

MCAT^{*}

Practice Test 2

Explanations



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1 H 1.0																	2 He 4.0
3 Li 6.9	4 Be 9.0											5 B 10.8	6 C 12.0	7 N 14.0	8 O 16.0	9 F 19.0	10 Ne 20.2
11 Na 23.0	12 Mg 24.3											13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 39.9
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.8	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La *	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0	89 Ac †	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (264)	108 Hs (269)	109 Mt (268)	110 Ds (269)	111 Rg (272)	112 Uub (277)	113 Uut (284)	114 Uuq (289)	115 Uup (288)	116 Uuh (292)	117 Uus (291)	118 Uuo (293)

* 58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
† 90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

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PHYSICAL SCIENCES ANSWER KEY

1. (B)	16. (B)	31. (C)
2. (A)	17. (B)	32. (D)
3. (C)	18. (C)	33. (C)
4. (C)	19. (A)	34. (B)
5. (B)	20. (A)	35. (C)
6. (C)	21. (D)	36. (A)
7. (B)	22. (A)	37. (C)
8. (D)	23. (C)	38. (D)
9. (A)	24. (C)	39. (B)
10. (B)	25. (A)	40. (B)
11. (D)	26. (C)	41. (C)
12. (A)	27. (B)	42. (B)
13. (A)	28. (D)	43. (C)
14. (B)	29. (C)	44. (A)
15. (A)	30. (A)	45. (B)

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PHYSICAL SCIENCES EXPLANATIONS

Passage I (Questions 1–6)

1. (B)

In an ideal system, total mechanical energy, the sum of potential and kinetic energy, is conserved. In such cases, potential energy is lost as it is translated into kinetic energy, so one knows that the kinetic energy of a system is always equal to the lost potential energy of the system. The cyclist in the above problem, however, is not in an ideal system. He must contend with non-conservative forces like wind resistance, which reduce the amount of kinetic energy he can develop from a given loss of potential energy. Consequently, not all of the lost potential energy is converted into kinetic energy; $U > K$, and choice (B) is correct.

2. (A)

The total weight of the rider and the bicycle on the tires is $90 + 10 = 100$ kg, which is approximately 1000 N. However, since there are two wheels, each wheel carries only about half that weight, or 500 N. The pressure within each wheel is given as 500 kilopascals, or 5×10^5 N/m². Since pressure equals force divided by area, we must divide force by pressure in order to determine the area: 5×10^2 N / 5×10^5 N/m² = 10^{-3} m². Answer choice (A) is correct.

3. (C)

This question is an application of Gay-Lussac's Law, which states that for a sample of gas with a given number of moles and constant volume, the pressure and temperature are directly related. It is often stated in equation form as $P_1/T_1 = P_2/T_2$. One must only remember in applying this law to convert the temperatures to Kelvin, and the pressures to atmospheres. If you didn't remember Gay-Lussac's Law directly, it can be easily derived from the Ideal Gas Law equation ($PV = nRT$) by eliminating those variables that are constant and setting up the appropriate ratio.

Because the temperature has increased, the pressure within the tires must also have increased, which means that choice (C) is correct.

4. (C)

The size of the contact patch will remain the same despite changes in the size of the tire because the size depends solely on the pressure within the tire. The size of the contact patch is independent of the size of the tire. A larger tire will have a greater frontal area, resulting in more wind resistance, but that is not what the question is asking. The size of the contact patch needed to balance the weight of the rider and bike to the pressure within the tire will remain the same for a narrower or smaller tire with the same pressure, and so choice (C) is correct.

5. (B)

It is true that the rider feels no wind resistance at that speed because he is effectively moving with the wind. However, the wind is not the only force he must overcome, just the most dominant one. The rider must still supply energy to overcome the internal friction within the bike's parts as well as rolling resistance. Thus, (B) is the correct answer.

6. (C)

This question requires you to utilize the second term in Equation 1 ($C_{rr}W_tV_g$) to calculate the energy spent in one minute to overcome rolling resistance. You are given values for each of the variables in this equation; $P = (1.25 \times 10^{-5})(80 \text{ kg})(g)(20 \text{ m/s}) = 0.2 \text{ W}$. Remember that the weight in this equation is the total weight *in Newtons* of the rider and the bicycle. But don't stop there and choose (D).

To finish the problem and get the correct answer, you must calculate the amount of energy expended in one minute. Since power is energy per unit time, you must multiply the power by 60 s:

$$E = (0.2 \text{ J/s})(60 \text{ s/min}) = 12 \text{ J, answer choice (C).}$$

Passage II (Questions 7–12)

7. (B)

For all electrochemical cells (the circuit completed by the ship's hull and surrounding water can be thought of as an electrochemical cell), the oxidation reactions occur at the anodes. Unfortunately, all the answer choices given in this problem are written as oxidation reactions. However, a keen eye will notice that choices

(C) and (D) have the electrons on the wrong side: in other words, neither conserve charge. Eliminate them.

Selecting the correct answer choice now depends on how well you read the passage. The passage states that the Fe^{2+} forms at and migrates from the anode. Only choice (B) correctly shows $\text{Fe}(s)$ being oxidized to Fe^{2+} .

8. (D)

For any electrochemical battery, the standard voltage can be expressed as $E_{\text{total}}^{\circ} = E_{\text{ox}}^{\circ} + E_{\text{red}}^{\circ}$. The passage states that “in the presence of H_2O and O_2 , the reduction reaction proceeds with $E_{\text{red}}^{\circ} = 1.229 \text{ V}$.” The oxidation reaction is the oxidation of solid iron, $\text{Fe}(s) \rightarrow \text{Fe}^{2+}(aq) + 2e^-$; the potential for this reaction can be found in Table 1 and is 0.447 V (the negative of the reduction potential). The standard potential is thus $1.229 + 0.447 = 1.676 \text{ V}$, choice (D).

9. (A)

A sacrificial anode is a material that is oxidized preferentially to another, which you learn in the second paragraph. In this question you want to know which material will *not* be oxidized before lead. Therefore you are looking for a material that has a lower oxidation potential (or higher reduction potential) than lead. Looking at Table 1, you see that only copper, choice (A), has a larger reduction potential than lead.

10. (B)

As the first paragraph of the passage indicates, iron in the metal hull is oxidized and migrates elsewhere (and is consequently “lost” from that part of the hull). Electrons resulting from the oxidation of $\text{Fe}(s)$ pass through ship’s hull at a rate of 0.5 A . Over the course of an hour you can calculate how many electrons are released by using dimensional analysis and Faraday’s constant:

$$\frac{0.50 \text{ C}}{1 \text{ s}} \times 1.0 \text{ hr} \times \frac{3,600 \text{ s}}{1 \text{ hr}} \times \frac{1 \text{ mol } e^-}{96,485 \text{ C}} \approx \frac{1,800}{100,000} \text{ mol } e^- = 0.018 \text{ mol } e^-.$$

Again, these electrons result from the oxidation of iron, given by the reaction $\text{Fe}(s) \rightarrow \text{Fe}^{2+}(aq) + 2e^-$. The stoichiometry indicates that for every mole of iron oxidized, two moles of electrons are released.

Therefore, 0.018 moles of electrons released corresponds to 0.009 moles of iron oxidized. Now you can use the molecular mass of iron, 55.85 g , to calculate the mass of iron lost:

$$0.009 \text{ mol Fe}(s) \times \frac{55.85 \text{ g}}{1 \text{ mol Fe}(s)} \approx 0.01 \times 50 \text{ g} = 500 \text{ mg}.$$

This approximation is very close to the correct answer, 521 mg , choice (B).

11. (D)

The question stem asks you to compare the difference between the corrosion reactions for ships on top of the ocean and those for ships on the bottom. Scanning through the answer choices you can see that the correct answer has something to do with oxygen and water. How, then, is the environment at the bottom of the ocean different than that at the top? The answer: a ship at the bottom of the ocean has plenty of water, but no oxygen.

The passage states that, in the presence of water and oxygen, the reduction reaction can take place. However, the question stem indicates that in the absence of oxygen, corrosion can still take place. Therefore, it must be true that the reduction reaction can take place in the absence of oxygen. Choice (D) states this fact.

12. (A)

The fundamental question presented here is, “What physical property facilitates the corrosion of solid iron?” Corrosion, as you read from the passage, is a series of oxidation/reduction reactions. In redox reactions, electrons are transferred between species as atoms change their oxidation states. You can infer that the rate of a redox reaction will be driven by the reduction potentials of the atoms and the ease with which electrons can be transferred. However, you do not need to consider the reduction potentials of the answer choices since none of them participate in the corrosion equations given in the passage. So you must then ask yourself which compound will best facilitate the transfer of electrons. Recall that the conductivity of a solution increases with the amount of ions in solution. This question is simply asking which compound will release the most ions. PbF_2 will release 3 moles of ions for every 1 mole of solid dissolved, while CuBr , PbSO_4 , and AgIO_3 will release only 2 moles of ions. Therefore, choice (A) should give the largest conductivity.

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Discrete Questions (Questions 13–17)

13. (A)

The reaction given is the decomposition of aluminum trichloride into aluminum and chlorine. Both aluminum and chlorine are in their standard states—a solid metal and a diatomic gas, respectively. The heat of formation (the thermodynamic value given) is the enthalpy change for the formation of one mole of a compound from its constituent elements in their standard state. Since the reaction given is the *decomposition* of two moles of AlCl_3 , its enthalpy change will be twice that (in magnitude) of the heat of formation, as well as opposite in sign. The correct answer is thus choice **(A)**.

14. (B)

Answer choices **(A)** and **(C)** can be eliminated right away. When resistors are connected in series, the total resistance is the sum of the individual resistances ($R_T = R_1 + R_2 + \dots$). Adding resistors in series will only increase the resistance of the circuit. On the other hand, when resistors are connected in parallel, the total resistance is given by

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

Check answer choice **(B)**:

$$\frac{1}{R_T} = \frac{1}{3\Omega} + \frac{1}{3\Omega} = \frac{2}{3\Omega} \rightarrow R_T = \frac{3}{2}\Omega$$

and **(D)**:

$$\frac{1}{R_T} = \frac{1}{3\Omega} + \frac{1}{6\Omega} = \frac{2}{6\Omega} + \frac{1}{6\Omega} = \frac{1}{2\Omega} \rightarrow R_T = 2\Omega.$$

The total resistance is lowest when the $3\text{-}\Omega$ resistor is added in parallel; answer choice **(B)** is correct.

15. (A)

NaCl is an ionic salt. It will be most soluble in solvents that can solvate ions—i.e., solvents that are polar. The question, therefore, is asking you to order the solvents based on their polarity. The three solvents are BF_3 , H_2O , and $\text{CH}_3(\text{CH}_2)_2\text{OH}$. Consider the molecular structure of each:

BF_3 : B has three valence electrons, each of which is shared with a F. There are no lone pairs to consider. The atoms assume a trigonal planar configuration to maximize the separation between the electronegative

fluorines. The bond dipoles geometrically cancel each other out, and the molecule thus has no net polarity. With no net dipole, BF_3 solvates the ionic salt very poorly.

H_2O : Water you should know to be a polar molecule that undergoes hydrogen bonding. Consequently, water can readily solvate free ions and salts like NaCl .

$\text{CH}_3(\text{CH}_2)_2\text{OH}$: Propanol has three carbons with tetrahedral geometry. Most of the dipoles associated with bonds are the same, but the C–C and C–OH bonds are different, so propanol is somewhat polar.

Therefore, from most to least polar, the order is H_2O , $\text{CH}_3(\text{CH}_2)_2\text{OH}$, BF_3 . The correct answer is choice **(A)**.

16. (B)

Even though we don't know whether or not the collision is elastic or inelastic, we do know that the total momentum of the system is conserved throughout. Begin by calculating the momentum of the system before the collision:

$$p_i = (10 \text{ kg})(4 \text{ m/s}) + (4 \text{ kg})(0 \text{ m/s}) = 40 \text{ kg m/s}.$$

The final momentum of the system will have to be the same. Let v be the unknown speed of the 10-kg block, and set the final momentum of the system equal to the initial momentum:

$$p_f = 40 \text{ kg m/s} = (10 \text{ kg})v + (4 \text{ kg})(3 \text{ m/s}) = 10v + 12 \text{ kg m/s}$$

$$10v = 28 \text{ kg m/s}$$

$$v = 2.8 \text{ m/s}.$$

Answer choice **(B)** is correct.

17. (B)

The only way to attack this question is to read through and consider each answer choice. Choice **(A)** is true. A species that undergoes resonance cannot be accurately described by any single Lewis structure. Instead, one or more alternative Lewis structures are drawn. Choice **(B)**, however, is false and therefore the correct answer. The species don't actually resonate between the possible electron distribution designated by the Lewis structures. There is but one electron distribution, which is a

combination of all the possible Lewis structures. Choice **(C)** is true. Having multiple Lewis structures means that there are more ways that the nuclei can “see” the electrons—the electrons are spread across several bonds, lowering the energy of the species. Choice **(D)** is also true. Electrons are more stable when they are placed near highly electronegative atoms.

Passage III (Questions 18–23)

18. (C)

The photon theory of light presents light as discrete packages, rather than as waves. Therefore, any answer choice that shores up this notion will strengthen the theory. Cycle through the choices. Choice **(A)** does nothing for the theory since even if light were only waves, and not photons, it would not necessarily interfere constructively all the time. Choice **(B)** is reiterating the Doppler effect, which occurs even with sound waves: Again, no help to the theory. Choice **(D)** has no bearing on the theory, since we know waves can reflect. Only choice **(C)** will strengthen the theory, since if an atom will only absorb light with a specific frequency, than light energy is quantized.

19. (A)

If a photon has twice the momentum, then it has twice the energy. The energy of a photon is $h\nu$, where $h = 6.63 \times 10^{-34}$ J s and ν is the frequency of the photon. So, in order to double the energy, the frequency must double or the wavelength must be cut in half. Therefore, choice **(A)** is correct. Choice **(D)** is incorrect since the velocity of light is constant in the same medium.

20. (A)

The passage states that when pair production occurs, charge is conserved. The resultant pair of particle must have a net charge of zero. Just looking at the answer choices, we see choice **(B)** yields a net $-e$ charge, choice **(C)** yields a net $+2e$ charge, and choice **(D)** yields a net $+e$ charge. Only choice **(A)** balances charge; an electron has a charge of $-e$, and a positron has a charge of $+e$.

21. (D)

Again, going back to the passage to find details is key. The passage states that pair production is reversible, and that one particle can annihilate the other. Therefore, if B particles are in an environment rich with

particles of type A, they will collide more often and particle B will not last too long. Choice **(A)** is wrong, as the half-life of A could be 100 billion years; therefore, B would still hang around for a very long time. Choices **(B)** and **(C)** are outer-space answers.

