PHYSICAL SCIENCES

DIRECTIONS: Most of the questions in the Physical Sciences test are organized into groups, with a descriptive passage preceding each group of questions. Study the passage, then select the single best answer to each question in the group. Some of the questions are not based on a descriptive passage; you must also select the best answer to these questions. If you are unsure of the best answer, eliminate the choices that you know are incorrect, then select an answer from the choices that remain. Indicate your selection by blackening the corresponding circle on your answer sheet. A periodic table is provided below for your use with the questions.

PERIODIC TABLE OF THE ELEMENTS

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 *** 138.9	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 †** 227.0	104 **Rf** (261)	105 **Ha** (262)	106 **Unh** (263)	107 **Uns** (262)	108 **Uno** (265)	109 **Une** (267)									

	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)

Physical Sciences

Time: 100 Minutes
Questions 1–77

<u>DO NOT BEGIN THIS SECTION UNTIL YOU ARE TOLD TO DO SO.</u>

Passage I (Questions 1–6)

Certain biological materials like human cartilage have the unique property of viscoelasticity. A viscoelastic material has both the characteristics of a solid and fluid, and therefore is often analyzed by its solid and fluid components separately. The solid component of the material is modeled as a spring, where the elastic force the material exerts to resist deformation is proportional to the degree of strain, as in Hooke's Law ($F = kx$, where x is amount of elongation and k is the stiffness, or elasticity, of the material). The fluid component is modeled as a damper, where the viscous force exerted is proportional to the speed of deformation ($F = \eta U$, where U is the speed of elongation and η is the dampening effect, or viscosity, of the material). Hence, the elastic force will increase with more strain, and the viscous force will increase the faster you strain the material. Using these basic principles, two models have been proposed for the analysis of viscoelasticmaterials:

The Maxwell Model

Viscoelastic materials should be analyzed with the viscous and elastic elements in series, as shown below:
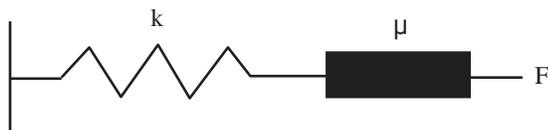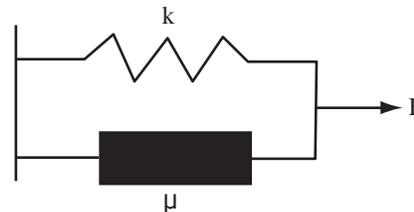

In this model, the stress provided by each force is the same, and the elongation of the material under constant stress is:
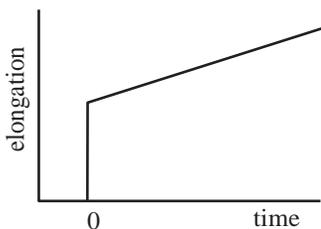

Note that the two component forces respond independently in two phases of time. Deformation of the elastic component occurs instantaneously, while the viscous component responds slowly over time.

The Voight Model

This model describes a viscoelastic material with the viscous and elastic components in parallel as shown below:

In this model, the strain provided by each force is the same, and the elongation of the material under constant stress is:
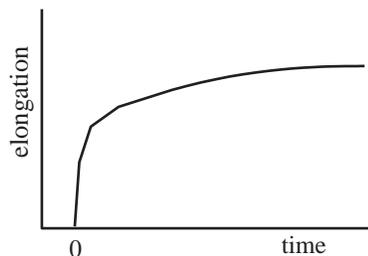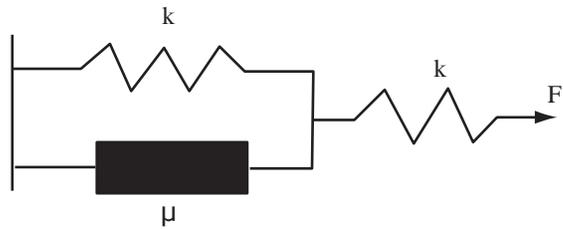

1. Why does the Voight model indicate an asymptotic limit of elongation during constant stretch over time while the Maxwell model does not?

   A. The two component forces in parallel are dissipated; this reduces the amount of stretch possible.
   B. The ability of the viscous component to stretch infinitely is limited by the elastic component.
   C. The ability of the elastic component to stretch infinitely is limited by the viscous component.
   D. The Voight model accounts for the potential of material failure under extreme strain.

2. Which of the following properties would always increase the Young's modulus of a viscoelastic material as described by either model?

   A.   increase k
   B.   increase μ
   C.   decrease k
   D.   decrease μ

3. If a constant force F_0 is applied to a material, which of the following information is sufficient to calculate the viscosity of the material?

   A.   original length of the material
   B.   time of elongation
   C.   speed of elongation
   D.   length of elongation

4. If a constant 25N force is applied to stretch a Maxwell material (k=5 N/m, μ=5 N·s/m), what is the work done in one second?

   A.   10 J
   B.   125 J
   C.   250 J
   D.   500 J

5. If a constant force F_0 is applied to stretch a material described by the Maxwell model, what would be the initial elongation value at t=0?

   A.   0
   B. F_0/k
   C. $F_0/(k+\mu)$
   D. $F_0/(k+\mu/t)$

6. Which of the following graphs best illustrate the elongation of a viscoelastic material as modeled by the diagram below?

k

k

F

μ

A.

elongation

0   time

B.

elongation

0   time

C.

elongation

0   time

D.

elongation

0   time

4

Passage II (Questions 7–12)

Coordination complexes are groups of ions that stay together as a unit even in solution. Coordination complexes of transition metals take a variety of forms and exhibit various colors and magnetic properties. This behavior is directly linked to the unique nature of bonding in coordination complexes. One energy model for coordination complexes is crystal field theory (CFT). According to CFT, the central metal ion is positively charged, while negatively charged ligands surround it. Therefore, the model treats bonding as though it were purely ionic. This model is especially useful for octahedral complexes because of the one-to-one correlation of axes to ligands: one of the six ligands occupies each half of each of the x, y and z axes. The interaction between ligands and the central metal ion cause a perturbation in the energies of the $3d$ orbitals of the transition metal; some of the orbitals (d_{z^2}, $d_{x^2-y^2}$) have larger repulsions, so their energies are raised by the bonding interaction, while other orbitals (d_{xy}, d_{xz}, d_{yz}) have smaller repulsions resulting in lowered energy levels. Depending upon the strength of the ligand, the crystal field splitting energy (called Δ_0) between the lower and higher energy levels may be large or small. A large Δ_0 leads to a complex that is *low spin*, while a small Δ_0 leads to a *high spin* complex.

