bags (bags with small pores that allow some substances to pass through, but not others) were partially filled with a fluid, tied, and then weighed (first weighing). The bags were then submerged into a large beaker of water, and at 10-minute intervals, removed from the beaker of water and re-weighed.

Experiment 1

A bag containing a 30% red dye solution (30% red dye and 70% water) weighed 100 grams. The bag was then submerged in a beaker of pure water. After 20 minutes, the bag weighed 110 grams. The beaker water remained clear.

Experiment 2

A second bag containing 40% red dye solution (40% red dye and 60% water) weighed 100 grams before being submerged in a beaker of pure water. After only 10 minutes, the bag weighed 110 grams. The beaker water remained clear.

Experiment 3

A third bag containing only pure water and weighing 100 grams was submerged in a beaker of 50% red dye solution (50% red dye and 50% water). After 20 minutes, the bag weighed 70 grams. The bag water remained clear.

17. In Experiment 1, a gain in bag weight suggests that:

A. material passed out from bag to beaker faster than it passed in from beaker to bag.
B. material passed in from beaker to bag faster than it passed out from bag to beaker.
C. material passed in and out of the bag at approximately the same rate.
D. material did not move at all.

18. Which of the following hypotheses is supported by the results of all three experiments?

F. Red dye can leave the bag but not enter.
G. Red dye can enter the bag but not leave.
H. Red dye can enter or leave the bag.
J. Red dye cannot enter or leave the bag.

19. Which of the following represents the best approximation for the weight of the bag in Experiment 2 after 20 minutes?

A. 90 grams
B. 100 grams
C. 110 grams
D. 120 grams

20. Which of the following questions is the entire set of experiments designed to answer?

F. How does concentration of red dye affect rate and direction of water flow?
G. How does concentration of water affect rate and direction of red dye flow?
H. How does rate of red dye flow affect direction of water movement?
J. How does direction of red dye movement affect rate of water flow?

21. A control experiment was set up to confirm the investigation's conclusion. A bag containing pure water and weighing 100 grams was submerged in a beaker of pure water. What is expected to occur?

A. The bag will slowly gain weight.
B. The bag will slowly lose weight.
C. The bag will remain approximately the same weight.
D. The bag will eventually become empty, and the water level in the beaker will rise.

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22. Assuming that salts cannot freely pass across a cell's membrane, what would happen to human red blood cells (approximately 1% salt and 99% water) submerged in sea water (approximately 5% salt and 95% water)?

F. The cells would shrink due to a loss of water.
G. The cells would shrink due to a loss of salt.
H. The cells would swell up due to a gain of water.
J. The cells would swell up due to a gain of salt.

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Passage V

The chart below shows various physical characteristics of different types of soil.

Physical Characteristics of Soil				
Types of Soil	Diameter of Particles (μm)	Relative Ability* to Hold Positively Charged Minerals (Ca^{+2}, K^{+}, Mg^{+2})	Relative Ability* to Maintain Air Spaces	Relative Ability* to Retain Water
Clay	less than 2	1	4	1
Silt	2–20	2	3	2
Sand	20–200	3	2	3
Coarse Sand	200–2,000	4	1	4

*Relative abilities are rated from 1, indicating the best (most able), to 4, indicating the worst (least able).

23. The soil type that is LEAST able to hold substances such as magnesium (Mg^{+2}) is:

A. sand.
B. coarse sand.
C. silt.
D. clay.

24. Based on the information in the chart, which of the following statements best describes the relationship between a soil's particle size and its other physical characteristics?

F. As particle size increases, the ability to hold positively charged minerals increases.
G. As particle size decreases, the ability to retain water decreases.
H. As particle size decreases, the ability to maintain air spaces increases.
J. As particle size increases, the ability to retain water decreases.

25. The size of particles in the soil type that is neither best nor worst at any of the listed abilities must be:

A. less than 20 micrometers.
B. more than 20 micrometers.
C. between 2 and 200 micrometers.
D. between 2 and 2,000 micrometers.