22. (A)

From Einstein, you know that the energy of an object at rest is its mass times the square of the speed of light ($E = mc^2$). In this problem, 1 mole of photons has 6.14×10^{29} eV of energy. Convert to Joules and divide by Avogadro’s number to calculate the number of Joules per photon.

$$\frac{6.14 \times 10^{29} \text{ eV}}{1 \text{ mol of photons}} \times \frac{1.6 \times 10^{-19} \text{ J}}{1 \text{ eV}} \times \frac{1 \text{ mol of photons}}{6.02 \times 10^{23} \text{ photons}} \approx 1.5 \times 10^{-13} \text{ J/photon.}$$

Now you can use $E = mc^2$ to calculate the mass of particles born from each photon:

$$m = \frac{E}{c^2} = \frac{1.5 \times 10^{-13} \text{ J}}{9 \times 10^{16} \text{ m}^2/\text{s}^2} \approx 2 \times 10^{-30} \text{ kg,}$$

and answer choice **(A)** is correct.

23. (C)

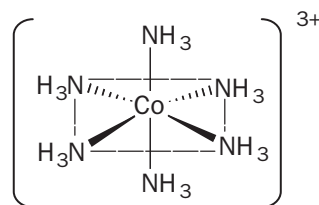
The scattered light has lost energy (remember, the whole point is that a photon colliding with an electron behaves as a particle!), and so it travels with a lower energy, and therefore a lower frequency. Which answer choices have lower energy than x-rays? All of them, except for gamma rays. Choice **(C)** is the only answer which would produce scattered light of a higher frequency and energy than the incident light (i.e., energy would be created, which is unphysical.)

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Passage IV (Questions 24–28)

24. (C)

In $\text{Co}(\text{NH}_3)_6^{3+}$, the Co^{3+} ion is surrounded by six identical NH_3 ligands. The lowest energy molecular geometry for this complex is octahedral:



Square planar and tetrahedral shapes would likely form with four ligands, while a trigonal bipyramid shape would form with five ligands.

25. (A)

The slowest step of a multi-step reaction is rate-determining, which would lead you initially to write the rate law as:

$$\text{Rate} = k[\text{OH}^-][\text{Co}(\text{NH}_3)_6^{3+}]$$

However, you must not forget that only *net* products and reactants may be expressed in the overall rate law. In order to eliminate the $[\text{OH}^-]$ term, you find the rate of formation of OH^- from the preceding step:

$$\text{Rate}(\text{OH}^-) = k[\text{Co}(\text{NH}_3)_6^{3+}]$$

Notice that you don't include water in the rate equation for the first step, since the concentration of water is always assumed to be essentially constant, unless otherwise stated. Now, substitute this rate of OH^- formation into the initial rate law to yield:

$$\text{Rate} = k[\text{Co}(\text{NH}_3)_6^{3+}]^2, \text{ choice (A).}$$

26. (C)

Since you are told that sodium oxide hydrolyzes in water to produce hydroxide ions, any sodium oxide added will basify the solution. This will occur in a ratio of 1 mol sodium oxide:2 mol hydroxide ions. By adding 0.0307 g of Na_2O , the chemist has effectively added 10^{-3} mol of hydroxide:

$$0.0307 \text{ g Na}_2\text{O} \times \frac{1 \text{ mol Na}_2\text{O}}{(2 \times 23 + 16) \text{ g Na}_2\text{O}} \times \frac{2 \text{ mol OH}^-}{1 \text{ mol Na}_2\text{O}} \approx \frac{3.1 \times 10^{-2} \times 2}{46 + 16} \text{ mol OH}^- = \frac{6.2 \times 10^{-2}}{62} \text{ mol OH}^- = 10^{-3} \text{ mol OH}^-$$

The initial pH was 9, a $[\text{OH}^-]$ of 10^{-5} M . In one liter of solution, the initial hydroxide plus the hydroxide produced in hydrolysis of sodium oxide will be: $10^{-3} + 10^{-5} \approx 10^{-3} \text{ M}$. This corresponds to a pOH of 3, or a pH of 11. You can now use the plot of pH versus relative rate to find that an increase from 9 to 11 in the pH causes the reaction rate to increase by a factor of 2, choice (C).

27. (B)

Molality is defined as moles of solute per kilogram of solvent. The solution in question contains 27 g of $\text{Co}(\text{NH}_3)_6\text{Cl}_3$ and 22 g of $\text{Co}(\text{NH}_3)_6\text{Cl}_2$, which corresponds to 0.1 mol of each compound (you are given the molecular weight of each compound at the end of the passage). However, you must consider the dissociation of these salts in solution:



Each mole of $\text{Co}(\text{NH}_3)_6\text{Cl}_3$ will produce 4 moles of ions in solution, while each mole of $\text{Co}(\text{NH}_3)_6\text{Cl}_2$ will produce 3 moles of ions in solution. Therefore, the solution contains 0.7 mol solute per kilogram of solvent, choice (B).

28. (D)

Elemental cobalt is a transition metal with nine valence electrons and an electronic configuration of $[\text{Ar}]4s^23d^7$. When it ionizes to become Co^{3+} , electrons are first removed from the higher energy 4s orbital, then the 3d orbital to give an electronic configuration of $[\text{Ar}]3d^6$. The stability of half-filled subshells may be tempting ($[\text{Ar}]4s^13d^5$), but this is a less favorable configuration due to the higher energy of the 4s orbital. The answer is $[\text{Ar}]3d^6$, choice (D).

Discrete Questions (Questions 29–33)**29. (C)**

An object submerged in a liquid feels two forces: buoyancy and its weight. Since its apparent mass is only 8 g, the other 4 grams are counterbalanced by the buoyant force:

$$F_B = \rho_f gV = (4 \text{ g})g,$$

where $\rho_f = 0.8 \text{ g/cm}^3$ is the density of the ethyl alcohol, and V is the volume of the object. Solving for V yields 5 cm^3 . Now you know the mass and the volume of the object; calculate the object's density:

$$\rho_{\text{object}} = \frac{m}{V} = \frac{12 \text{ g}}{5 \text{ cm}^3} = 2.4 \text{ g/cm}^3,$$

and answer choice **(C)** is correct.

30. (A)

A spontaneous reaction has by definition a negative change in Gibbs free energy, which is related to entropy and enthalpy by the equation $\Delta G = \Delta H - T\Delta S$. For a reaction that *must* be spontaneous, ΔH must be negative and ΔS must be positive. What does this mean? A negative ΔH corresponds to a reaction that is exothermic—i.e., one that releases bond energy in the form of heat energy. Exothermic reactions make energy more disordered. A positive ΔS corresponds to a reaction that increases entropy—an increase in the disorder of the matter in the system. Consequently, a reaction in which both energy and matter become more disordered will always be spontaneous. Choice **(A)** states this.

31. (C)

One half-life is how long it takes for the rate of decay to drop to half its original value. The decay rate began at 300 counts per second, so after one half-life, the count should be $300/2 = 150$ counts per second. After two half-lives, the rate is $150/2 = 75$ counts per second, and after three half-lives, the rate is $75/2 = 37.5$ counts per second. So 5 minutes is approximately the length of three half-lives; one half-life is 5 minutes/3 half-lives = 1.67 minutes/half-life; the correct answer is choice **(C)**.

32. (D)

This question is fairly straightforward—you need to know what an oxidizing agent is to get the correct answer. An oxidizing agent is a substance that accepts

electrons and is itself reduced in a redox reaction. From this definition, you can see that choice **(D)** must be the correct answer. Choice **(A)** is wrong because if a species accepts electrons, its oxidation number will decrease. Choice **(B)** is wrong because although oxygen is often an oxidizing agent, an oxidizing agent does not necessarily have to be oxygen. Choice **(C)** is wrong because a species that accepts electrons is said to be reduced, not oxidized.

33. (C)

This is a kinematics problem: an object with an initial speed of zero is accelerating at 1.5 m/s^2 and is traveling 300 m. So you know v_0 , a , and d , and you need to solve for t . Applying the correct formula,

$$d = v_0 t + \frac{1}{2} a t^2$$

$$300 \text{ m} = (0 \text{ m/s})t + \frac{1}{2}(1.5 \text{ m/s}^2)t^2$$

$$t^2 = (300 \text{ m}) \frac{2}{1.5 \text{ m/s}^2} = 400 \text{ s}^2$$

$$t = 20 \text{ s},$$

making choice **(C)** the correct answer.

Passage V (Questions 34–39)**34. (B)**

This question isn't about dielectrics at all, it's simply about the charge on a plate. You are given the surface charge density (whose dimensions are charge per square meter) and the area of the plate (square meters), and asked for the total charge. The total charge will be the charge density multiplied by the area:

$$Q = \sigma A = (3 \times 10^{-6} \text{ C/m}^2)(2 \text{ cm}^2).$$

You'll need to convert square centimeters into square meters to keep the units consistent:

$$2 \text{ cm}^2 \times \frac{(1 \text{ m})^2}{(100 \text{ cm})^2} = 2 \times 10^{-4} \text{ m}^2.$$

The total charged stored on the plate is:

$$Q = (3 \times 10^{-6} \text{ C/m}^2)(2 \times 10^{-4} \text{ m}^2) = 6 \times 10^{-10} \text{ C},$$

answer choice **(B)**.

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35. (C)

This question sets up a new scenario: two identical capacitors, hooked up in series. You know that to calculate the total capacitance C_T of the system, you'll need to use the formula,

$$\frac{1}{C_T} + \frac{1}{C} + \frac{1}{C} = \frac{2}{C} \rightarrow C_T = \frac{C}{2}.$$

When the dielectric materials are inserted into each capacitor, the new capacitance is each is κC . So the total capacitance of the new system, C_T' , satisfies:

$$\frac{1}{C_T'} = \frac{1}{\kappa C} + \frac{1}{\kappa C} = \frac{2}{\kappa C} \rightarrow C_T' = \frac{\kappa C}{2}.$$

The ratio of the new total capacitance to the old is:

$$\frac{C_T'}{C_T} = \frac{\kappa C/2}{C/2} = \kappa,$$

making choice **(C)** the correct answer.

36. (A)

This question calls upon some fairly advanced reasoning. The passage discusses what happens when the dielectric is inserted into a capacitor that isn't connected to a battery; but you want to know what happens to the electric field when the battery is still hooked up.

The function of a battery is to provide a potential difference between two points. In this case, the battery holds the two plates of the capacitor at potential difference V , regardless of whether or not the dielectric is present. Because the distance between the plates is unchanging, the formula $V = Ed$ implies that the electric field has to stay the same between the plates; answer choice **(A)** is correct. What happens is that the battery pumps more charge into the plates, overcoming the effects of the induced charges set up on both sides of the dielectric. This eliminates answer choice **(C)**.

Since the potential between the plates doesn't drop, choice **(B)** is incorrect. Although more charge is rushed to the plates by the battery, there is no net effect on the E -field, as the extra charge is present to counterbalance the induced E -field inside the dielectric. Choice **(D)** is incorrect.

37. (C)

As the dielectric is inserted, the system must be losing energy somehow, as the passage states that the total energy stored drops by a factor of κ . Ask yourself—what is happening as the dielectric is inserted? The answer is, the electric field from the capacitor plates is aligning the molecules of the dielectric. That takes energy—work is being done on the dielectric. That's where the energy goes, and choice **(C)** is correct. You are given no reason to believe that the temperature of the system is changing [choice **(A)**], or that heat energy is being lost [choice **(D)**]. And there is no current through the capacitor; once the capacitor is charged, all current in the circuit stops. In any case, a current through a capacitor would mean that the capacitor has broken down, since the purpose of a capacitor is to store charge and not allow it to flow. Choice **(B)** is incorrect.

38. (D)

A question with numbers in the answer choices; a calculation is probably required. You are given the surface-charge density of the capacitor plates and the induced charge density of the dielectric after it is inserted, and asked to find the dielectric constant. There are some more complicated ways of figuring this out, but the easiest way is to use the formula that the passage provides:

$$\begin{aligned} \sigma &= \frac{\kappa - 1}{\kappa} \sigma_0 \\ 4.5 \times 10^{-7} \text{ C/m}^2 &= \left(\frac{\kappa - 1}{\kappa} \right) 5.0 \times 10^{-7} \text{ C/m}^2 \\ \frac{\kappa - 1}{\kappa} &= \frac{4.5}{5} = \frac{9}{10} \\ \kappa &= 10, \end{aligned}$$

answer choice **(D)**.

39. (B)

The wire in this problem is used to "short out" the fully charged capacitor. You are asked for the current across the wire. Since you are given the time it takes the charge to travel, you are probably being asked to apply the definition of current: Current = Total Charge over Time Elapsed. So what's missing in this problem is the total charge.

You are given the capacitance and the voltage across the plates; that's enough to calculate the charge:

$$Q = VC = (3 \text{ mV})(3 \text{ nF})$$

$$= (3 \times 10^{-3} \text{ V})(3 \times 10^{-9} \text{ F}) = 9 \times 10^{-12} \text{ C.}$$

And so the total current across the wire is:

$$I = \frac{Q}{t} = \frac{9 \times 10^{-12} \text{ C}}{4 \times 10^{-6} \text{ s}} = 2.25 \times 10^{-6} \text{ s,}$$

answer choice **(B)**.

Passage VI (Questions 40–45)

40. (B)

In Table 1, you read that silver chloride is more soluble than silver iodide. Therefore, silver iodide will precipitate out of solution first. Because the solubility constant of silver iodide is so much smaller than that of silver chloride, the silver chloride will only precipitate out after all the silver iodide has left solution. This corresponds to the endpoint of the silver iodide titration, which is point B in Figure 1. The answer is therefore choice **(B)**. Point D, the endpoint of the silver chloride titration, marks the end of the silver chloride precipitation. Points A and C are not endpoints.

41. (C)

Think about what is going on in the solution as the titrant, AgNO_3 , is added. At the beginning of the titration, the solution is full of excess quantities of the ions K^+ , Cl^- , and I^- . When you add the AgNO_3 to the solution, it dissociates into Ag^+ and NO_3^- . Immediately, AgI crashes out of solution. AgI is the most insoluble salt in solution, and will therefore precipitate first. As you continue to add AgNO_3 , AgI will continue to precipitate until excess the original I^- has been consumed. The first equivalence point occurs where the number of moles of Ag^+ added equals the number of moles of I^- initially present. This occurs at point B. At point A, close to but before the first equivalence point, most of the I^- has been consumed due to precipitation with Ag^+ . None (or a negligible amount) of the Cl^- has been consumed. Therefore, the answer is choice **(C)**.

42. (B)

In Figure 1 as it presently exists, there are two endpoints signifying the precipitation of two different salts of differing solubility. If you were to throw a third salt into the mixture, you would expect to see a third endpoint. Where the endpoint lies on the curve depends

on the solubility of that salt relative to the other two. You can find the solubility of AgBr in Table 1. AgBr has a solubility product between that of AgI and AgCl , so the endpoint of its titration is between that of I^- and Cl^- . Only choice **(B)** represents this location.

43. (C)

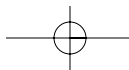
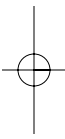
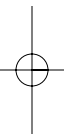
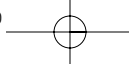
The second substance (AgCl) begins to precipitate only after the first substance (AgI) has been completely precipitated. AgI has been completely precipitated at its endpoint, point B. AgCl has been completely precipitated at its endpoint, point D. Therefore, only the volume between the two endpoints (points B and D) is considered when calculating the concentration of the second ion precipitated. Using the total volume of AgNO_3 added before point D is reached would overestimate the amount Cl^- in solution—it would give you the total amount of salt (KCl and KI) originally present in solution. Point C is not used at all because it is not an endpoint.