Many coordination complexes have brilliant colors. These colors are the result of the promotion of an excited electron from a low-lying t_{2g} orbital to a higher e_g orbital. The magnitude of Δ_0 determines the frequency of light absorbed according to the following equation: $h\upsilon = \Delta_0$.

In addition to understanding the colors produced by coordination complexes, CFT is also useful in predicting whether a complex will have magnetic properties. A paramagnetic substance is one in which there are unpaired electrons, while in a diamagnetic substance, all electrons are paired.

The spectrochemical series gives the order of various ligands, from high spin to low spin complexes:

$$I^- < Br^- < Cl^- < F^- < OH^- < H_2O <:NCS^- < NH_3 < en < CO CN^-$$

high spin   low spin

7. A Zn^{2+} complex is colorless in aqueous solution because:

   A. all zinc complexes are colorless; zinc metal is silver in color, and the loss of two electrons makes the metal ion less colorful.
   B. the crystal field splitting energy is very large for a zinc complex; therefore, the transition between the low–and high-lying orbitals is great enough to be beyond the visible range in the electromagnetic spectrum.
   C. the crystal field splitting energy is very small for a zinc complex, so the transition between t_{2g} and eg orbitals is not great enough to produce a color.
   D. the e_g orbitals are filled for zinc complexes, making a promotion impossible.

8. As the bromide ions in $K_3[CrBr_6]$ are exchanged for CN^- ions, what happens to the color of the solution?

   A. Both bromide and cyanide are negatively charged ions, so the color of the solution will not change as the ions are exchanged.
   B. Since the complex is dissolved in water, the color will not change because all the ions stay in solution.
   C. The color will become more intense as the complex changes from high spin to low spin.
   D. The color will change from blue to red because the frequency of the transition will decrease as D0 decreases.

9. Will a complex of Mn^{2+} exhibit paramagnetic qualities?

   A. No, because all the electrons are paired in a manganese complex.
   B. Yes, because there are unpaired electrons in a manganese complex.
   C. Yes, because all the electrons are paired in a manganese complex.
   D. No, because there are unpaired electrons in a manganese complex.

10. As a Fe^{2+} complex shifts from high spin to low spin, how will its magnetic properties change?

   A. All iron compounds are paramagnetic, so a change from high to low spin will not affect the magnetic properties of an iron complex.

   B. The complex will lose its paramagnetic properties because the large crystal field splitting energy will force electrons to occupy the lower-lying t_{2g} orbitals.

   C. The complex will lose its paramagnetic properties because the small crystal field splitting energy of the low spin complex will force electrons to be paired in the e_g orbitals.

   D. The complex will become paramagnetic because a shift from high to low spin will raise the crystal field splitting energy, causing electrons to become unpaired.

11. How many electrons does it take to fill the d orbitals of a low-spin coordination complex?

   A. 10
   B. 6
   C. 5
   D. 3

12. An aqueous solution of $Mn(NO_3)_2$ has a faint color, while an equimolar solution of $K_4[Mn(CN)_6]$ is brightly colored. Will a solution of $K_4[MnCl_6]$ have a bright or faint color?

   A. The solution will be brightly colored because the complex has a similar structure to that of the brightly colored $K_4[Mn(CN)_6]$ solution.

   B. The solution will be faintly colored because the complex has a similar structure to that of the $Mn(NO_3)_2$ solution.

   C. The solution will be brightly colored because chloride ions tend to cause a strong color when coordinated with manganese ions.

   D. The solution will be faintly colored because chloride ions produce high spin coordination complexes.

Passage III (Questions 13–18)

A jet attempting to reach supersonic speed must break a "sound barrier". When the jet is flying at subsonic speed, the soundwaves it produces—represented by circles in Figure 1—travel faster than the jet.
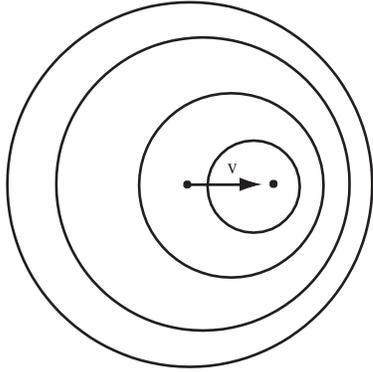
Figure 1

As the jet reaches the speed of sound, the sound waves emitted by the nose of the jet will pile up in front of it. This "sound barrier" is an energy barrier, which can only be broken through with the addition of extra thrust. Once supersonic, the speed of the jet is often given as a Mach number, which is the ratio of the jet's speed to the speed of sound in that medium. For example, a jet flying at a speed of 600 m/s may be at Mach 2.0 when flying at one height, but at Mach 2.1 as it gains altitude, although the speed of the jet remains constant.

Once a jet flies at supersonic speeds, the sound waves emitted by the jet pile up behind it. These waves overlap and constructively interfere with each other to form a single shock wave. When a shock wave hits a detector, it is perceived as a very loud "sonic boom." Additionally, since sound waves are emitted from the nose, wings, and back of the jet, the sonic boom is actually made up of multiple shock waves.

(Note: v_{sound} high in the atmosphere is about 300 m/s)

13. If a jet flying at Mach 3 high in the atmosphere attempts to fly around the Earth, about how long will it take to complete the trip? (Diameter of Earth = 1.28×10^4 km)

    A. 3.1 hours
    B. 12.4 hours
    C. 24.8 hours
    D. 37.2 hours

14. Which of the following is implied by the passage?

    A. The velocity of sound is constant in air.
    B. The frequency of sound decreases as it passes from one medium to another.
    C. Sound waves emitted by the nose of the jet have the same intensity as those emitted by the back.
    D. The density of air decreases as altitude increases.