26. Loam is a type of soil that is mostly clay, but it also contains some sand and silt particles. Which prediction is most likely to be accurate about the ability of loam to support plant growth?

F. Plants will grow well because loam primarily has small particles that can hold minerals and retain water, yet it also has enough large particles to provide air spaces containing oxygen.
G. Plants will grow well because loam primarily has large particles that can provide air spaces containing oxygen, yet it also has enough small particles that can hold minerals and retain water.
H. Plants will not grow well because although loam is excellent at maintaining air spaces for oxygen, it will not hold enough minerals or water.
J. Plants will not grow well because although loam has enough minerals and air spaces for oxygen, it cannot retain enough water.

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27. Based on the information provided in the chart, which of the following conclusions about soil types is NOT correct?

A. Soils best at retaining water are also best at holding positively charged minerals.
B. No two soil types have the exact same combination of relative abilities.
C. Clay and coarse sand are the soil types that are most different in every physical characteristic.
D. At each listed ability, a different type of soil is best.

Passage VI

Theory 1

The rate of a chemical reaction is defined as the number of moles of a specified reactant consumed in one second. Reactants must collide in order for a reaction to occur, so it might seem that rates would depend upon the concentration of reactants—the more reactants that are present, the greater the likelihood of a collision. In fact, this is the case; a concrete example makes this clear. For the reaction: $2NO + O_2 \Rightarrow 2NO_2$, the rate is proportional to the amount of NO and O_2 present. This fact is expressed in the following "rate law": $\text{rate} = k[NO]^2[O_2]^1$, where k is the rate constant, and the exponents reflect the coefficients in front of the reactants in the reaction. The relationship between numbers of reactant molecules and exponents in the rate law is a general one.

Theory 2

Theory 1 is very often true, for it expresses the reasonable insight that the greater the concentration of reactants, the greater the likelihood of a reaction. It has a great shortcoming, however, in its assumption that all reactions proceed in one fell swoop rather than in several skirmishes.

For example, let letters A, B, and C stand for molecules. In the reaction $A + 2B \Rightarrow C$, Theory 1 predicts a rate law as follows: $\text{rate} = k[A][B]^2$. However, if the reaction actually proceeds in two stages, the first one would be $A + B \Rightarrow AB$ and the second one would be $AB + B \Rightarrow C$.

Thus, Theory 2 implies that one must understand the details of the reaction, including the relative speeds of the sub-reactions, in order to predict a rate law. Theory 1 is not completely wrong, just incomplete.

28. Theory 1 relates:

F. reaction rate to the concentration of products.
G. reaction rate to the concentration of reactants.
H. the relative amounts of products to one other.
J. reaction rate to the individual rates of various stages of the reaction.

29. According to a proponent of Theory 2, Theory 1:

A. can never give a correct prediction for a rate law.
B. will give a correct result if the reactant coefficients are all equal to 1.
C. will give a correct result for a single-stage reaction.
D. is in error because it claims that collisions are required for reactions to occur.

30. According to Theory 1, the rate of the reaction $3M + 2N \Rightarrow 4P$ will be given by:

F. $k[M][N]$.
G. $k[M]^3[N]^2$.
H. $k[M]^3[N]^2[P]^4$.
J. $k([M]^3 + [N]^2)$.

31. A chemist studies the rate of the reaction $2NO_2 + F_2 \Rightarrow 2NO_2F$. According to Theory 1, the rate of the reaction is proportional to:

A. the first power of NO_2 and the first power of F_2.
B. the second power of NO_2 and the second power of NO_2F.
C. the second power of NO_2 and the second power of F_2.
D. the second power of NO_2 and the first power of F_2.

32. Supporters of Theory 2 would best be able to defend their positions if:

F. they could show that the reaction occurs in more than one stage.
G. they slowed the reaction down by cooling the reactants.
H. they sped the reaction up with additional heat.
J. they eliminated all collisions.