44. (A)

The red color must come from the iron atom, so eliminate any choice that does not include Fe: choice **(C)**. Now think about what is happening in the solution. After AgCl precipitates, Ag^+ is still present in solution, since the student overshot the endpoint during the titration. When KSCN is added, it dissociates into K^+ and SCN^- . AgSCN is then formed and precipitates. What is left in the solution? Fe^{3+} , K^+ , and SCN^- , and NO_3^- . The answers that includes only the ions left in solution are choices **(A)** and **(B)**. Now use your reasoning skills. Nitrate is present in solution whether or not there is SCN^- present in excess, so $\text{Fe}(\text{NO}_3)_3$ would not make a good indicator. FeSCN^{2+} is the red color, which makes sense because this will only form when all of the excess Ag^+ has been consumed.

45. (B)

Precipitation is an equilibrium process. A compound can precipitate before its solubility product has reached. Precipitation of AgCl would explain the additional consumption of Ag^+ , shifting the endpoint higher than if AgI had been in solution alone. So choice **(B)** is correct. Choices **(A)** and **(D)** are not correct because it is unknown whether the solution is saturated. Choice **(C)** is incorrect because Cl^- precipitates after I^- , not before.



VERBAL REASONING ANSWER KEY

46. (A)	61. (A)	76. (B)
47. (B)	62. (C)	77. (B)
48. (B)	63. (B)	78. (D)
49. (A)	64. (B)	79. (D)
50. (B)	65. (D)	80. (D)
51. (C)	66. (C)	81. (C)
52. (D)	67. (B)	82. (A)
53. (C)	68. (D)	83. (C)
54. (C)	69. (C)	84. (A)
55. (B)	70. (C)	85. (B)
56. (C)	71. (A)	86. (C)
57. (A)	72. (A)	87. (C)
58. (D)	73. (D)	88. (A)
59. (B)	74. (D)	89. (A)
60. (A)	75. (A)	90. (B)

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VERBAL REASONING EXPLANATIONS

Passage I (Questions 46–52)

Topic and Scope: Nautical archaeology; specifically, why it is has scientific importance and what is necessary for its scientific importance to be fulfilled.

Paragraph Structure: The first paragraph identifies the historical scope of underwater wreckage potentially available to be discovered under the sea. It mentions the SCUBA gear as a factor in making more systematic exploration possible, and introduces the author’s position that proper methods of exploration and recovery are of paramount importance. The second paragraph explains that exploration and recovery of shipwrecks is part of the study of archaeology, then returns to explain that this necessitates proper attention to methods of work. The third and fourth paragraphs explore specific issues related to proper methods of exploration and recovery. The third paragraph explains that proper extraction and subsequent preservation of extracted artifacts is important. The fourth paragraph identifies why keeping proper and detailed records of the recovery is important.

46. (A)

This is a Main Idea question. It requires the reader to consider the passage as a whole and to identify an answer choice that is appropriate to the passage and represents the purpose of the entire passage, rather than an individual paragraph or section. The passage does two things: it explains why exploration of shipwrecks is scientifically important, and argues that these activities must, therefore, be done in accordance with appropriate methodology, rather than as an undisciplined recreational activity (“treasure hunting”). Only choice **(A)** reflects this dual purpose. **(B)** is off the mark. Although the passage does include some information about historical developments, its primary purpose is not to develop a time line. Furthermore, the passage does not establish that maturation of treasure hunting into nautical archaeology has already occurred. Indeed, the concerns expressed indicate that this maturation may have a way to go. **(C)** is closer to a correct answer, but too narrow. It leaves out most of the discussion in the first and second paragraph explaining why shipwrecks are scientifically important. **(D)** is even farther off the mark. Although the passage indicates

that its author considers discovery, exploration, and recovery of shipwrecks important, the *primary* concern expressed in the passage is not to spur more of it, but to assure that what is done is done appropriately.

47. (B)

This is an Inference question, which requires the reader to scan various parts of the passage in order to pinpoint the details the question requires. The passage makes a clear distinction (in the last sentence) between nautical archaeology and “treasure hunting.” This is a clue that it may be helpful to consider what might be characteristic of “treasure hunting,” but not of nautical archaeology. However, the passage does not discuss “treasure hunting” in any detail, so what this practice involves must be considered based on the plain meaning of the term. The physical fitness of divers and their skilled use of SCUBA gear **(C)** is mentioned in the first paragraph as useful to study of underwater remains. It is a reasonable inference, however, that such gear and skill in its use could also be important to treasure hunting. “Treasure hunting” can also be inferred to involve recovering an artifact **(A)**, in order to realize its value. Another reasonable one-step inference is that a “treasure hunter” could be interested in preserving the value of what is recovered **(D)**, in order to realize or maintain this value. The last paragraph discusses the importance, to archaeologists, of context, and the fact that context is lost unless records are kept. There is no indication in the passage that record-keeping would be important to “treasure hunting,” and the plain meaning of the phrase “treasure hunting” does not imply keeping records. Additionally, the sentence that contrasts nautical archaeology to “treasure hunting” immediately follows, and is in the same paragraph as, the discussion of the importance of record keeping to archaeologists. Thus it is a reasonable, one-step inference from the passage that detailed records distinguish nautical archaeology from “treasure hunting,” and **(B)** is correct.

48. (B)

This is a Detail question. Careful reading of the question stem indicates that it focuses on the expansion of the scope of nautical archaeology. The passage as a whole focuses on several issues related to the contribution of the study of underwater remains to our understanding of history. Which of these issues is related to the “scope” of nautical archaeology? Scope is the range, breadth, or area covered. The first paragraph indicates that many

more sites have become accessible (able to be discovered) due to the development of SCUBA gear. Thus, **(B)** is correct. **(A)** and **(C)** are distortions. Conservation of artifacts and systematic record keeping are identified as important to progress in the formation of archaeological inferences about cultures, but formation of inferences from discovered and preserved material is different from discovery itself. **(D)** is too broad to be the correct answer.

49. (A)

This question asks the reader to identify the function of a particular statement in the passage. Such a question must be considered in terms of the argument presented in the passage. In this case, the reference to the search for obsidian follows a statement that the study of underwater wreckage is important to the study of history. It is one of several examples of activities that probably resulted in underwater wreckage. The search for obsidian occurred in a time period very far from the period of exploration and immigration to the Americas, another example the author provides. The author is providing a range of examples, which represent early and late activities that might be represented by underwater wreckage. Thus, **(A)** is correct. **(B)** is incorrect because the type of tools found is not significant to the context of the statement. **(C)** is incorrect because providing an example of different natural resources is not significant to the author's argument. Nor is the author's argument concerned with the development of ancient trade routes **(D)**.

50. (B)

This is a Deduction question. To answer the question, it is necessary to identify what characterizes a nautical archaeologist, what characterizes a traditional archaeologist, and how the two differ. In the first sentence of the second paragraph the passage defines archaeology, in general, as concerned with the recovery and study of artifacts. Thus, **(A)** cannot be used to distinguish between the traditional and nautical archaeology. Likewise, since archaeologists (in general) are more concerned with the culture represented by artifacts than with the artifacts themselves (paragraph 2), **(D)** can be eliminated. Archaeologists must be very familiar with the underwater environment. Whether or not they personally do any of the diving and physical recovery of the artifacts, they are intimately concerned with that activity and also with how the

underwater environment affects the condition of the artifacts recovered. Since human beings are naturally adapted to living on land, **(B)** is the correct answer.

51. (C)

The passage indicates that an archaeologist is more interested in the human activities that can be inferred from artifacts than the artifacts themselves. Thus, **(C)** is correct, since medical equipment would provide a basis for inferences about human activities that represented medical care at the time.

52. (D)

This question asks about the next topic the author could logically be expected to discuss. To answer this question, you need to consider the overall focus of the passage. The passage discusses the scientific importance of nautical archaeology and the necessity of adherence to proper methods of exploration and recovery. It finishes with a sentence distinguishing nautical archaeology from "treasure hunting." Since the focus of the passage is on a problem and its importance, it would be logical for the next topic to focus on what should be done about the problem i.e., recreational divers who discover wrecks and take items without following proper procedures for extraction, preservation, and/or documentation. Thus, **(D)** is correct. The passage provides no clues on which to base a shift to the topic of museum displays **(A)**, improvements in technology used to locate shipwrecks **(C)**, or skills required in using SCUBA gear **(B)**.

Passage II (Questions 53–60)

Topic and Scope: The contribution of Jean Jacques Rousseau to the understanding of the human psyche and its relationship to society; specifically, how his work represented a change in direction.

Paragraph Structure: Paragraph 1 provides context by explaining that Rousseau's work took place at the time of the Enlightenment, a movement that represented a reorientation away from religious faith and toward reason as a means of explaining the nature of the human world. This paragraph also indicates that Rousseau's way of viewing the conflicts within human nature shared a dualistic view of human nature with the religious thought that preceded it. Rousseau's dualism posited a "rupture" of the psyche that occurred as

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humans participated in society. Paragraph 2 explains what Rousseau meant in characterizing humans, before the advent of society, as “good,” and how this “natural” goodness differs from “moral” goodness. The paragraph also explains that natural goodness is the result of the natural characteristics of self-love and pity, rather than the result of the exercise of judgment. Paragraph 3 contrasts “society” to the “state of nature” and indicates that, in society, self-interest eclipses self-love and pity, becoming the primary motivator of human behavior. This paragraph also explains the negative consequences of self-interest. Paragraph 4 concludes by recapping the main points of the passage: the relationship between self-love and happiness, the relationship between self-interest and unhappiness, and Rousseau’s significance in the development of models for understanding human nature. Paragraph 4 also makes a brief reference to the need for society to mitigate the harm it creates.

53. (C)

The question focuses on both Rousseau’s model and its influence. Rousseau’s model has several aspects. The aspect that the passage mentions as an influence on subsequent thought is the introduction of a secular duality: self-love and self esteem. This duality is a way of understanding the human mind (the psyche). The subsequent dualities (mentioned in the last sentence of the first paragraph) are also ways of understanding the psyche. Thus, (C) is correct. (A) and (B) are incorrect because, while these are aspects of Rousseau’s model, they do not represent the shift in thought that the passage identifies as the philosopher’s primary influence on subsequent thought. This is apparent both from the first paragraph, which indicates that both Rousseau and his predecessors tried to explain human wickedness and human unhappiness, and from the last sentence of the passage, which reinforces the idea that Rousseau’s contribution was in proposing a secular basis for understanding the conflicts within the human psyche. (D) is a distortion of the passage. The passage does not focus on the development of children.

54. (C)

This is a Detail question. In order to answer the question, determine to what “desire” the statement refers and why, in terms of information in the passage, it is impossible for the desire to be fulfilled. The

preceding sentence in the passage mentions the desire of each particular individual for other individuals to put his interests before theirs. What is the context of this statement? The second paragraph focuses on individuals in society, where they are governed by self-interest. This contrasts to the second paragraph, which focuses on individuals in the “state of nature,” who are governed by self-love and pity. If each individual is motivated by self-interest, then he will prefer his own interests, and the desires of different individuals will therefore conflict. Thus, (C) is correct. (D) is incorrect because the demands of self-interest will only conflict if more than one individual is involved. In considering (A) and (B), it is important to focus on the logic of the passage. Paragraph 2 discusses self-love, and argues that it exists when individuals are in a “state of nature.” It defines the state of nature as one in which the goods of the world are held in common and, therefore, the needs of an individual are not in conflict with the needs of others. Therefore, the argument of the passage does not support a statement that self-love makes contradictory demands, and this could not be the meaning of the referenced statement.

55. (B)

Paragraph 1 identifies Rousseau’s thought as a turning point. Original sin was part of the Christian thought that Enlightenment philosophers rejected. Thus, (B) is correct. (A) is incorrect because Rousseau did not incorporate, but rejected, original sin in his work. (C) is incorrect because the passage does not indicate that Rousseau lacked religious beliefs. Even if Rousseau rejected original sin, he may have possessed other religious beliefs. (D) distorts the passage. Virtue is a quality that is associated with moral goodness. Although Rousseau argued that humans in a state of nature are naturally good, he distinguishes that quality from moral goodness.

56. (C)

This is another question that asks about the function of a particular statement in the passage. In the passage the statement is preceded by a sentence that provides information about human self-love: 1) it is like the self-love of other mammals; 2) it causes each person to watch over his own preservation; 3) it causes each person to form attachment to whomever aids him. Which of these pieces of information does the statement about Romulus reflect? Note that the passage cannot require

that the reader knows who Romulus is or to be familiar with the myth about him; this would require outside knowledge. The passage indicates that the wolf suckled Romulus, and that Rousseau postulated that Romulus would have developed an attachment to the wolf. This reflects the third piece of information about self-love—it can encompass love of those who aid us. Thus, **(C)** is correct. **(A)** is a distortion. The passage does not indicate a general similarity between humans and other mammals. **(B)** and **(D)** are incorrect because Romulus, not the wolf, was postulated to have developed feelings of attachment. While it is reasonable to infer that the wolf may also have been attached, the wolf is not the locus of the attached feelings identified in the sentence.

57. (A)

This question requires the reader to make an analogy between Rousseau's secular model and the religious model it replaced. The passage indicates that religious thought identified original sin as the cause of both wicked deeds and human suffering. What is most analogous in Rousseau's thought? Since the passage gives no cause for original sin, it can be inferred to be the primary cause. In Rousseau's thought, the primary cause of wicked deeds and human suffering is identified as unequal distribution of goods and obligations. This is what causes self-interest and the division of the psyche. While the reader can speculate about the possible causes of the unequal distribution of goods and services, just as he can speculate about what caused original sin, the passage addresses neither. Thus, **(A)** is correct. **(B)** and **(D)** are incorrect because they are secondary, rather than primary causes. **(C)** is incorrect because self-love is associated with neither wicked acts nor suffering.

58. (D)

This is an Inference question. The passage defines self-interest (in paragraph 3) as a phenomenon that arises in society. The first paragraph of the passage states that an individual, in the state of society, begins to compare his circumstances to those of others. The third paragraph extends this idea by stating that individuals then develop a preference for their personal interests. To have a preference implies that there are at least two things, one of which is preferred and one of which is not. In this case, the preference is between one's own interests and the interests of others. Therefore, self-interest cannot exist without the

presence of at least one other, and thus **(D)** cannot be true. It can be inferred from the passage that self-interest is an artificial sentiment. Natural and artificial make up a duality. Self-love is identified as a natural sentiment and it contrasts with self-love. Thus, **(A)** can be true and is not a correct answer. Paragraph 3 of the passage states that self-interest gives rise to hateful passions, thus **(C)** is a statement that can be true of self-interest, and is not a correct answer.

59. (B)

The fourth paragraph indicates that an individual governed by self-love will be content when his basic needs are satisfied. It also indicates that an individual governed by self-interest will not be content. An individual who is content is generally happy. Thus, **(B)** is correct. While there is a basis in the passage to conclude that a person governed by self-love will be happier than a person governed by self-interest, the passage provides no indication of what Rousseau's opinion is of the happiness of an individual living in isolation. Therefore, **(A)** can be eliminated. **(D)** can be eliminated because the passage does not indicate that there is a "natural balance" between self-love and self-interest that promotes happiness.