15. The figure shown below best diagrams a jet moving at:
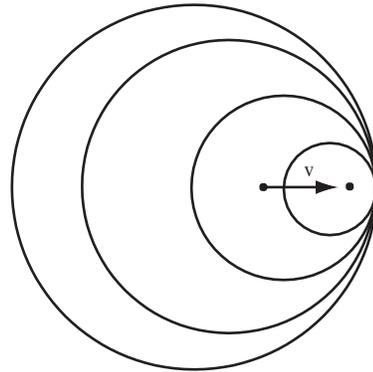
    A. subsonic speed.
    B. the speed of sound.
    C. supersonic speed.
    D. supersonic speed, then slowing to subsonic speed.

16. Two jets, at the same subsonic speed and emitting identical sound waves, start at the same position and fly away from a detector. Later, as one of the jets increases its speed, the beat frequency detected by the stationary detector:

    A. increases from an initial frequency of zero.
    B. decreases from an initial frequency of zero.
    C. increases from an initial non-zero frequency.
    D. decreases from an initial non-zero frequency.

17. At the exact time a supersonic jet is flying overhead and emitting sound waves, two people are swimming underwater in the ocean, while their friend is sunbathing on land. Which of the following must be true?

    A. All three people will hear the sound waves at the same time.
    B. All three people will hear the same frequency of sound waves.
    C. The swimmers will hear the sound waves before the sunbather hears them.
    D. The swimmers will hear the same wavelength of sound as the sunbather.

18. Suppose the pilot chair in a supersonic jet is constructed with a single large spring in its back to support the pilot. As the pilot lands his jet, he brings it from supersonic speed to rest at a constant acceleration, the force exerted by the spring is:

    A. inversely proportional to the mass of the pilot.
    B. inversely proportional to the constant of the spring.
    C. directly proportional to the time it takes to bring the jet to rest.
    D. directly proportional to original velocity of the jet.

Passage IV (Questions 19–24)

A student is studying carbonic acid, a weak diprotic acid. Since carbonic acid has two protons available for dissociation, two equilibria exist simultaneously in solution. The equilibria involved in the ionization of carbonic acid are shown in Reactions 1 and 2, along with their Ka values:

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$$

$$K_{a_1} = 4.3 \times 10^{-7}$$

Reaction 1

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq)$$
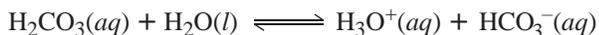
$$K_{a_2} = 4.8 \times 10^{-11}$$

Reaction 2

Experiment 1

The student performs a titration to determine the equivalence points of carbonic acid. The initial concentration of carbonic acid was 0.034 M. This was titrated with 0.034 M NaOH.

Experiment 2

The indicator bromothymol blue is sometimes used to determine when a solution changes from basic to acidic. In basic solutions, it is blue-violet, while in acidic solutions it is colorless. A few drops of bromothymol blue are added to a dilute solution of aqueous potassium hydroxide (KOH). Then, a solid chunk of dry ice is added, and the solution is monitored for any color changes.

19. The K_{a_2} value for carbonic acid smaller than the K_{a_1} value because once the first hydrogen ion is removed from carbonic acid, the:

   A. negative charge on the bicarbonate ion causes the second hydrogen ion to be more tightly held.
   B. concentration of bicarbonate ion decreases, so there are fewer ions from which to dissociate a hydrogen ion.
   C. molecular geometry of the bicarbonate ion changes, causing the negative charge to be more tightly held.
   D. bicarbonate ion forms hydrogen bonds between oxygen lone pairs and the hydrogen atoms of neighboring bicarbonate ions.

20. What is the molecular geometry of the carbonate ion?

   A. tetrahedral
   B. bent
   C. trigonal pyramidal
   D. trigonal planar

21. In Experiment 2, how does the color of the solution change when the dry ice is added?

   A. The solution started out blue and was not changed by the addition of dry ice because dry ice sublimes; the carbon dioxide was released from the solution as a gas.
   B. The solution started out blue and became colorless upon addition of dry ice because the CO_2 dissolved to form carbonic acid.
   C. The solution started out clear and turned blue upon addition of dry ice because the CO_2 dissolved, forming carbonic acid that neutralized the potassium hydroxide.
   D. The solution started out clear and was unaffected by the addition of the dry ice.

22. Which of the following quantities are equal?

   A. $K_{a_1}[HCO_3^-]$, $K_{a_2}[CO_3^{2-}]$

   B. $\dfrac{[H_3O^+][HCO_3^-]}{[H_2CO_3]}$, $\dfrac{[H_3O^+][CO_3^{2-}]}{[HCO_3^-]}$

   C. $\dfrac{K_{a_2}[H_2CO_3]}{[HCO_3^-]}$, $\dfrac{K_{a_1}[HCO_3^-]}{[CO_3^{2-}]}$

   D. $\dfrac{K_{a_1}[H_2CO_3]}{[HCO_3^-]}$, $\dfrac{K_{a_2}[HCO_3^-]}{[CO_3^{2-}]}$

23. What is the equilibrium concentration of bicarbonate ion prior to addition of sodium hydroxide in Experiment 1?

   A. $4.8 \times 10^{-11}\,M$
   B. $4.3 \times 10^{-7}\,M$
   C. $1.2 \times 10^{-4}\,M$
   D. $3.4 \times 10^{-2}\,M$

24. How many major resonance structures does the carbonate ion have?

   A. 2
   B. 3
   C. 4
   D. None; the carbonate ion has just one major structure.

25. A beam of light refracts as it passes from air into water (n = 4/3). What is the speed of the refracted light beam?

   A. 2.00×10^8 m/s
   B. 2.23×10^8 m/s
   C. 3.00×10^8 m/s
   D. 4.00×10^8 m/s

26. Which of the following is true of a galvanic cell?

   A. ΔG is negative and the half-reactions are non-spontaneous.
   B. ΔG is negative and the half-reactions are spontaneous.
   C. ΔG is positive and the half-reactions are spontaneous.
   D. ΔG is positive and the half-reactions are non-spontaneous.

27. Which of the following describes the entropy change for the sublimation of carbon dioxide $CO_2(s) \rightarrow CO_2(g)$?

   A. $\Delta S < 0$
   B. $\Delta S = 0$
   C. $\Delta S > 0$
   D. The value for the entropy change depends on temperature.