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33. According to Theory 2, if in a two-stage reaction Stage 1 is much slower than Stage 2, then the overall reaction rate will be:

A. primarily determined by the rate of Stage 1.
B. primarily determined by the rate of Stage 2.
C. undeterminable unless all collisions are counted.
D. undeterminable unless the rate law is measured experimentally.

34. When discussing the rates of reactions that have more than one stage, Theory 2 would not be necessary if:

F. all stages went quickly.
G. all stages had different rates.
H. the sum of the rates of each stage always equaled the rate of the reaction as a whole.
J. the sum of the rates of each stage was never equal to the rate of the reaction as a whole.

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Passage VII

Closely related species of butterflies are often found living in very different environments. A pair of experiments was performed in which butterfly species previously captured in either desert areas or mountain areas were tested in laboratory incubators to determine the conditions at which they could carry out important life functions such as mating, oviposition (egg-laying), and pupation (the stage in which the stationary cocoon undergoes its final development into an adult).

Experiment 1

Under conditions of 100% relative humidity (maximum moisture content of the air), 100 desert butterflies (Species D) and 100 mountain butterflies (Species M) were tested at temperature intervals of 2°C (from 0°C to 40°C) to determine if they could mate, oviposit, and pupate. Each species achieved at least 90% success at the following ranges of temperatures:

Table 1

	Temperature Ranges (°C)		
	Mating	Oviposition	Pupation
Species D	10–34	14–34	4–38
Species M	6–30	10–28	4–34

Experiment 2

The experiment was repeated at 0% relative humidity (minimum moisture content of the air). The species achieved at least 90% success at the following ranges of temperatures:

Table 2

	Temperature Ranges (°C)		
	Mating	Oviposition	Pupation
Species D	10–34	14–34	4–38
Species M	6–24	10–22	4–28

35. Results of Experiments 1 and 2 indicate that the life function with the narrowest range of temperature at which both species achieve 90% success is:

A. mating.
B. oviposition.
C. pupation.
D. different in Experiment 1 than it is in Experiment 2.

36. Which condition has the most detrimental effects on Species M for mating, oviposition, and pupation?

F. Moist air at low temperatures
G. Moist air at high temperatures
H. Dry air at low temperatures
J. Dry air at high temperatures

37. A third experiment was conducted at 100% relative humidity in which the temperature range for caterpillar survival (another life function) was tested in Species D and Species M. Species D achieved 90% success at 12–36 (°C), while Species M achieved 90% success at 8–30 (°C). Which temperature range is a good prediction of survival in Species D under dry conditions?

A. 8°C–30°C
B. 8°C–24°C
C. 12°C–36°C
D. 12°C–30°C

38. If an investigator wanted to set up an experiment to determine the effects of light and dark on mating ability in Species D and Species M at 100% relative humidity, which set of conditions would provide the most complete results?

F. Test both species at 6°C in the light and 6°C in the dark.
G. Test both species at 20°C in the light and 20°C in the dark.
H. Test both species at 34°C in the light and 34°C in the dark.
J. Test both species at 34°C in the light and 30°C in the dark.

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39. Which hypothesis is NOT supported by the results of Experiment 1 and Experiment 2?

A. For all tested life functions, dry conditions only affect Species M at the high end of its temperature ranges.
B. For all tested life functions, dry conditions have no effects on the temperature ranges of the desert species.
C. Species D does better than Species M at high temperatures in all tested life functions.
D. Species M does better than Species D at low temperatures for pupation.

40. Which of the following statements best explains the broad range of temperatures for pupation observed in both butterfly species?

F. Since the cocoon is stationary, it must be able to survive changing temperature conditions until the adult butterfly emerges.
G. Deserts can get very hot and mountains can get very cold.
H. Mountain butterflies would not survive long in the desert, and desert butterflies would not survive long in the mountains.
J. The stationary cocoon must be able to survive under light and dark conditions until the adult butterfly emerges.

END OF TEST 4

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