60. (A)

This is a question in which the reader must identify which of several issues receives least attention in the passage. This question is best approached by an elimination strategy. In paragraph 2, the passage clearly defines the type of feelings that prevail in the state of nature **(C)**. What constitutes good behavior in the state of nature **(B)** is implied in paragraph 2. It is not moral goodness (behavior resulting from judgments about the rightness or wrongness of actions), but behavior stemming from natural affection and an antipathy for seeing others suffer. This is clearly an indication that individuals in the state of nature are "good" because they help each other and share resources. This is a significant exploration of what constitutes good behavior in the state of nature, and indicates that **(B)** is probably not the answer choice. Paragraph 3 identifies the feelings that arise in society **(D)** and contrasts these with the feelings that prevail in the state of nature, clearly making a value judgment that the feelings in the state of nature are to be preferred. Good behavior in society **(A)** is briefly mentioned—only in the assertion that, in society, it is

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difficult for individuals to be good. Presumably they are at times good, but the passage does not address what constitutes good behavior in society. At best we can infer that it is similar to good behavior in the state of nature. This treatment of what constitutes good behavior for individuals in society **(A)** is thus alluded to, but receives less specific treatment than the three alternative answer choices. Thus, **(A)** is correct.

Passage III (Questions 61–68)

Topic and Scope: The strategy that has been implemented to protect the spotted owl under the Endangered Species Act, and what the owl’s situation has been subsequently.

Paragraph Structure: Paragraph 1 cites the controversial nature of measures protecting the spotted owl and the purpose of the Endangered Species Act, under which the measures were implemented. Paragraph 2 explains the basis for the conclusion that logging should be restricted under the ESA in order to protect the spotted owl from extinction and indicates that the rate of spotted owl population decline subsequently slowed. Paragraph 2 explains that the barred owl has subsequently been identified as a threat to the spotted owl. Paragraph 3 describes a theory environmentalists advance for why the barred owl has recently become a threat to the spotted owl. Paragraph 4 considers the interaction between the two species from two different perspectives: how the behavior of the two owls seems to indicate that the barred owl threatens the spotted owl, and how mating between the species is consistent with a theory placing the two separate species in a context that considers their separateness less significant than their relatedness. Paragraph 5 introduces evidence advanced by logging companies to indicate that protection of mature forests may not be necessary for preservation of the spotted owl, while indicating that environmentalists continue to argue that habitat preservation remains crucial.

61. (A)

This question requires the reader to understand the evidence in the passage and determine which of several statements it best supports. To answer this question correctly, think precisely about the definitions of the words used. Choice **(A)** indicates that, based on evidence of a threat to the spotted owl, regulators took

action to protect mature forests in the Pacific Northwest. Based on information in the second paragraph, this is correct. Logging restrictions were implemented, and this constitutes protection of the owl’s habitat, which was determined to be mature forest. The use of the word “findings” in the first sentence of the second paragraph indicates that regulations were based on evidence—not just on opinion. Choice **(B)** is incorrect for two reasons: 1) the influx of the barred owl is postulated in paragraph 3 to be an effect of human activity in settling the west and planting trees; 2) The passage does not indicate that the barred owl and spotted owl are currently the same species—but that they *may have been* the same species at some time in the past. **(C)** is too extreme. The spotted owl is threatened, but to deem its current situation a “demise” is not accurate. **(D)** is not only too extreme, but also fails to consider all the information in the passage. While preservation of mature forests *could help* ensure survival of the spotted owl, it is not at all certain that it *will* ensure it. The barred owl is a threat which exists whether or not mature forests are preserved.

62. (C)

This question asks what explains the barred owl’s migration from the eastern United States to the northwest. Paragraph 3 indicates that activities of Caucasian settlers modified the Great Plains and provided an opportunity for the barred owl to travel west (I) and mentions that the barred owl is adaptable, nesting either in cavities of large fallen trees (old growth forest) or in young conifers (new growth forests) (II). Although the passage indicates that the barred owl is aggressive, this characteristic is not hypothesized to have contributed to its migration. Thus, **(C)** is correct.

63. (B)

The passage discusses the situation of the spotted owl over a period of time. Prior to protection under the ESA, the spotted owl was considered to be most threatened by habitat loss. Currently, however, not only are logging restrictions in place, but also the spotted owl is found in younger forests previously considered unsuitable for it. Thus, **(A)** is not currently the most significant threat. Competition from the barred owl is, however, a current threat on which the passage focuses considerable attention. Thus, **(B)** is correct. Loss of food sources and predators **(C)** and **(D)** are not mentioned as current threats to the spotted owl.

64. (B)

Paragraph 5 of the passage indicates that 603 spotted owls were found on medium-age timberland managed by Simpson Timber, a lumber company. This is evidence that the spotted owl does not always need a mature forest habitat. Thus, (II) can be inferred. However, (I) and (III) are too broad to be reasonable inferences. The passage does not indicate whether the management techniques used by Simpson Timber are typical of those used by other lumber companies, or whether there are characteristics unique to the particular forest environment managed by that firm that have attracted spotted owls.

65. (D)

This question is a combination of a Scattered Detail and an Inference question. In the last paragraph the passage indicates that environmentalists (II) have expressed opinions about (i.e., debated) the preservation of the spotted owl. The earlier discussion in the passage, for example, at the end of paragraph 2 provides a basis to infer that environmentalists (II) have expressed opinions. Similarly, the last paragraph in the passage indicates that a biologist employed by a logging company has expressed an opinion. This, along with the conflict between logging and spotted owl habitat contained in paragraph 2 provides basis to infer that logging companies (I) also debate the issue. In the first and second paragraph, the passage indicates a regulatory framework for protection of the spotted owl. If regulations were issued directed at protecting the owl, based on findings about the owl's needs, this is a basis to infer that regulators (III) have considered and deliberated (i.e., debated) the issue. Thus, (D) is correct.

66. (C)

This question is asking the reader to determine, in terms of issues discussed in the passage, which of four alternatives best explains why no change has occurred in protected habitat designation. To identify the correct answer, it is necessary for the choice to have an explanatory effect *and* for the choice to be relevant in terms of issues discussed in the passage. (C) meets both of these tests. Regulators focused on both dietary and nesting needs of the species. The logging company biologist reports the presence of the bird in habitat considered unsuitable and presents an hypothesis focused on the bird's diet. However, there is no indication of what time(s) of year the spotted owls were found in the medium-age forest. The biologist

hypothesizes that the owl *may* adapt its nesting requirements, but provides no evidence that it *does*. (A) is incorrect because, although it focuses on an issue discussed in the passage, it does not explain why the protected habitat would be unchanged. Although (B) may sound plausible, it is incorrect because it focuses on an issue outside the scope of the passage. (D) is incorrect because there is no basis in the passage for an inference that the spotted owl has, or is able to, migrate to forest habitat in the Great Plains.

67. (B)

This is a Function question. The answer choices each reflect a possible viewpoint of the passage. The referenced statement, in isolation, does not provide any information revealing what the author's attitude is toward logging companies. (A), (C), and (D) each contain an assumption about what view of lumber companies the author may be trying to convey. But there is no support for choosing any one of them over the other two. The passage as a whole does provide neutral context for several pieces of information provided: it is "environmentalists" who "today feel" that "preserving the habitat of the spotted owl is more important than ever" (paragraph 5). It is a "biologist with the U.S. Forest Service" who hypothesized that "the barred and spotted owl were once a single species" (paragraph 4). It is regulators (i.e., "regulations" in paragraph 2) that implemented measures to protect habitat, based on particular findings. The passage contains no information indicating that the author has any opinion about the relative validity of the different opinions or findings discussed. Thus, the information in each case simply provides context that may be of interest to the reader, and (B) is correct.

68. (D)

This is a Global question that tests the reader's ability to understand the overall purpose of the passage. The passage presents information relevant to protection of the spotted owl under the EPA. It presents information and opinion from several sources, and the overall tone is neutral. (D) best describes this purpose. (A) and (C) are incorrect because the passage as a whole does not adopt a view on whether the owl or its habitat should be protected. (B) is incorrect because it represents only a part of the passage, not the passage as a whole.

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Passage IV (Questions 69–75)

Topic and Scope: Different views of geological change prevalent in the 18th and 19th centuries, particularly catastrophism and uniformitarianism.

Paragraph Structure: Paragraph 1 introduces the scope of the passage, indicating that aspects of a controversy are about to be explored. This paragraph then goes on to describe catastrophism, along with its Neptunist and Plutonist schools. Paragraph 2 describes uniformitarianism. Paragraph 3 offers a conclusion indicating that both catastrophist and uniformitarian perspectives continue to have value in explaining geological change.

69. (C)

This is a Detail question that tests the reader's understanding of uniformitarianism, covered in Paragraph 2 of the passage. To answer this question, identify which of the answer choices most accurately reflects what the passage states about the uniformitarian view. A key phrase in the question is "significant impact." This indicates that the question is concerned with what shapes major features of the earth over long periods of time, rather than what shapes local features over relatively short periods. Paragraph 2 contrasts change of local features, which may be directional, to the relative stability of more general characteristics of the earth, such as temperature and percentage of land to sea. This indicates that the correct answer must be either (C) or (D), as, in terms of general features of the earth, uniformitarianism views change as nondirectional (reflecting stability) rather than directional. The second sentence of Paragraph 2 indicates that uniformitarians viewed geologic change as occurring gradually, over extremely long time periods. This is consistent with (C), which is thus correct; and inconsistent with (D) which is thus incorrect.

70. (C)

This is an Inference question. In order to identify which of the four types of theorists would have been most likely to have made the statement, consider what the passage tells you about each viewpoint, and determine whether it is consistent or inconsistent with the statement. Generally, one inconsistency is sufficient to eliminate an answer choice. Paragraph 2 indicates that uniformitarians believe that geological change happens slowly, over long periods. This is consistent with

"leisurely" and, absent contradictory evidence, probably is not inconsistent with a view that the earth is "incalculably old." Catastrophists, by contrast, held that geological features resulted from sudden catastrophes. This is inconsistent with the slow, steady, gradual change referred to in the statement quoted in the question stem. Thus, (A) is incorrect. Since Werner and Murchinson are identified as catastrophists in addition to being, respectively, Neptunist and Plutonist, (B) and (D) can also be eliminated. This leaves (C) with no identifiable inconsistency and this choice is thus correct.

71. (A)

This is another Inference question. The statement, "The present is the key to the past" indicates a view that emphasizes the strong connection between the present and the past, rather than discontinuity or abrupt change. This is most similar to the uniformitarian view (as expressed in the first sentence in Paragraph 2), and James Hutton and Charles Lyell are identified as its adherents. Since only one of the two, James Hutton, is indicated as an answer choice, the correct answer can be determined to be (A). The correct answer cannot be (B), (C), or (D), since Cuvier, Murchinson, and Werner are all identified as catastrophists, and each hypothesizes that in its youngest days the earth was radically different from today: either completely covered with water or a ball of fire.

72. (A)

To answer this question, look for information in the passage that provides a clue to why Murchinson and Werner might have decided to use different criteria. What was different about their background or research? The passage provides no information on either man's background or education. However, it does indicate that Werner explored one area—Saxony, while Murchinson explored several areas, ranging from Great Britain to other parts of Europe and also Russia. Thus, Murchinson's observations could be more diverse than Werner's. A clue in the passage reinforcing this view is the statement that Werner "extrapolated" that the sequence of rocks in Saxony was representative of other locations. Since Murchinson explored more locations and elected to form a sequence based on fossils, it is reasonable to infer that he may have done so because fossil sequencing provided a system that was more applicable to several locations than the sequence of

rocks. **(D)** and **(C)** are possible explanations for why Murchinson chose fossils. However, the passage provides more basis to infer **(A)**.

73. (D)

This is an Application question. To answer it, consider the process by which the Grand Canyon is thought to have been formed. The time period is very long, and the process of change can be characterized as erosion. Although the result is dramatic enough to be described as a “scar,” the process is lengthy and very slow. Thus, it does not qualify as catastrophist **(C)**. Nor is it consistent with Neptunism **(A)** or Plutonism **(B)**, which are types of catastrophism. Although the change is in one direction, the Canyon is a local feature, rather than a general characteristic of the earth. Uniformitarianism admits local change in a single direction. Thus, the formation of the Grand Canyon is not inconsistent with the uniformitarian theory. Although the change involved water, it does not qualify as Neptunist **(A)**. Neptunism is defined as a school that hypothesized that the earth was once completely covered with water, and that all minerals precipitated out of water. The formation of the Grand Canyon as described involves neither of these original causes.

74. (D)

This is a Scattered Detail question. To answer this question, you need to identify whether the first sentence applies all the forces mentioned or only some. The first sentence is introductory. As such, it is likely to pertain to the discussion in the passage as a whole. The logic of the sentence indicates that there is probably more than one view about the nature and relative importance of the forces that shaped the earth to be discussed. The second sentence in the first paragraph introduces “catastrophism,” which is then discussed for the remainder of the paragraph. The first sentence of the second paragraph introduces uniformitarianism, which is discussed for the remainder of the paragraph. This structure of the passage indicates that “forces” in the first sentence could include forces of change mentioned in relation to any of the theories described. Volcanoes are mentioned in connection with the catastrophic theory of change, and erosion is mentioned in connection with the uniformitarian theory of change. “Divine intervention,” while mentioned in the third sentence of the passage (paragraph 1) is only mentioned parenthetically, and not

discussed. The first paragraph takes the position that catastrophists focused on physical evidence, not religious texts. Thus, there is no indication that divine intervention was one of the forces discussed by geologists. Thus, **(C)** is correct.

75. (A)

This question requires you to identify a major theme of the passage. The passage focuses on the structure of particular theories and on what each assumes about the nature of change. Thus, **(A)** is correct. While the passage asserts that catastrophists argued for their view based on evidence, it does not explain how the evidence led to a particular theory. For example, although the passage asserts that Werner observed a particular series of rock strata and this led him to conclude that the earth was once covered by water, the passage does not explain what it was about the rock strata that led him to form that conclusion. Similarly, the passage explains that Plutonists also observed a universal order of strata, but does not indicate how this observation explains their belief that the earth originated as a ball of fire that then cooled. The passage does not indicate what evidence led uniformitarians to conclude that change was gradual and nondirectional. Thus, **(B)** is incorrect. The passage does not indicate that one theory of geological change is more consistent with evidence than another **(D)**. Rather, it indicates that both have explanatory value. The passage does not discuss the backgrounds of the geologists associated with each theory **(C)**; it only discusses where they made their observations.

Passage V (Questions 76–83)

Topic and Scope: Genetic engineering of food crops and problems in assuring safety.

Paragraph Structure: The first paragraph places genetic engineering of food crops in historical context, as a type of modification of plants to achieve certain goals. It goes on to define what distinguishes genetic engineering from these other techniques. The second paragraph focuses on why genetic engineering has effects that are more significant (and possibly more risky) than traditional methods of breeding and crossbreeding. Paragraph 3 briefly identifies the attitudes of proponents and opponents of genetic engineering. Paragraph 4 argues that risk assessment

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is a particular skill, that the food industry cannot be relied upon to assure proper risk assessment, and that regulation is probably needed. Paragraph 5 introduces the notion that identifying appropriate research questions is essential to the validity of experiments intended for hazard identification. Paragraph 6 identifies differences in U.S. and European approaches to regulating genetically engineered foods, and how these differences may be becoming less sharp.