28. If two moles of an ideal gas absorb 900 J of heat energy while they perform 600 J of work on their surroundings, what is the change in the temperature of the gas?

   A. 100 K
   B. 150 K
   C. 200 K
   D. 300 K

A child pulls two boxes across the floor:
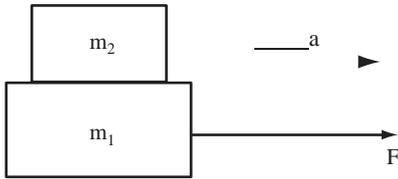
Figure 1

The boxes are both at rest, the less massive box atop the more massive one, when the child begins pulling horizontally on the rope with force F. The rope, attached to the lower box, pulls the boxes over the floor without friction with acceleration a.

The less massive box is pulled along with the heavier box because of the frictional contact force C that exists between the two. The coefficient of static friction between the two boxes is m, and the magnitude of C is:

$$C = \frac{m_2 F}{m_1 + m_2}$$

29. Which of the following forces does work on the box with mass m_1?

    I. applied force F

    II. the weight of the box with mass m_2

    III. contact force C

A. I only

B. I and II only

C. I and III only

D. II and III only

30. What would have to occur in order for the top box to begin to slide?

A. The contact force would have to be larger than $\mu m_2 g$.

B. The contact force would have to be larger than $\mu m_1 g$.

C. The contact force would have to be larger than the applied force, F.

D. The top box would not begin to slide under any conditions.

31. Which of the following would be the minimum amount of information needed to determine the speed of the boxes at a given time t?

A. the mass of both boxes and the magnitude of the applied force

B. the magnitude of the applied force and the acceleration due to gravity

C. the mass of both boxes

D. the acceleration of the boxes

32. The applied force F is increased until the top box begins to slide. At that moment, what is true about the acceleration of each box?

A. The acceleration of the bottom box decreases and the acceleration of the top box decreases.

B. The acceleration of the bottom box decreases and the acceleration of the top box increases.

C. The acceleration of the bottom box increases and the acceleration of the top box decreases.

D. The acceleration of the bottom box increases and the acceleration of the top box increases.

33. If m_1: $m_2 = 3$:1, how does the acceleration of the system change if the top box is removed?

    A.   The acceleration decreases by a factor of 3/4.

    B.   The acceleration stays the same.

    C.   The acceleration increases by a factor of 5/4.

    D.   The acceleration increases by a factor of 4/3.

Passage VI (Questions 34–39)

Titanium (atomic number 22) has long been prized for its strength, its low density and its resistance to corrosion. Both elemental titanium and compounds containing the metal are widely used in medical products, in skywriting chemicals and in thin films for lenses and ceramics. Medical products companies also use titanium in artificial hip replacements for human patients. This metal, which is effectively inert, is ideal for medical use, as even continuous contact with bodily fluids leaves it unchanged. Along with its resistance to corrosion, the low density of titanium makes its use in the body less burdensome than denser metals. One way titanium resists corrosion is to form a thin layer, or skin, of titanium dioxide. Titanium dioxide is a stable white compound which is formed by the following reaction:

$$TiCl_4(l) + 2H_2O(l) \rightarrow TiO_2(s) + 4HCl(s)$$
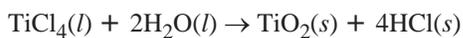
Reaction 1

This reaction is also useful for skywriting because moisture from the air hydrolyzes the titanium tetrachloride when it is released from an isolated container. Some thermodynamic data for this reaction are shown below:

$$\Delta G = -202.74 \text{ kJ/mol}$$

$$\Delta S = -115.79 \text{ J/mol·K}$$

Titanium thin films are used in microelectronics and as optical coatings on lenses. One of these coatings is formed by mixing gaseous hydrogen with titanium tetrabromide according to the following reaction:

$$TiBr_4(g) + 2H_2(g) \rightarrow Ti(s) + 4HBr(g)$$
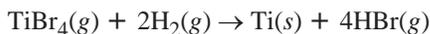
Reaction 2

The solid titanium is deposited on the surface to be coated in a layer that can be as thin as one atom. The coated substance can then be removed from the gaseous environment and used in air.

34. Is Reaction 1 spontaneous?
    A. Yes, because ΔS is negative for the reaction.
    B. Yes, because ΔG is negative for the reaction.
    C. No, because ΔG is negative for the reaction.
    D. No, because ΔS is negative for the reaction.

35. The oxidation state of titanium in TiO2 is:
    A. –2
    B. +2
    C. +4
    D. +6

36. Reaction 1 is best described as:
    A. an oxidation-reduction reaction in which Ti is reduced.
    B. an oxidation-reduction reaction in which Ti is oxidized.
    C. an exchange reaction.
    D. an hydrolysis reaction.

37. Which of the following is the electronic configuration of Ti^{4+} in titanium tetrachloride?
    A. [Ar]
    B. $[Ar]4s^13d^3$
    C. $[Ar]4s^23d^2$
    D. $[Ar]3d^4$

38. Based on the information in the passage, which of the following reactions is least likely to occur?

   A. $TiO_2(s) + O_2(g) \rightarrow TiO_4(g)$
   B. $TiCl_4(g) + 2\,H_2(g) \rightarrow Ti(s) + 4\,HCl(aq)$
   C. $TiCl_4(g) + 2\,Mg(l) \rightarrow Ti(s) + 2\,MgCl_2(s)$
   D. $TiBr_4(s) + 2\,H_2O(l) \rightarrow TiO_2(s) + 4\,HCl(aq)$

39. Which of the following would inhibit the production of titanium dioxide according to Reaction 1?

   I. performing the reaction in a humid area
   II. performing the reaction in the presence of a base
   III. performing the reaction in the presence of hydrogen gas

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

Passage VII (Questions 40–44)