76. (B)

This question tests your understanding of detailed information about genetic engineering scattered throughout the passage and asks you to identify the statement that is inconsistent with those details. **(B)** is the inconsistent statement. It contradicts the thrust of the second paragraph—that genetic engineering can do far more than traditional techniques of breeding and crossbreeding. For example, in addition to more rapidly accomplishing what traditional methods accomplished, it also permits transfer of genes between virtually any two organisms. **(A)** is basically a paraphrase of (and consistent with) the second sentence of the second paragraph. **(C)** is consistent with the second sentence of the second paragraph. **(D)** is consistent with the second sentence of the final paragraph; if the FDA focuses on whether GEOs are substantially equivalent to existing foods, then some GEOs must be substantially equivalent to existing foods.

77. (B)

This is a New Information question. You are asked to identify the part of the author's argument to which the new information is most relevant. To answer this question, a strategy is to consider how the information contained in the question could be used to support the four alternative points from the passage. The new information is like the information contained in the fifth paragraph about the genetically modified wheat. It indicates a hazard resulting from a particular genetically engineered crop that does not appear to be an obvious one. As such, it could be used as an illustration of the importance of asking the best questions. If the researcher were only to focus on the health of the corn plant, or the nutritional value of the corn, the hazard to butterflies might not be identified. Thus, **(B)** is correct. The new information provides an example of a hazard of genetic engineering of crops **(A)**, but does not illuminate *why* this is more dangerous than traditional methods of

modifying crops. **(C)** is incorrect because the effect of the pollen on the butterfly does not illustrate the relative value of focusing on the product (the U.S. approach) or the process (the European approach) in predicting the hazard. **(D)** is incorrect because, while the new information is an example of genetic engineering, it does illustrate any similarity between traditional methods of plant modification and genetic engineering.

78. (D)

This question asks you to identify which of four statements is unsupported by evidence. To approach this question, look for information to support each answer choice. **(A)** is supported by the evidence in the first paragraph that breeding, crossbreeding, and genetic engineering have all been used to increase desirable qualities in agricultural products. **(B)** is a statement made at the beginning of the second sentence in the second paragraph, and is supported by the evidence in the rest of the sentence, that genetic engineering allows genes to be transferred between almost any two organisms. That genetic engineering is likely to be increasingly used **(C)** is a statement made in the last sentence of the second paragraph, and is supported by the reference to the efficiencies of genetic engineering, which in turn refers to the information in the preceding two sentences. **(D)** is the correct answer. Although it is a plausible statement, careful examination reveals that there is no support for it in the passage.

79. (D)

This is a Detail question. To answer it correctly, focus on precisely what information the passage contains about the three methods of changing the characteristics of food. The first two sentences of the passage indicate that breeding and crossbreeding have been used to enhance productivity (I) and to enhance flavor (III). The third sentence defines genetic engineering and indicates it can be used for increasing edible portion, which is basically a productivity increase (I), and for improving flavor (III). Increased resistance to insects is mentioned as a possible result of genetic engineering, but not as a possible result of breeding or cross-breeding. Thus, the correct answer is **(D)**.

80. (D)

This question asks you to identify which of four statements would be most supported by the evidence that an FDA official made a particular statement. The

statement indicates that the FDA considers the characteristics of the product (the food) important, and the process by which it was developed unimportant. Thus, the correct answer is **(D)**. Since the author states that European approach is to consider the process important, the FDA statement is evidence of that difference. The statement does not indicate that the U.S. position is becoming any closer to the European position, i.e., that the distinction is becoming blurred **(C)**. Although the passage itself provides basis to expect Congress may require labeling GEOs, there is nothing in the FDA statement that provides a basis to predict the likelihood of congressional action on labeling or to support a position that genetically engineered products should be labeled. Rather, the FDA statement indicates that it considers such labeling unnecessary.

81. (C)

This is an Inference question. If Congress is considering requiring labeling of genetically engineered foods, this is a basis to infer that such a restriction may be passed. If so, it would be similar to a restriction currently in place in Europe. Thus, **(C)** may be inferred. There is no indication that Europe is planning to adopt a U.S. restriction. Thus, **(D)** and **(A)** are incorrect. **(B)** is incorrect because, while Europeans were required to cease restricting importation of U.S. cattle treated with genetically engineered growth hormones, there is no indication that the United States is planning to reduce any current restrictions.

82. (A)

The passage provides evidence, in the fourth paragraph, that industry may not be objective in determining appropriate research questions, because of economic incentive to focus on profits. While it is plausible that government agencies, international organizations, or scientists could have their own sources of bias, the passage does not include any evidence of this. Thus, the only correct inference is **(A)**.

83. (C)

The passage addresses the need for appropriate research questions in the fifth paragraph, and gives one example of a failure to generate appropriate questions: an experiment conducted using sterile soil that identified no hazard, while a hazard was later identified using natural soil. The example indicates that the original experiment was too narrow in scope, and did

not include all areas of possible impact **(C)**. The passage does not cite lack of adequate experience or lack of consultation as a problem in this regard. **(B)** is wrong as it is the opposite of the correct answer choice.

Passage VI (Questions 84–90)

Topic and Scope: The art of puppetry including types of puppets and aspects of their appeal.

Paragraph Structure: Paragraph 1 introduces puppetry, indicating its relationship to other visual arts and to theatre. Paragraph 2 gives an example of the simplest form of puppetry and describes hand puppets and how they are used. Paragraph 3 describes rod puppets and marionettes, and indicates how they differ from hand puppets. Paragraph 4 describes shadow puppets. Paragraph 5 discusses large puppets, how they are used, and indicates that they may be difficult for some audience members to distinguish from costumes. Paragraph 6 reflects back to the notion in the first paragraph that successful puppets emotionally engage the audience, giving a specific example of a puppet character that endured far beyond the career of any single operator, and competed with a more respectable form of theatrical entertainment: the opera. Paragraph 7 concludes with the observation that puppetry, although commonly associated with children's entertainment in the United States, has broader appeal in other countries.

84. (A)

This is a Detail question. Note that it asks what “essentially defines a puppet.” To distinguish between an essential and a nonessential characteristic, try using the words “may or may not.” The passage gives two examples of very simple puppets in the first and second paragraphs. In neither case is it indicated that the operator is concealed. Thus, a puppet may or may not be manipulated by a concealed operator. That a puppet must be made of nonliving materials is indicated by the last sentence of paragraph 1. Don't be confused by the reference to leather and fish skin in paragraph 4. The material may be organic, but if it has been made into a shadow puppet, it is clearly no longer alive. Since we must eliminate (III) and retain (II), The answer must be **(A)**. **(A)** also includes the characteristic “can be made to appear animate.” Clearly, this is what distinguishes a puppet from a doll.

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85. (B)

This question focuses on the essential characteristics of a puppet, but in this case you are asked to focus on the characteristic that differentiates a puppet from a costume. In paragraph 5 the passage mentions that audience members may have trouble distinguishing a puppet from a costume when the puppet is large and the puppeteer is entirely inside it. The sentence implies that there is a distinction, but does not explicitly state what the distinction is, since both size of the figure and the puppeteer being contained inside it are sources of confusion. This is a clue to consider that the passage does not define a puppet by its size or by whether or how its operator is concealed. If we return to the definition of a puppet, it is not defined by its size or its size relative to its operator (C). It is not defined by whether the actor/puppeteer is completely concealed. The description of hand puppets, for example, indicates that the operator may be completely concealed. Concealment of the operator thus cannot be the essential difference, (A). The passage indicates that voice is usually used in a puppet show, but that cannot be used to distinguish a puppet from an actor wearing a costume. The characteristic of a puppet given most attention in the passage is that it is made to move by an operator, but that the motion is to varying degrees indirect. This indirectness is either because an intervening device is used, such as a string or a rod, or because the part of the body moved by the operator (such as a finger, in the case of the hand puppet) moves a different part of the puppet's body.

86. (C)

In the first paragraph, the passage indicates that success of a puppet show depends on imagination, realism, skill of the puppeteer, and production of emotional involvement. Does the passage provide a basis to infer which was most important in the case of Punch? It probably was not the skill of the puppeteers (A), since the character endured beyond any single lifetime. While the character used props (D), the information about the props provides no basis to believe that they were particularly creative or imaginative. While striking another character and killing him could happen in real life, the quality of realism (B) referred to in the first paragraph implies more than just that an action could actually theoretically happen, but that it has a sense of emotional truth. That leads us to emotional involvement (C). If a character is boisterous and disreputable, it

certainly could engage the audience emotionally. Since the first paragraph indicates a particular charm of puppetry is its production of emotional involvement, it is most reasonable to infer that this is the source of Punch's extended popularity, and (C) is correct.

87. (C)

This question asks you to consider what a statement indicates, in context of the particular passage. The passage speaks about different types of puppets and what characteristics define a puppet. In this case, the statement that the doll was "used as a prop" can be contrasted to the doll as an "example of simple puppetry" in the first paragraph. In the first paragraph, the doll "waves," and thus becomes a puppet. In the context of this discussion about puppets, the fact that the baby was a doll used as a "prop" (rather than as a "puppet") indicates that it did not appear to move itself. The passage provides no basis to determine that the baby was not important to the story line of the puppet show. A prop may be essential to a story line. Consider, for example, the bean seeds in "Jack and the Beanstalk." Similarly, the fact that the baby was used as a prop does not mean the parents did not care about it. A prop can be used in a way that indicates it is very important to a character in a performance.

88. (A)

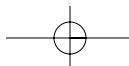
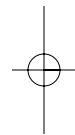
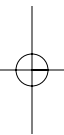
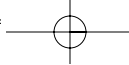
Paragraph 5 identifies "The North Wind" as a puppet in the third sentence. Thus, it would not be logical to infer that the author would classify it as a costume (B). Rod puppets are discussed in the third paragraph. Although the first sentence indicates that the design of rod puppets "permits" their operation from a distance away, the word leaves open the possibility that they may be used even if they are not operated from a distance. The third paragraph also indicates that a rod puppet is manipulated by rods and manipulated from below. Both of these characteristics are true of the "The North Wind." The only characteristic the "The North Wind" shares with a hand puppet (C) is that the puppeteer's hand is within the puppet. However, the sense in which the puppeteer's hand is within the puppet is totally different in the case of the "The North Wind." "The North Wind" is manipulated using rods, and it is thus a rod puppet (A).

89. (A)

Paragraph 2 indicates that a hand puppet covers the puppeteer's hand. The same paragraph describes a hand puppet as having a head and arms, but indicates it may have other extremities. Thus, **(C)** cannot be correct. The passage does not attribute particular fluidity of movement to hand puppets, but does specifically attribute the quality to rod puppets. Thus, **(B)** and **(C)** cannot be correct, and the correct answer is **(A)**.

90. (B)

The reference is to the lines right at the beginning of the passage that show how effectively a doll can be used as a puppet.



BIOLOGICAL SCIENCES ANSWER KEY

91. (C)	106. (B)	121. (C)
92. (B)	107. (D)	122. (A)
93. (C)	108. (C)	123. (C)
94. (B)	109. (D)	124. (B)
95. (C)	110. (B)	125. (D)
96. (A)	111. (C)	126. (C)
97. (D)	112. (B)	127. (D)
98. (B)	113. (D)	128. (B)
99. (A)	114. (A)	129. (B)
100. (C)	115. (A)	130. (C)
101. (B)	116. (C)	131. (A)
102. (B)	117. (A)	132. (D)
103. (A)	118. (A)	133. (C)
104. (B)	119. (D)	134. (C)
105. (D)	120. (C)	135. (A)

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BIOLOGICAL SCIENCES EXPLANATIONS

Passage I (Questions 91–96)

91. (C)

In Hypothesis A, viral proteins are processed and presented in association with an MHC class I molecule. This allows CTL to recognize viral antigens and mediate the lysis of virally infected cells. In Hypothesis D, expression or recognition of foreign antigens is not required for any cell expressing Fas receptor is lysed. Choice (A) is incorrect because both hypotheses describe T cell mediated destruction of CD4⁺ T cells. Choice (B) is incorrect, for in Hypothesis D the immune response is directed against virally infected cells and not against T cell proteins. Choice (D) is incorrect because in Hypothesis D, CD4⁺ T cells are killed and are not simply rendered inactive.

92. (B)

Hypothesis B is the only hypothesis in which the immune response is directed against cellular proteins. This hypothesis would thus be most similar to autoimmune diseases.

93. (C)

This question tests knowledge of clonal selection theory. The basic tenets of this theory are:

- 1) Each lymphocyte expresses unique receptor specificity, which is determined prior to the appearance of antigen.
- 2) Binding of an antigen to a specific receptor activates the cell, resulting in its proliferation into a clone of cells, each with the same immunologic specificity as the original parent cell.

Of all the presented answer choices, only choice (C) acknowledges the existence of HIV specific T cell clones prior to infection with the virus.

94. (B)

If the observation shows that the number of T cells destroyed is greater than the number of T cells infected, then the correct hypotheses must account for the elimination of infected and noninfected cells. Hypothesis B accounts for the elimination of

noninfected cells because the immune response is directed against the CD4 molecule, which is present on all CD4⁺ T lymphocytes regardless of infection status. Hypothesis C also accounts for elimination of noninfected cells because, according to this hypothesis, infected cells fuse with noninfected cells and undergo programmed cell death.

95. (C)

Of all the hypotheses given, only Hypothesis C discusses a mechanism in which the decline of CD4⁺ T cells occurs solely as a result of infection (i.e., without the involvement of CTLs). This hypothesis would thus be challenged if no decline of CD4⁺ T lymphocytes is observed.

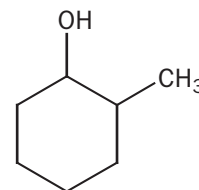
96. (A)

According to Hypothesis A, infected CD4⁺ T cells are lysed after CTLs recognize viral proteins in association with the MHC class I molecule. Thus, the observation that a more rapid MHC class I processing pathway leads a more efficient CTL response supports Hypothesis A. Choices (B) and (C) do not support Hypothesis A because any disruption in the MHC class I processing pathway would be expected to hinder CTL response against the infected cells. Choice (D) is incorrect because according to Hypothesis A, cell-to-cell interaction must occur in order for a CTL to recognize viral antigens in association with MHC class I molecules.