On a sunny day, bands of color can be seen atop liquid pools of oil and on the surface of soap bubbles. This occurs because the differently colored beams of light that reflect off both the top and the bottom of a thin film undergo wave interference. When you see a bright band of color, that wavelength of light has undergone constructive interference.
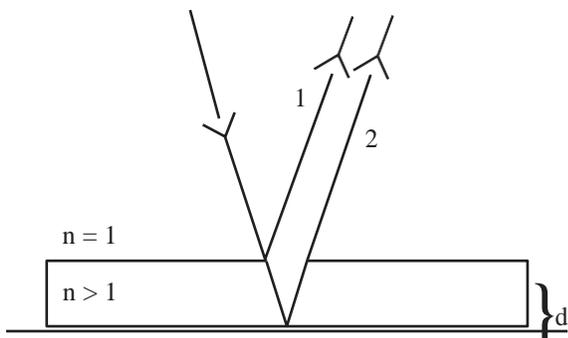
Figure 1

Figure 1 demonstrates what happens when light strikes a thin film. The light comes down from the air (n = 1) and strikes the surface of the thin film. Ray 1 represents the light that reflects off of the surface of the film. Because the film has a higher index of refraction than air, ray 1 is phase-shifted by a half wavelength. This is similar to what happens to when a mechanical wave is sent down a string towards a fixed end: the wave that is reflected back is upside down. Ray 2 passes into the film, reflecting off the bottom surface of the film. This reflected ray is also phase-shifted by a half wavelength, since the material on which the film rests has a higher index of refraction than the film.

Ray 2 covers a longer distance than ray 1; for light that comes in nearly vertically, this path difference can be approximated as twice the depth d of the film. If the difference in the path lengths of the two rays is a multiple of the wavelength, then constructive interference occurs:

$$2d = mh_n,$$

Equation 1

where h_n is the wavelength the light inside the film, and $m = 1, 2, 3, ...$

A student performs experiments to measure the thickness of various oil films by shining white light down on the films, and observing which colors form bright patterns (or fringes) on the surface.

40. When looking straight down on a thin film (n = 1.5), an observer can see two bright bands of light, one with a wavelength of 400 nm, and the other with wavelength 600 nm. Which of the following could be the depth of the film?

   A. 300 nm
   B. 400 nm
   C. 500 nm
   D. 600 nm

41. Why does the passage make the assumption that the light rays enter and leave the film close to the vertical?

   A. Because Snell's Law only works for small angles.
   B. If the rays were to come in at a shallower angle, the formula relating the film depth to the wavelengths that interfere constructively would need to be dependent on that angle.
   C. Light rays that enter the film at a shallower angle won't go through a half-wavelength phase shift when reflected from the boundary at the bottom of the film.
   D. No light rays can enter the film from a shallow angle.

42. In two separate experiments, monochromatic beams of red and violet light are shone upon a thin film (n = 1.3). Which color of light is deflected the farthest from its original path upon entering the film?

   A. Red, because red light has a longer wavelength than violet light.
   B. Violet, because violet light has a smaller wavelength than red light.
   C. Both rays are deflected by the same amount, because the angle of refraction doesn't depend on the wavelength of the light.
   D. Both rays are deflected by the same amount, because the index of refraction of the film is greater than the index of refraction of air.

15

43. Would Equation 1, which provides the relationship between the film thickness and the wavelengths of light which constructively interfere, apply to light reflecting off of the surface of a soap bubble suspended in the air?

  A. Yes, as the behavior of rays 1 and 2 would be the same.
  B. Yes, as both rays 1 and 2 would no longer be phase-shifted during reflection.
  C. No, as ray 1 will no longer be phase-shifted.
  D. No, as ray 2 will no longer be phase-shifted.

44. When white light is shined upon a thin film of depth 900 nm, which of the following are the wavelengths of the two visible fringes?

  A. 450 nm, 600 nm
  B. 450 nm, 900 nm
  C. 600 nm, 900 nm
  D. 300 nm, 450 nm

Passage VIII (Questions 45–50)

Fireworks use a handful of simple compounds to produce an array of dazzling colors. A standard formula requires an oxidizer, a fuel, and metal salts for special effects. The oxidizer and fuel react, producing the noise and flashes commonly associated with fireworks. The purpose of the oxidizer is to provide a high concentration of oxygen within the firework. A typical oxidizer is potassium perchlorate ($KClO_4$), which releases all four of its oxygen atoms into the atmosphere during combustion. The fuel, often sulfur or carbon, binds to the oxygen and produces an extremely hot gas. Metals such as aluminum or magnesium, can be used as a fuel; using metals increases the rate at which the oxygen burns while enhancing the brightness of the other colors. Furthermore, using aluminum or magnesium granules will create sparks of light (as is done in sparklers).

When metal salts are included in the mixture, the heat released from the oxidizer and fuel is sufficient to promote the outer shell electrons into an excited orbital, thereby creating a brilliant display of color. Elements used for color in fireworks are listed below in Table 1.

Desired Color	Element Used
Red	Strontium
Green	Barium
Yellow	Sodium
White	Magnesium, Aluminum
Purple	Potassium

Table 1

Sodium is a powerful emitter, producing so much yellow light that other colors are generally washed out. On the other hand, the use of magnesium or aluminum will enhance the brightness of other colors. Purple is a difficult color to produce because potassium salts are often contaminated with sodium, which washes out any purple produced. In order to produce a good purple, a very pure form of the potassium salt must be used.

Another component of fireworks is the binding material. The binding material, such as dextrin, is used to hold the metal salts together in a ball, or star. These stars may then be ignited by means of a fuse. Ignition liquefies the mixture, prompting the fuel and oxidizer to react, generating large amounts of heat and, consequently, brilliant displays of color and light.

45. What can be stated about the light emitted by potassium as compared to sodium? Potassium emits light with a:

   A. longer wavelength and higher energy than sodium.
   B. shorter wavelength and higher energy than sodium.
   C. longer wavelength and lower energy than sodium.
   D. shorter wavelength and lower energy than sodium.

46. Elements in the same group are known to have similar chemical properties. Would sodium perchlorate be a good oxidizer for a red firework?

   A. No, sodium is less reactive than potassium. Consequently, sodium perchlorate will not produce enough energy.
   B. Yes, sodium is more reactive than potassium. Consequently, sodium perchlorate will produce enough energy to create the red color.
   C. No, sodium will create its own color (yellow), thereby washing out the red color.
   D. Yes, sodium will create its own color (yellow), thereby enhancing the red color.