Passage II (Questions 97–102)

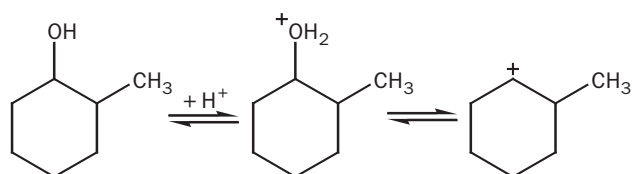
97. (D)

Zaitsev's rule predicts that when an elimination reaction can lead to the production of more than one alkene, the major product is the most thermodynamically stable alkene—in other words, the most highly substituted one. To predict the product in this particular case, we need to determine what the possibilities are given the starting compound, 2-methylcyclohexanol, which has the following structure:

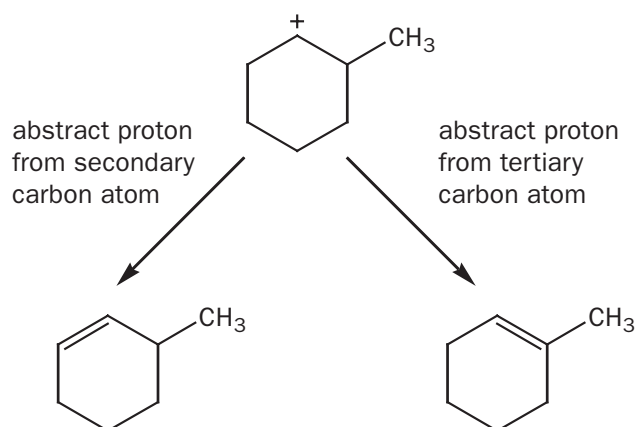


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Because the reaction employs acid and heat, we know that it is an $E1$ reaction. It progresses via a carbocation intermediate. Since the compound does not contain a good leaving group, the first step is the conversion of the hydroxy group into a water molecule by the addition of acid.



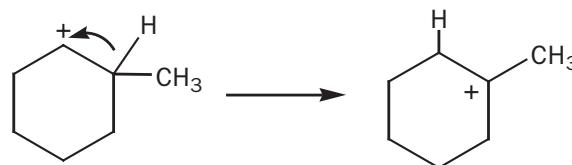
A proton is then abstracted from the carbocation intermediate, thus regenerating the acid catalyst and also leading to the formation of a pi bond. The proton can be abstracted from either of the two carbon atoms adjacent to the positive charge:



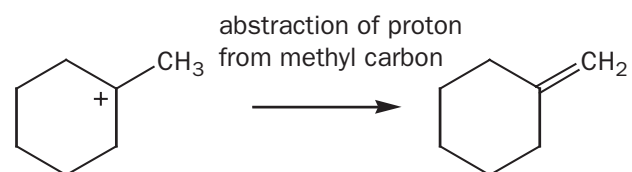
The two alkene products are not equally thermodynamically stable. The structure shown on the right, formed by the abstraction of the proton from the tertiary carbon atom, is more substituted and thus more stable; the double bond is attached to a total of three alkyl groups, while the other alkene product has a double bond attached to only two alkyl groups. The structure shown in choice **(D)** is therefore the most likely product of the reaction.

98. (B)

The intermediate formed with the leaving of the water molecule can lead to one of two possible alkene products, as illustrated above. This arises from the structure of the compound and the nature of the reaction. However, yet another possibility exists because the carbocation intermediate can undergo rearrangement via a hydride shift:



The driving force behind this rearrangement is the additional stability of the carbocation: prior to the hydride shift, the carbocation is secondary, but the hydride shift leads to a tertiary carbocation, which is more stable because of the electron-donating ability of alkyl groups. With this new intermediate, a new alkene product is possible:



(Notice that a proton can also be abstracted from an adjacent carbon atom that is part of the ring. However, that leads to the same Zaitsev product.) The percentage yield of this product depends on the rate of the hydride shift versus the rate of proton abstraction leading to the alkene product, among other factors. Not all intermediates undergo rearrangement. The fact that hydride shift may occur is hence at least partly responsible for the formation of multiple products.

Choice **(A)** is incorrect because the positive charge is not delocalized. It resides on only one carbon atom at a time. (Do not confuse the moving of the charge from rearrangement with charge delocalization! The movement of the charge arises from an actual modification of the skeleton of the molecule. In other words, the structures

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for the intermediate before and after rearrangement are *not* resonance structures.)

Choice **(C)** is incorrect because the reaction is an $E1$ reaction, not an $E2$ reaction, so considerations of conformation are not relevant.

Choice **(D)** is incorrect because the methyl group, compared to hydrogen, is actually electron-donating, not electron-withdrawing.

99. (A)

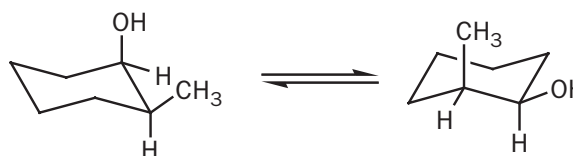
Knowledge of characteristic IR frequencies of common functional groups is necessary to answer this question. The O–H stretch of an alcohol occurs as a broad peak somewhere between $3,200\text{ cm}^{-1}$ and $3,600\text{ cm}^{-1}$. Since the hydroxy group is absent from the alkene products, this peak will not be observed in their IR spectrum. Choice **(B)** is therefore one way in which the IR spectra of the reactant and of the products differ, and is not the correct choice. A peak at around $1,660\text{ cm}^{-1}$ corresponds to the $\text{C}=\text{C}$ bond stretch. This peak is expected in the IR spectrum of an alkene, but not that of the reactant alcohol. Choice **(C)** then also points to a distinguishing feature between the two spectra. Similarly, a peak at around $3,090\text{ cm}^{-1}$ corresponds to a vinylic ($\text{C}=\text{H}$) stretch, which again is observed only in the alkene. Choice **(D)** is therefore also incorrect.

Choice **(A)**, however, is not a distinguishing feature between the two spectra. Neither one would be expected to display a peak at $2,100\text{ cm}^{-1}$, which corresponds to the stretch of an alkyne ($\text{C}\equiv\text{C}$).

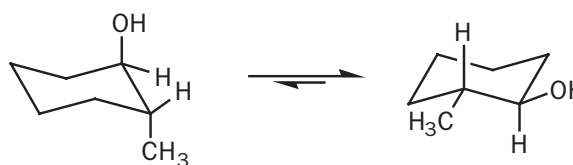
100. (C)

The first step in answering this question lies in determining the favored conformation of each of the compounds given. In general, a cyclohexane derivative preferentially adopts a conformation in which its substituents all occupy the equatorial position. However, this is not always possible, as can be seen by the following:

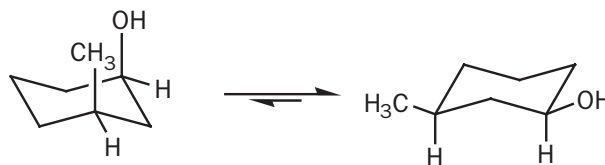
cis-2-methylcyclohexanol:



trans-2-methylcyclohexanol:



cis-3-methylcyclohexanol:



trans-3-methylcyclohexanol:



Choices **(A)** and **(D)** can only have one of its substituents occupy the equatorial position. Only choices **(B)** and **(C)** can adopt a conformation in which

both substituents are equatorial, and this is the favored conformation for the compound. We next need to decide which of the two diequatorial compounds is more stable: *trans*-2-methylcyclohexanol or *cis*-3-methylcyclohexanol. In *trans*-2-methylcyclohexanol, the substituents are on adjacent carbon atoms. When they both occupy the equatorial position, *gauche* interactions arise between the two. This is not as stable as in the case of *cis*-3-methylcyclohexanol, in which the two substituents are farther apart and hence no *gauche* interactions exist between them. Choice **(C)** is therefore the correct answer.

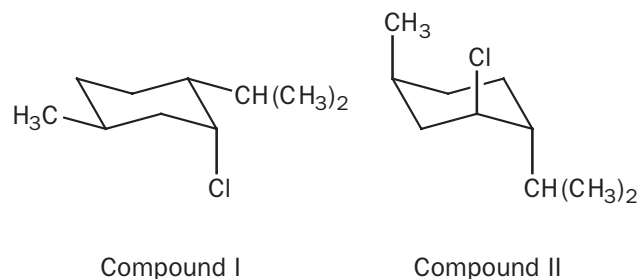
101. (B)

Vinylic protons are ones directly attached to sp^2 hybridized (alkenyl) carbon atoms. In proton-NMR spectra, they have a chemical shift somewhere between 4.5 and 6.5 ppm. Choice **(B)** is therefore the correct answer.

Choice **(A)**, 2–4 ppm, is the chemical shift range for protons of an alkyl halide ($-CHX-$). Choice **(C)**, 6–8.5 ppm, is the chemical shift range for aromatic protons ($Ar-H$). Choice **(D)**, 10.5–12 ppm, is the chemical shift range for carboxylic acid protons ($-COOH$).

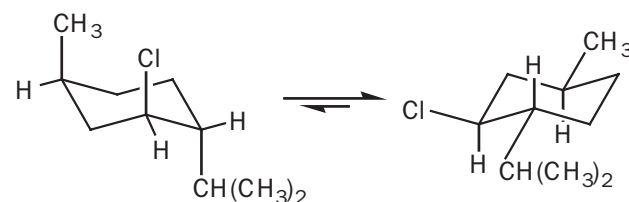
102. (B)

Since the question asks specifically about $E2$ reactions, we expect the conformation of the compounds to come into play. As mentioned in the passage, the leaving group needs to be antiperiplanar to the abstracted hydrogen. For the two compounds shown in the question stem, the requirement means that the chlorine (leaving group) needs to be in the axial position for $E2$ to take place. We need to be careful in deducing the position of the alkyl substituents from the *cis/trans* relationship.



The conformation for each compound shown above is not necessarily the favored one. Rather, it is the conformation that the molecule must adopt if $E2$ were to occur, i.e., one in which the chlorine is in the axial position. For example, in Compound I the isopropyl group is *cis* to the chlorine. When the chlorine is in the axial position, it *has* to occupy the equatorial position. Similarly, the methyl group two carbon atoms away from the chlorine has to be in the equatorial position based on its *cis/trans* relationship with chlorine.

The question stem asks us to determine two things: which compound would undergo $E2$ more rapidly, and whether it leads to one or more products. As mentioned above, the conformation required for $E2$ is not necessarily the favored one. If, in order to undergo $E2$, the molecule must first adopt a conformation that is highly unfavorable, the reaction will be slow. This is the case for Compound II. With a “ring flip,” the molecule can adopt another chair conformation in which the axial/equatorial positions of all substituents are reversed, leading to the following favored conformation in which all substituents are equatorial:

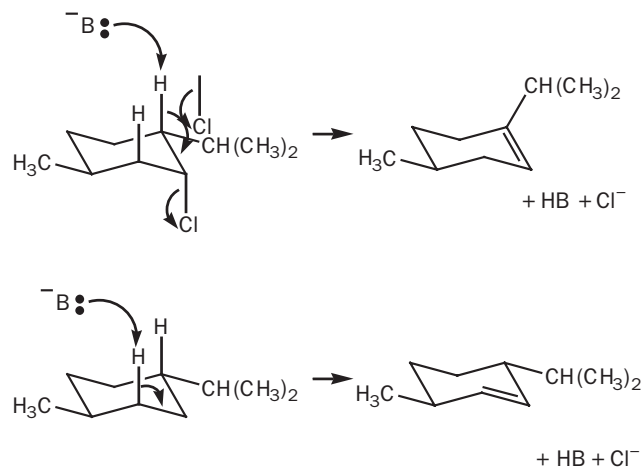


In other words, a molecule of Compound II must first adopt an unfavorable (strained) conformation before $E2$ can occur. This is expected to cause the reaction rate to decrease. In contrast, in its most stable conformation, Compound I is ready for $E2$ reaction: the chlorine is in the axial position and the two alkyl groups are equatorial. (It is not possible for all three substituents to occupy the equatorial position; a “ring flip” would result in two axial substituent groups and one equatorial substituent group.) The $E2$ reaction of Compound I is therefore expected to proceed more rapidly.

The remaining question we need to answer is: Does the $E2$ reaction of Compound I lead to one alkene product,

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or is there a possibility of multiple products? The base can abstract either one of the two protons antiperiplanar to the chlorine:



The reaction therefore leads to more than one product, and choice **(B)** is the correct answer.

Passage III (Questions 103–108)

103. (A)

The passage tells us that the systems that respond to PTH do so with the goal of raising blood calcium. Recall that osteoclasts are cells that break down bones, and osteoblasts are cells that lay down bone. Choice **(A)** is therefore correct because stimulation of osteoclasts breaks down bone, releasing calcium from bone into blood. Increasing osteoblast activity will lower blood calcium by placing it into bone, contrary to the purpose of PTH. Choices **(B)** and **(D)** are incorrect because they pair the cells with incorrect roles.

104. (B)

This question requires combining three pieces of information presented in the passage. First, we know from paragraph 1 that the amino terminus has the biological activity. Second, we know that PTH is degraded quickly by hydrolysis. Third, we know from paragraph 1 that these degradation products have no biological activity. In order to remove the biological activity from the hormone, the amino terminus must be destroyed. Therefore there must be a hydrolytic cleavage

site near the amino terminus. If the amino terminus were left intact, the degradation product would be active. Choice **(C)** is incorrect because while PTH is hydrolyzed by the liver, we are told that it is excreted from the body in the urine. Choices **(A)** and **(D)** are incorrect because we receive no information about the primary or secondary structure of PTH from the passage and cannot come to conclusions about them.

105. (D)

(D) is the correct choice because we are told that the products of hydrolysis are directly excreted in the urine. In order to be excreted in the urine, a substance must be water soluble. Water-insoluble compounds are either stored in the body, converted to water-soluble products, or eliminated in the feces. Choice **(A)** is incorrect because we are told the products are excreted. Choice **(B)** is incorrect because the peri-tubular capillaries contain the molecules that the kidney *reabsorbs*; the PTH byproducts are excreted not absorbed. Choice **(C)** is incorrect because in order to get into the urine, a molecule must be filtered from the blood through the glomerulus and into the renal tubule for transport to the ureter and bladder.

106. (B)

The key to answering this question is the information that that half-life of PTH is only a few minutes. Choice **(B)** is correct because once the source of the excess PTH is removed, the hormone circulating in the body will be exhausted quickly. Choice **(A)** is incorrect because the passage states that surgical therapy is not necessary unless the patient is symptomatic—simply having high levels of PTH is not enough. Choice **(D)** is incorrect because the passage tells us that the other three parathyroid glands compensate adequately.

107. (D)

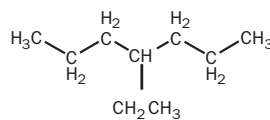
Choice **(D)** is correct based on the bottom row of the chart. PTH secretion is under the control of a negative feedback loop. If calcium levels go up due to the presence of a tumor secreting PTHrP, blood calcium concentration will begin to rise and PTH secretion (and its breakdown products) will go down. Calcitonin will be secreted in response to the increased blood calcium concentration, and bone density will go down because the PTHrP is stimulating breakdown of bone.

108. (C)

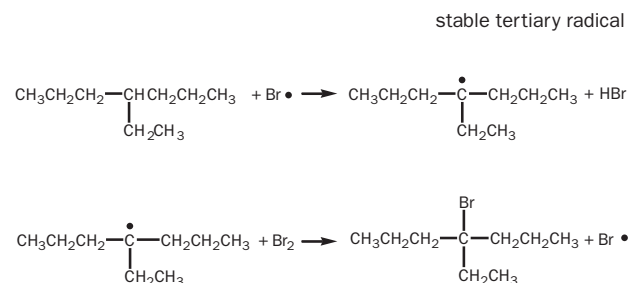
This question tests your understanding of a negative feedback loop. Choice **(C)** is correct because, if the receptor is always activated, then the calcium concentration in the blood will rise because the receptor is acting as if PTH were present. As blood calcium concentration rises, PTH secretion will be shut off, decreasing the level of PTH breakdown products in the blood—of course the receptors will still be acting as if PTH were high! Choice **(B)** is incorrect because if calcium sensing in the parathyroid gland were ineffective, then the gland would think that calcium was too low, stimulating (not decreasing) PTH secretion. In choice **(D)**, if a mutation produced increased function of calcitonin, calcium concentration in the blood would be low. On the other hand, if a mutation produced low function, calcium concentration would be normal because the parathyroids would simply decrease their secretion until calcium levels normalized. Absence of two of the four glands would be compensated for by the other two, and PTH levels would be either normal or only slightly low.