47. What is the balanced heat generating reaction in a firework when aluminum and potassium perchlorate are used?

   A. $Al + KClO_4 \rightarrow Al_2O_3 + KCl$
   B. $Al + KClO_4 \rightarrow AlO_2 + KCl$
   C. $8Al + 3KClO_4 \rightarrow 4Al_2O_3 + 3KCl$
   D. $Al + KClO_4 \rightarrow 2AlO_2 + KCl$

48. Why don't the oxidizer and fuel react while being stored?

   A. The oxidizer and fuel are solid; therefore, they do not mix and cannot react.
   B. They do react and cannot be stored.
   C. They are physically separated in the firework by dextrin.
   D. An inhibitor such as dextrin is added that prevents the oxidizer and fuel from reacting until the firework is lit.

49. Why do strontium salts produce a red color while barium salts produce a green color?

   A. The energy difference between a 5s and a 5d orbital is more than between a 6s and a 6d orbital.
   B. The energy difference between a 5s and a 5d orbital is less than between a 6s and a 6d orbital.
   C. The energy difference between a 5s and a 6s orbital is more than between a 6s and a 7s orbital.
   D. The energy difference between a 5s and a 6s orbital is less than between a 6s and a 7s orbital.

50. Why is lighting the fuse of a firework necessary to generate a reaction between the fuel and the oxidizer?

   A. The heat from the fuse melts the dextrin separating the fuel and oxidizer, allowing the two to mix.
   B. The reaction is endothermic, and therefore requires heat from the fuse in order to take place
   C. The heat from the fuse melts the oxidizer and fuel, allowing them to mix completely and begin reacting.
   D. The heat from the fuse causes the oxidizer to release its oxygen, which must take place before the fuel can react with the oxidizer.

51. A 0.2-kg, 3-meter wire contains a 1-A current:
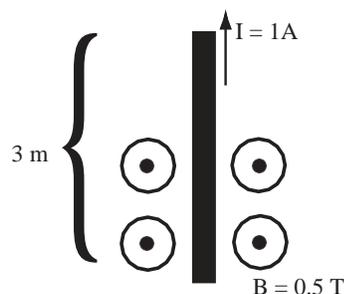
   If a 0.5-T magnetic field is applied out of the page, what is the ensuing force on the wire?

   A. 1.5 N to the left
   B. 1.5 N to the right
   C. 7.5 N to the left
   D. 7.5 N to the right

52. The magnetic quantum number is a measure of which of the following?

   A. approximate radial size of an electron cloud
   B. number of valence electrons about a nucleus
   C. number of protons in the nucleus of an atom
   D. approximate shape of an electron cloud

53. A 20-cm spring is hung vertically, and a 2-kg mass is hung from the end. If the spring stretches 6 cm due to the weight of the mass, then what is the spring's force constant?

   A. 0.75 N/m
   B. 3.33 N/m
   C. 75.4 N/m
   D. 333 N/m

Questions 51 through 55 are **NOT** based on a descriptive passage.

GO ON TO THE NEXT PAGE.

54. By how much does the oxidation number of chromium in $Cr_2O_7^{2-}$ differ from that of Cr^{3+}?

   A. 1
   B. 2.5
   C. 3
   D. 4

55. Two trumpeters each attempt to produce identically pitched note. However, the frequency from one trumpet is 880 Hz, while the frequency from the other is 883 Hz. How much time passes between the beats generated by these two sound waves?

   A. 0.33 s
   B. 1.00 s
   C. 1.50 s
   D. 3.00 s

56. Which of the following compounds contains an atom with an expanded octet?

   A. NH_4^+
   B. BF_3
   C. $POCl_3$
   D. CCl_4

Passage IX (Questions 57–62)

Electromagnetic waves are caused by accelerating electric charges. The higher the acceleration of the charges, the greater the rate of emission of radiation. Most forms of electromagnetic communication are achieved by using an antenna to produce EM waves. A simple antenna is shown in Figure 1:
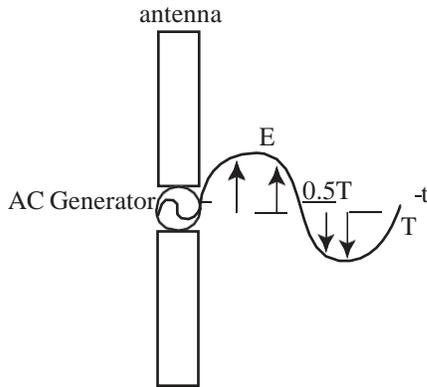
Figure 1

The AC generator creates an oscillating current in the two metal rods. The field causes charges to oscillate up and down the rods. This motion of charges generates the electromagnetic wave that leaves the antenna. The figure shows only how the electric field leaving the antenna varies with time; the magnetic field emitted is not shown. T represents the period of oscillation of the emitted electric field. In reality, the EM wave propagates in all 360º degrees about the antenna.

57. In Figure 1, what direction do the emitted magnetic fields flow?

A. away from the antenna, just like the electric fields

B. in horizontal concentric circles around the antenna

C. in vertical concentric circles, in the plane of the antenna

D. The magnetic field flows in random directions.

58. If, at a particular time, the electric field E near the antenna is pointing upwards (along the antenna), in what direction is the force on a stationary electron inside that field?

A. upward

B. downward

C. toward the antenna

D. away from the antenna

59. If the wavelength of the EM wave propagating from the antenna is 5 m, what is the period of oscillation?

A. 1.7×10^{-8} s

B. 1.1×10^{-7} s

C. 3.8×10^{-6} s

D. 6.0×10^{7} s

60. Which of the following would increase the intensity of the EM wave emitted from the antenna?

A. increasing the frequency of the AC generator

B. increasing the period of the current in the antenna

C. increasing the length of the two rods

D. increasing the maximum voltage of the AC generator

61. If the electrical potential across a conducting metal rod of length l is V, how much work is done in moving a charge of +ne across the length of the rod, from low to high potential?

A. $+neV$

B. $-neV$

C. $+neVl$

D. $-neVl$

62. A strong radio antenna broadcasts with a power of 50 kW. How much energy is broadcast in 1 minute?

A. 833 J

B. 50 kJ

C. 300 kJ

D. 3 MJ

Passage X (Questions 63–67)

Modern automobiles are equipped with a safety feature called airbags. These are pillows of gas that inflate when the automobile is involved in a violent collision. The bag is deployed from the steering wheel or dashboard, protecting the driver and passengers from the impact of the crash.