Discrete Questions (Questions 109–113)**109. (D)**

The structure of 4-ethylheptane is as follows:



The UV light creates bromine radicals, which can substitute for hydrogen atoms. Bromine radicals are more selective than, say, chlorine radicals, and preferentially substitute at tertiary carbons. The more substituted the radical (the more alkyl groups bonded to the carbon with the unpaired electron), the more stable it is. Substitution at the tertiary progresses through the most stable (most highly substituted) radical intermediate:

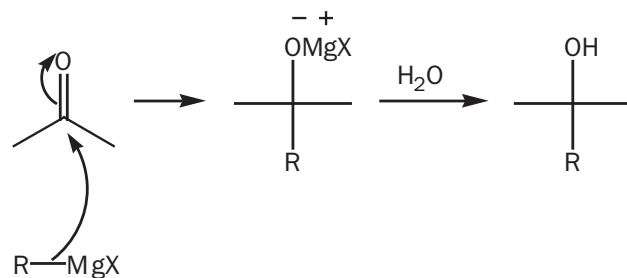


The product is therefore 4-bromo-4-ethylheptane, choice **(D)**.

Choices **(A)** and **(B)** are incorrect because they are dibromo products. They would arise through addition to an alkene, but are not expected with alkanes. The probability of 4-bromo-4-ethylheptane undergoing another substitution at carbon #3, for example, is low. Choice **(C)** is incorrect because the bromine would substitute for a hydrogen, not the ethyl group.

110. (B)

A Grignard reagent has the general formula RMgX ; i.e., it is an alkylmagnesium halide. It is a very versatile reagent, and is often used to add an alkyl group to carbonyl compounds:



If the carbonyl compound is an ester or an acyl chloride, the alkoxide or chloride group acts as a leaving group allowing for reaction with another molar equivalent of the Grignard reagent. In any case, the product is an alcohol. However, the Grignard reagent can also be thought of as a powerful base, and when the compound is a carboxylic acid, instead of addition to the carbonyl carbon, we have instead an acid-base reaction, in which

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the negatively polarized alkyl portion of the Grignard reagent abstracts a proton to form the alkane:



In fact, an acid-base reaction occurs even with a water molecule, which is why we need to ensure that Grignard reactions are carried out in moisture-free environments.

111. (C)

Call the disease allele X^A . The corresponding normal allele is X^a . If the patient's mother inherited the disease from her father (the patient's grandfather), her genotype is $X^A X^a$. Since the patient's father is also affected, his genotype is $X^A Y$. The cross is therefore $X^A X^a \times X^A Y$. Using a Punnett square, the offspring can have the following genotypes:

	X^A	X^a
X^A	$X^A X^A$	$X^A X^a$
Y	$X^A Y$	$X^a Y$

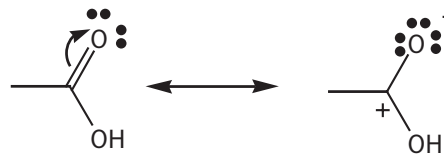
The patient's chances of having the disease are 75%, since from the Punnett square, 75% of the offspring will inherit the X^A allele.

112. (B)

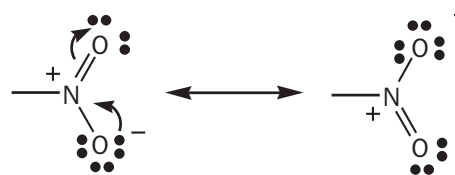
Oxygen is the terminal electron acceptor in the electron transport chain of the mitochondrion; thus choice **(B)** is the correct answer. This oxygen is the oxygen required for aerobic respiration.

113. (D)

Substituent groups that are meta-directors in electrophilic aromatic substitution reactions can generally be identified by the fact that they are bonded to the phenyl ring via a positively charged or positively polarized atom. The carbon atom in the cyano group is positively polarized because of the highly electronegative nitrogen atom. Choice **(A)**, therefore, is a meta-director. The carbonyl carbon is also positively polarized as can be seen from the following resonance structures:



The nitrogen atom in the nitro group in choice **(C)** has a formal positive charge:



The negative charge is delocalized over both oxygen atoms, but the positive charge resides on the nitrogen. The nitro group is also a meta-director. The nitrogen of the amino group in choice **(D)**, however, is not positively polarized or positively charged. Instead, it has a lone pair of electrons that can be donated to the phenyl ring via resonance. It is an ortho/para-director, and is therefore the correct answer.

Passage IV (Questions 114–119)**114. (A)**

Depolarization of the membrane is a normal function of the axon as a result of stimulation either by an electrode or by a stimulus on the nociceptor (pain receptor). Thus, the possibility exists that the bacteria do not affect transduction at the level of depolarization. Choice **(B)** is incorrect because no impedance has occurred. Choice **(C)** is incorrect because the lack of depolarization or nerve firing does not rule out an effect on synaptic transmission. Choice **(D)** is incorrect, since nothing is related to bacteria number, and depolarization has occurred. Polarization occurs due to Na^+/K^+ pumps in the membrane, not due to bacterial action.

115. (A)

Elimination of postsynaptic stimulation is most likely a result of a weakening of presynaptic signal strength. This is not typically achieved in the all-or-nothing axon, but can result from an effect on release of

neurotransmitter. Choice **(B)** is incorrect because electrode C does not register a weakening. Choice **(C)** is incorrect because increasing post-synaptic receptors would increase sensitivity to the neurotransmitter and enhance the signal strength. Choice **(D)** is incorrect because amplification of the presynaptic signal would again enhance signal strength across the synapse.

116. (C)

Stimulation at electrode B in the infected animal results in a near-resting potential energy reading at electrode C, showing that the infection blocks the normal depolarization of the axon. Stimulation at electrode C (between the infection and synapse) creates a normal depolarization at electrode D, arguing that the presynaptic release of neurotransmitter is unaffected by infection.

117. (A)

Given this assumption (which is likely to be incorrect in reality), only interference with axon traffic does not necessarily involve axon transmission rates. Choice **(B)** says that pumps which maintain axon polarity are disrupted; this would make axon transmission impossible. Choice **(C)** suggests the degeneration of the template for protein manufacture; protein turnover involves pumps. More importantly, the cell would die; this is a poor strategy for long-term survival as a parasite. Choice **(D)** would increase axon signal strength or possibly frequency, and would likely give the opposite effect, namely increased sensory axon output.

118. (A)

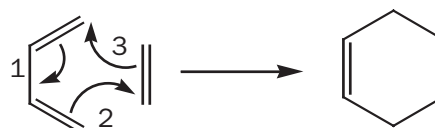
Humoral immunity responses require access to surface antigens present on the foreign cells. This is not possible for intracellular pathogens that multiply within the target cells. Choice **(B)** suggests the opposite, and implies that antibodies gain access to *M. leprae*. Choices **(C)** and **(D)** may both be correct or incorrect: there is no basis for certainty. It is also possible that *M. leprae* infections have no effect on transmission rates, but limit the availability of neurotransmitter at the synapse. Thus, there is no basis from the question and passage for implying either with any confidence.

119. (D)

Bacteria lack defined organelles. The acquisition of organelles, including the nucleus, is thought to be a part of the genesis of eukaryotes (the endosymbiont theory). Bacteria have all of the other components listed (cell membrane, ribosomes, and cytoskeleton).

Passage V (Questions 120–125)**120. (C)**

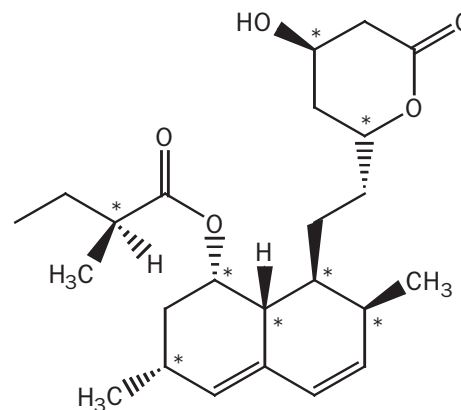
One can draw the mechanism for the Diels-Alder reaction shown in Equation 1 as follows. (The numbers next to the electron-pushing arrows are simply used for labeling convenience, *not* to imply the order in which the events occur. In fact, the reaction is concerted.)



In 1, the pair of pi electrons is “shifted” to become the pi electrons of the double bond in the product. In 2, however, the pi electrons are used to form a sigma bond linking the diene and the dienophile. Similarly, in 3, the pi electrons (this time from the dienophile) are also used to form a new sigma bond. The number of sigma bonds has therefore increased by two as we go from reactants to products. Since each double bond contains one pi bond, and the number of double bonds decreases from three to one in the reaction, the number of pi bonds has decreased by two.

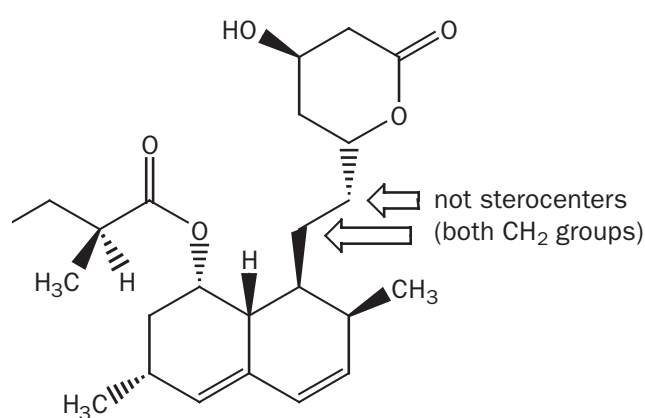
121. (C)

A stereogenic center—or stereocenter or chiral center—is usually a carbon atom bonded to four different groups. (Nitrogen and some other heteroatoms can also act as stereocenters if the arrangement of groups about the atom leads to distinct, nonsuperimposable mirror images.) The stereocenters of lovastatin, whose structure is shown in Equation 2, are labeled with an asterisk in the following diagram:

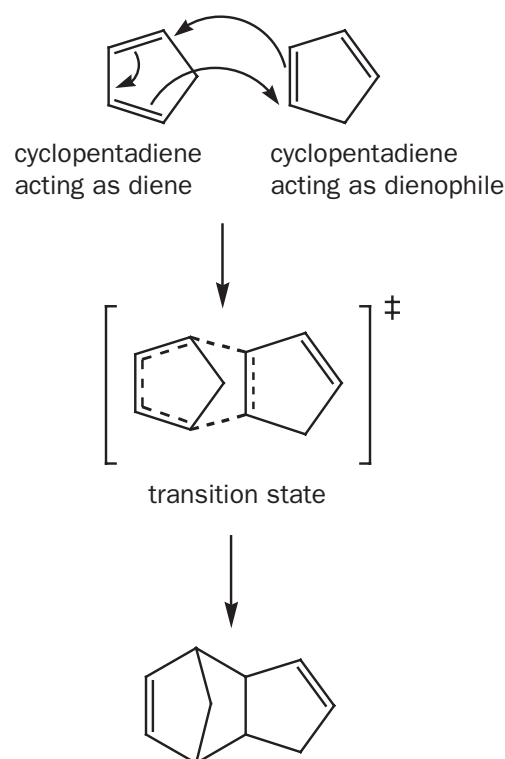


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There are a total of eight stereocenters. Notice that we always need to keep in mind that hydrogen atoms needed to saturate the carbon atoms are not always indicated explicitly in chemical structures. However, if there are two such “implied hydrogens” attached to a carbon atom, that carbon atom cannot possibly be a stereocenter because it will not be bonded to four different groups. For this reason, the two carbon atoms labeled below are not stereocenters:

**122. (A)**

To answer this question, we need to first of all determine the structure of cyclopentadiene and then apply Equation 1 to the situation in which one molecule of cyclopentadiene acts as the diene while another molecule acts as the dienophile.

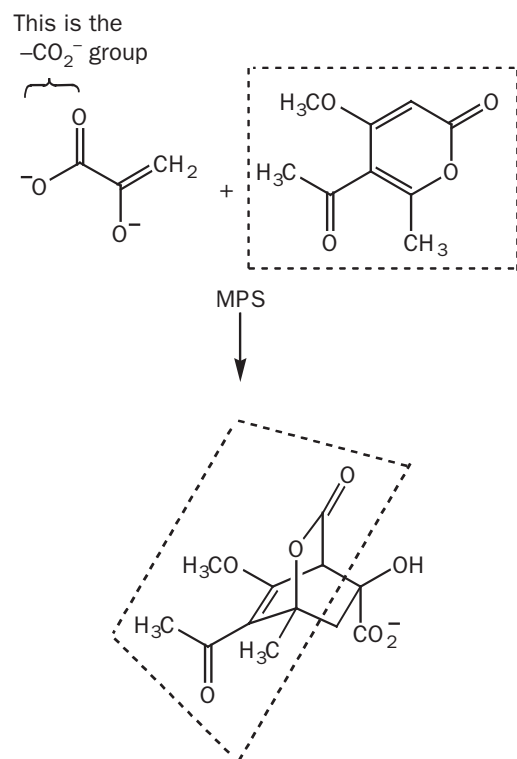


This is the structure shown in choice **(A)**. Even if we had not been able to visualize how the spatial relationships between the bonds evolve over the course of the reaction, we could have eliminated the other answer choices by some reasoning and close examination of Equation 1. In Equation 1, we see that the diene and the dienophile join to form a six-membered ring, with a double bond in the position between the two double bonds in the original diene. Furthermore, three double bonds (one from the dienophile and two from the diene) become one double bond in the product. In the case with two molecules of cyclopentadiene, however, we start off with an extra double bond: the dienophile itself contains two double bonds, one of which does not participate in the reaction. The number of double bonds

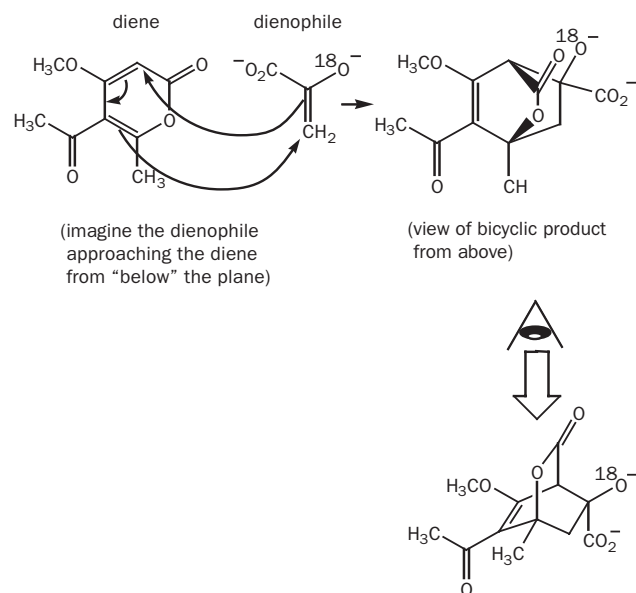
in the product, then, is expected to be two. This enables us to eliminate choice **(D)**. Furthermore, we know that the second double bond in the product should not be part of the six-membered ring; i.e., the six-membered ring should only contain the one double bond that forms as a result of the reaction. Choice **(B)** can therefore be eliminated. Finally, choice **(C)** can be eliminated because the six-membered ring does not contain any double bond. The structure shown has both double bonds as part of a five-membered ring, which contradicts the reaction as illustrated in Equation 1.

123. (C)

In this question, we are asked to determine where an isotopic label ends up after the reaction. This can be a very challenging question as the reaction, as illustrated in Equation 3, contains very little that can help us orient ourselves spatially and see how the two compounds join to form the bicyclic compound. However, we can keep track of certain functional groups. By examining where the $-\text{OCH}_3$, $-\text{COCH}_3$ and $-\text{CH}_3$ groups end up in the bicyclic compound, we can deduce how the molecule is “put together”:



With the spatial relationships established, we can see that the radiolabeled oxygen in the question stem becomes the oxygen in the hydroxy group of the bicyclic compound. Choice **(C)** is therefore correct. The following diagram illustrates how the electrons are actually shifted around in the reaction.



Presumably the oxygen is protonated at some point to create the hydroxy group.

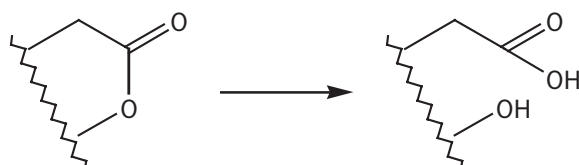
124. (B)

The question is essentially asking us to identify the one compound that will not participate in a Diels-Alder reaction. The choices are meant to act as analogs of the 2-pyrone shown in Equation 3. As the passage states, the Diels-Alder reaction involves the addition of an alkene (acting as a dienophile) to a conjugated diene. In addition, as can be deduced from examining the reaction shown in Equation 3, the 2-pyrone acts as the diene. In other words, the analogs must also be conjugated dienes. The compound shown in choice **(B)** is not a conjugated diene: the two carbon-carbon double bonds are separated by sp^3 hybridized atoms and the pi electrons are therefore not delocalized. It therefore cannot react with a dienophile to yield a Diels-Alder adduct.

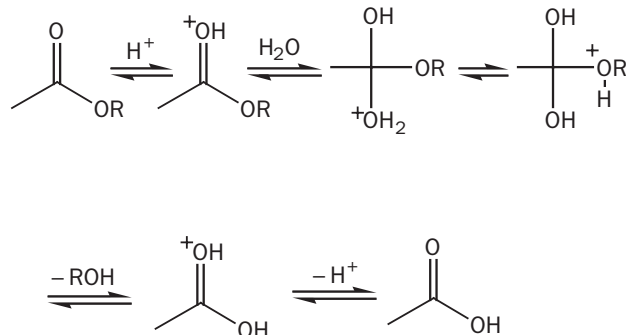
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125. (D)

The question is asking us to identify the process that will convert lovastatin as it appears in Equation 2 to the structure shown in the question stem. Focusing in on the portion of the molecule that has undergone change, we are essentially asked to determine the name for the following transformation:



The original functionality is a (cyclic) ester, with the formula $-\text{COOR}$. The functionalities after the transformation are a carboxylic acid and an alcohol. The process is therefore one of ester hydrolysis. The general reaction scheme (under acidic conditions) is as follows:

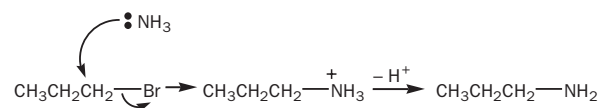


Choices **(A)** and **(B)**, oxidation and reduction, are incorrect because the number of carbon-oxygen bonds has not changed. The carbonyl carbon in the ester has three C-O bonds (one double and one single); the same is true in the carboxylic acid product. Choice **(D)**, ozonolysis, refers to the formation of carbonyl compounds by breaking a carbon-carbon double bond.

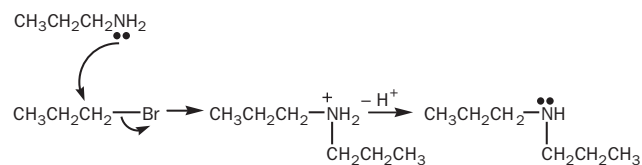
Passage VI (Questions 126–130)

126. (C)

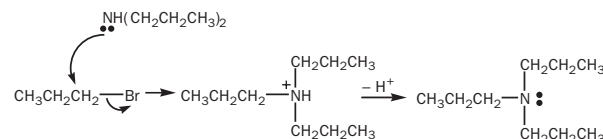
The first amine product formed from the reaction of ammonia with 1-bromopropane is propylamine:



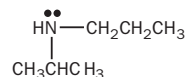
As indicated in the passage, however, this amine product can participate in further reactions with the original substrate:



The product thus formed is dipropylamine. Dipropylamine itself can also act as a nucleophile to react with 1-bromopropane:



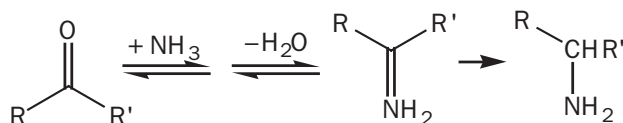
This is tripropylamine. (It can at least in principle also act as a nucleophile, although steric hindrance is considerable and the resulting product cannot deprotonate to yield a neutral product.) Therefore, choices **(A)**, **(B)**, and **(D)** can all potentially form when ammonia is reacted with 1-bromopropane. Choice **(C)**, isopropylpropylamine, has the following structure and is not expected to form:



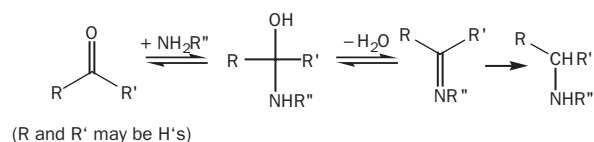
127. (D)

In Equation 2 in the passage, we see that when ammonia reacts with an aldehyde through reductive amination the product is a primary amine (NH_2R). The question asks us to determine what is necessary to obtain a tertiary amine, i.e., a compound with the formula $\text{NRR}'\text{R}''$. One approach we can take is to take each pair of reagents from the answer choices and see what the product would be.

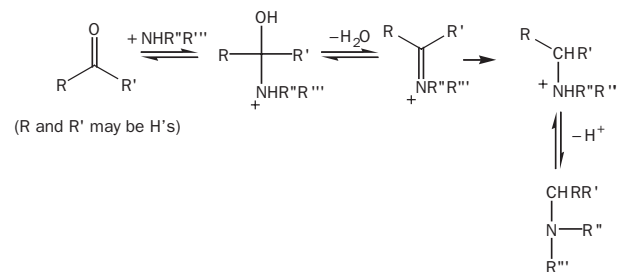
If we react ammonia with a ketone [choice **(A)**], we realize that the product is still a primary amine, since the nitrogen atom is still bonded to only one alkyl group:



So choice **(A)** is incorrect. At this point, if we are test-savvy, we can eliminate choices **(B)** and **(C)** as well. Why? We have just determined that whether the carbonyl compound is an aldehyde or a ketone does not affect the kind of amine we get as the product. Ammonia, whether it reacts with an aldehyde or a ketone, still yields a primary amine. Since choices **(B)** and **(C)** differ only in the aldehyde/ketone distinction, if one is correct, the other will have to be correct as well. This is not possible, so both must be incorrect. Indeed, the product of both reactions is a secondary amine, since the nitrogen is attached to two alkyl groups, R'' and $\text{CHR}'\text{R}$:



The correct choice must therefore be **(D)**. The reaction between a secondary amine and an aldehyde or ketone is as follows:

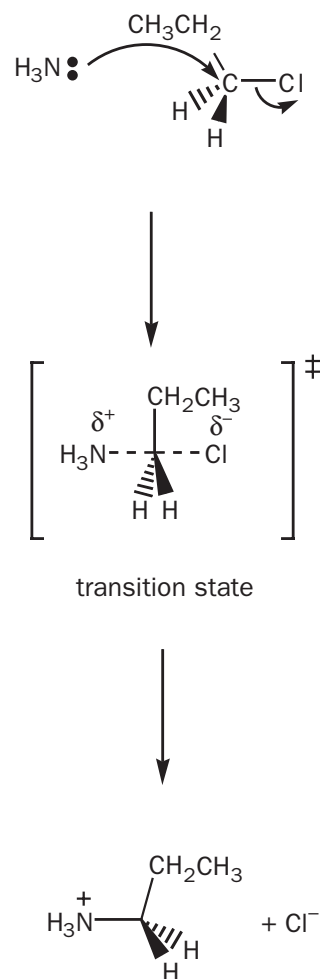
**128. (B)**

The boiling point of a compound is determined by the intermolecular forces it experiences. The stronger the intermolecular forces, the higher the boiling point. Intermolecular forces can run the gamut from weak dispersion forces (among nonpolar hydrocarbons) to strong hydrogen bonding. Among the choices given, only the secondary amine in choice **(B)** is capable of hydrogen bonding because it contains a hydrogen atom bonded to the highly electronegative nitrogen atom. The other compounds have similar molecular weights, so the ability to hydrogen bond is the decisive factor. (The amine in choice **(C)** is a tertiary amine; no hydrogen is directly attached to the nitrogen.) The compound in choice **(B)** therefore has the highest boiling point.

129. (B)

The aminium salt is formed when ammonia replaces the chloro group in the haloalkane. It is therefore a substitution reaction. No double bond is formed and hence it is not an elimination reaction. Since we know that primary alkyl halides participate in the reaction, we know that it cannot be an $\text{S}_{\text{N}}1$ -type reaction. An $\text{S}_{\text{N}}1$ reaction proceeds via the formation of a carbocation intermediate: The leaving group departs, leaving behind a carbocation which in a subsequent step is attacked by the nucleophile. However, primary alkyl halides do not form stable carbocations, so they do not participate in $\text{S}_{\text{N}}1$ reactions. Instead, the reaction is an $\text{S}_{\text{N}}2$ reaction in which the attack of the nucleophile and the departure of the leaving group take place in a concerted fashion, i.e., in the same step. This is illustrated as follows:

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**130. (C)**

In the quaternary ammonium ion, there are four groups (in this case hydrogens) bonded to the central nitrogen atom. To minimize the repulsion between the electron pairs in the N–H bonds, these hydrogen atoms are arranged as far apart as possible. Since there are no lone (nonbonding) electron pairs on the nitrogen, the most favorable arrangement is one in which the hydrogens point toward the corners of a tetrahedron.

The geometry is such that the H–N–H bond angle is 109.5° , closest to choice **(C)**. Notice that the fact that the nitrogen bears a formal positive charge does not affect the reasoning.

Incidentally, the H–N–H bond angle in neutral ammonia is also closest to choice **(C)**. Even though there is one fewer group attached to the nitrogen in the molecule, the nitrogen bears a nonbonding pair of electrons which must be taken into account when determining the geometry.

Discrete Questions (Questions 131–135)**131. (A)**

The sympathetic nervous response is the “fight-or-flight” response, which prepares the body for action and the expenditure of energy. The pupils dilate, allowing more light to enter the eyes; thus (I) does occur during the sympathetic nervous response. Digestive processes are slowed, thus (II) does not occur during the sympathetic nervous response. Blood is shunted toward the skeletal muscles; thus (III) does not occur during the sympathetic nervous response. The correct answer is thus “I only”, or answer choice **(A)**.

132. (D)

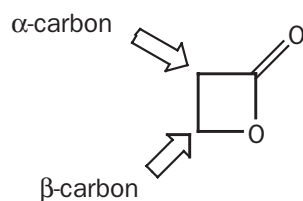
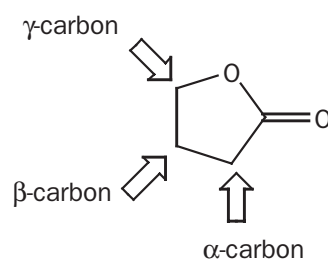
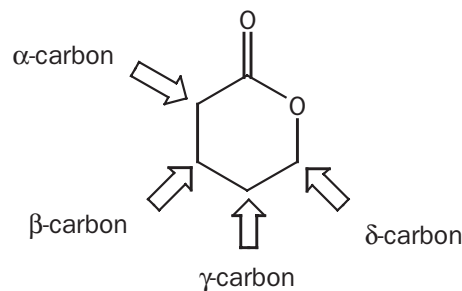
Nonpolar steroid hormones cross the plasma membrane with ease and bind to their receptors inside the cell to directly modify cellular activity. In contrast, non-steroid hormones (i.e., peptide hormones such as insulin and ADH) cannot cross the plasma membrane with ease. Instead, they bind to membrane receptors located on the outside of the plasma membrane. Peptide hormones indirectly modify cellular activity via an internal second messenger. Steroid hormones include testosterone, estrogen, androgens, glucocorticoids, and mineralocorticoids. Thus only choice **(D)** is true of nonsteroid hormones.

133. (C)

As chyme enters the small intestine from the stomach, it contains many dissolved ions and molecules, and is therefore hypertonic, not hypotonic or isotonic; thus choices **(A)** and **(D)** are incorrect. The acidity of the stomach leaves the chyme acidic, thus choice **(C)**, hypertonic and acidic, is the correct answer.

134. (C)

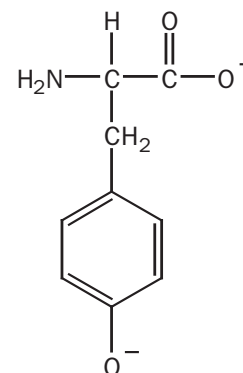
A lactone is a cyclic ester. The Greek letter prefix indicates the ring size by specifying whether the non-carbonyl oxygen (the oxygen atom that is part of the ring) is attached to the beta, gamma, or delta carbon. (The carbon atom adjacent to the carbonyl carbon is the alpha carbon; the next carbon atom is the beta carbon; etc.) A β -lactone, therefore, has a four-membered ring made up of the carbonyl carbon, the alpha carbon, the beta carbon, and the oxygen.

a β -lactonea γ -lactone

A γ -lactone, as we can see, has a five-membered ring. Choice **(C)** is a γ -lactone. Choice **(A)** is a β -lactone, as the diagram above illustrates. Choice **(B)** is not a lactone at all since there is no ester functionality. It is the molecule furan. Choice **(D)** is a cyclic acid anhydride.

135. (A)

The pH of the environment is higher than the pK value of every functionality of tyrosine, so each group acts as an acid towards the solvent. In other words, they all exist in the deprotonated, conjugate base form. The carboxyl group thus exists as the negatively charged carboxylate: $-\text{COO}^-$ instead of $-\text{COOH}$. The amino group exists as the neutral $-\text{NH}_2$ group instead of the $-\text{NH}_3^+$ group. The phenolic side chain exists as $-\text{Ph-O}^-$ instead of $-\text{Ph-OH}$. The structure of the amino acid at pH 11 is therefore as follows:



The net charge is therefore -2 .



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