A cylinder is installed in the steering column of the car; it contains sodium azide pellets and an ignition device. When the car experiences a sudden jolt from a collision, the ignition device is activated, initiating the following decomposition reaction:

$$2 \text{ NaN}_3(s) \rightarrow 2\text{Na}(l) + 3\text{N}_2(g)$$
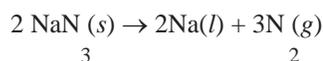
Reaction 1

In order to consume dangerous elemental sodium and to help drive the reaction, iron oxide is also added to the reaction cylinder. This helps inflate the bag with maximum speed and produces less harmful compounds. The reaction between sodium and iron oxide is shown below:

$$6\text{Na}(l)\ \text{Fe}_2\text{O}_3(s) \rightarrow 3\text{Na}_2\text{O}(s) + 2\text{Fe}(s)$$
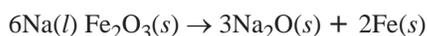
Reaction 2

The energy profile for Reaction 2 is shown in Figure 1.
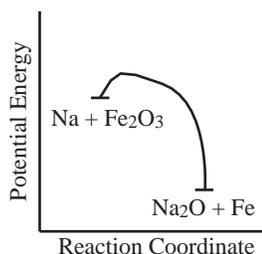
Figure 1

In an experiment designed to simulate the process of airbag activation, a chemist places 106 grams of sodium azide and 35 grams of iron oxide in a reaction chamber. The chamber is fitted with a nozzle, to which is attached a balloon. The balloon has a maximum capacity of 100 liters.

---

63. Will Reaction 2 go to completion?

A. Yes, because there are equimolar amounts of Na and Fe_2O_3.

B. Yes, because Na and Fe_2O_3 are in the correct molar ratio for all reactants to be consumed.

C. No, because there is excess sodium.

D. No, because there is excess iron oxide.

64. What is the root-mean-square speed of the gaseous nitrogen molecules in the balloon?

A. $\dfrac{1}{3}\left\{\dfrac{RT}{10^{-3}}\right.$

B. $\left\{\dfrac{3}{28 \times 10^{-3}}RT\right.$

C. $\dfrac{1}{2}\left\{\dfrac{RT}{10^{-3}}\right.$

D. $\left\{\dfrac{3}{14 \times 10^{-3}}RT\right.$

65. What will happen to the volume of the balloon if the experiment is performed at an elevation of 14,000 feet?

A. The volume will be unchanged because the automobile airbag was designed to work at all altitudes.

B. The volume will be greater because the pressure is greater and the temperature is lower at high altitudes.

C. The volume will be lower because the pressure is greater and the temperature is greater at high altitudes.

D. The volume will be slightly greater because both the pressure and the temperature are lower at high altitudes.

66. A catalyst is added to the reaction chamber. Which of the following could be the plot of the reaction coordinate?

A.

Potential Energy vs. Reaction Coordinate

Na$_2$O + Fe

Na + Fe$_2$O$_3$

Reaction Coordinate

B.

Potential Energy vs. Reaction Coordinate

Na + Fe$_2$O$_3$ Na$_2$O + Fe

Reaction Coordinate

C.

Potential Energy vs. Reaction Coordinate

Na + Fe$_2$O$_3$

Na$_2$O + Fe

Reaction Coordinate

D.

Potential Energy vs. Reaction Coordinate

Na + Fe$_2$O$_3$

Na$_2$O + Fe

Reaction Coordinate
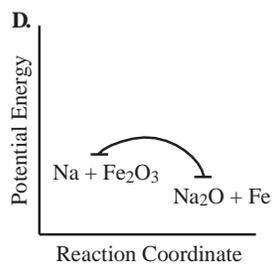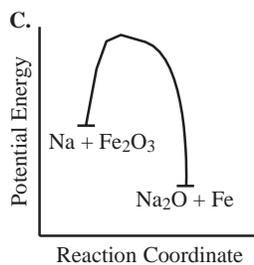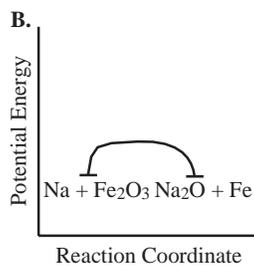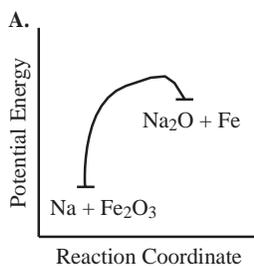
67. What is the change in oxidation state of iron in Reaction 2?

A. The oxidation number of iron changes from +3 in the reactant to 0 in the product.

B. The oxidation number of iron changes from +2 in the reactant to 0 in the product.

C. The oxidation number of iron changes from +3 in the reactant to +2 in the product.

D. The oxidation number of iron changes from 0 in the reactant to +2 in the product.

Passage XI (Questions 68–72)

Students designed an experiment to measure the coefficient of kinetic friction between wooden disks and different types of surface.

Experiment 1

Identical, 0.5-kg wooden disks were sent sliding across a surface at different initial speeds. Students measured the elapsed time between when the disks are pushed and when they slide to a stop. Using this data, they are able to calculate *m*, the coefficient of kinetic friction between the surface and the disks.

Initial Speed (m/s)	Stopping Time (s)
2.0	0.6
4.0	1.2
6.0	1.7
10.0	2.9

From this experiment, the students determined that $\mu = 0.35$.

Experiment 2

Identical, 0.5-kg wooden disks were sent sliding over three different types of surface. Each disk started at 4 m/s. The stopping time was measured for disks on each surface.

Surface	Stopping Time (s)
A	1.02
B	1.36
C	2.04

68. In Experiment 1, how much work is done by friction in stopping the disk that started at 10 m/s?

- **A.** 2.5 J
- **B.** 10 J
- **C.** 25 J
- **D.** 50 J

69. Assuming a uniform deceleration, what was the deceleration for the disk that started at 4 m/s in Experiment 1?

- **A.** 1.0 m/s^2
- **B.** 1.7 m/s^2
- **C.** 3.3 m/s^2
- **D.** 4.0 m/s^2

70. Which of the following surfaces has the largest value of μ?

- **A.** the surface in Experiment 1
- **B.** surface A
- **C.** surface B
- **D.** surface C

71. What effect does the mass of the disk have on the deceleration?

- **A.** The higher the mass, the higher the deceleration.
- **B.** The higher the mass, the lower the deceleration.
- **C.** The mass has little to no effect on the deceleration.
- **D.** The answer depends on the type of material used.

72. In Experiment 2, approximately how far did the disk travel on surface A?

- **A.** 0.5 m
- **B.** 1.0 m
- **C.** 2.0 m
- **D.** 4.0 m

73. A closed system is one in which:

    A. energy and matter are kept separate from the surroundings.

    B. matter is kept separate from the surroundings, but energy can be exchanged.

    C. energy is kept separate from the surroundings, but matter can be exchanged.

    D. both energy and matter can be exchanged with the surroundings.

74. How much extra pressure is exerted on an object with a 4 cubic centimeter volume if it is pulled down from the surface of a fluid ($p = 1.2$ g/cm^3) to a depth of 2 m?

    A. 4.70×10^{-2} Pa

    B. 2.35×10^{1} Pa

    C. 1.18×10^{4} Pa

    D. 2.35×10^{4} Pa

75. All of the following affect the solubility of a substance EXCEPT:

    A. the quantity of solute.

    B. the properties of the solvent.

    C. the temperature of the solution.

    D. the addition of other substances to the solution.

76. How fast does a 100-kg projectile have to leave a gun fired vertically if it is to reach a height of 20 meters?

    A. 1.99 m/s

    B. 9.8 m/s

    C. 14.1 m/s

    D. 19.9 m/s

77. A chemist has a sample of ice at 0ºC. If she holds it over a flame momentarily, what will happen to the ice?

    A. All of the ice will melt, because ice melts at 0ºC.

    B. All of the ice will melt, and the temperature will increase slightly.

    C. Some of the ice will melt as the temperature increases slightly.

    D. Some of the ice will melt, but the temperature will remain the same.

STOP. IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK. YOU MAY GO BACK TO ANY QUESTION IN THIS SECTION ONLY.

Verbal Reasoning

Time: 85 Minutes
Questions 78–137

VERBAL REASONING

DIRECTIONS: There are nine passages in the Verbal Reasoning test. Each passage is followed by several questions. After reading a passage, select the best answer to each question. If you are not certain of an answer, eliminate the alternatives that you know to be incorrect and then select an answer from the remaining alternatives. Indicate your selection by blackening the corresponding oval on your answer document.

Passage I (Questions 78–83)

The interaction of atmospheric and oceanic currents plays a major role in determining climate. Scientists are increasingly concerned that what might appear to be a minor ecological change could cause fluctuations that
5 would greatly change our climate. The ocean's thermohaline circulation directs the flow of the deep ocean and is intricately linked with major climate patterns. Differences in water density drive the thermohaline, or abyssal, circulation. The salinity and temperature of water affect its den-
10 sity. Saltier, colder water sinks in parts of the ocean and warmer, fresher water upwells in other areas. Dense, deep water moves slowly through the oceans. Oceanographers studying the disruption or cessation of the creation of oceanic deep water have found that variations in circula-
15 tion patterns could have a damaging effect on climate. The creation and sinking of deep water takes place in only a few areas of the world: the Labrador Sea, the Greenland and Norwegian Seas, and parts of the Southern Ocean off the Antarctic coast.

20 There are interconnected factors causing waters in the North Atlantic to sink. When the atmosphere absorbs heat from northern Atlantic waters, the water becomes cooler and thus density increases. The position of mountain ranges in relation to prevailing wind patterns increases the
25 rate of surface evaporation, increasing salinity. In fact, the Atlantic loses more water from evaporation than it gains from continental runoff, ice melt, and precipitation combined. Of all surface waters of high-latitude, the Atlantic's waters are the saltiest. The generation of this cold, dense
30 water (North Atlantic Deep Water) is crucial for keeping the thermohaline circulation flowing. In the Southern Ocean deep water is formed when maximum thermal density is reached, encouraged by seasonal ice growth and the influx of salt to underlying waters provided by this ice
35 growth. These southern waters, the densest in the ocean, cascade off the continental shelf. The rate of deep-water formation is about equal between the northern Atlantic and the Southern Ocean, and approximately one-one thousandth of the volume of all the deep water descends annu-
40 ally. For thermohaline circulation to continue, the generation of deep water must counterbalance the loss of density that occurs when colder waters mix with warmer at the ocean's main thermocline. The thermocline provides a strong barrier to mixing, but tides and wind induce the
45 slow mixing of these waters. As the density of deep water is decreased, this differential creates new deep water.

There are many possibilities for thermohaline disruption in the North Atlantic. If the salt-heavy surface waters become diluted from an influx of freshwater from melting
50 ice sheets, from an increase in precipitation, or from the influx of warm waters from the south, the waters may not achieve the density necessary to sink. In addition, if the winds blowing across the ocean's surface do not initiate enough evaporation to increase salinity, sinking will not
55 occur. A drop in the salinity of the outgoing North Atlantic Deep Water of only 0.32 grams a liter would mean that the waters would need to be cooled an additional 1.4 degrees Celsius. Assuming that this temperature difference could be achieved, the global salt budget would still be disrupted.
60 Theoretically, the flow of ocean waters would have to double for the salinity differential to be corrected. The chances are high that a slight shift in the salt-heat balance could trigger an instability that might reorganize the global circulation system and possibly disrupt the world's climate in
65 ways difficult to imagine.

78. It can be inferred from the passage that a decrease in the prevailing winds in the Northern Hemisphere would cause which of the following?

  A. an increase in evaporation rates in the northern Atlantic

  B. a decrease in evaporation rates in the northern Atlantic

  C. no change in evaporation rates in the northern Atlantic

  D. an increase in continental runoff and precipitation

79. The author discusses a hypothetical drop in the salinity of North Atlantic Deep Water (line 55) in order to:

  A. illustrate an interesting phenomenon.

  B. emphasize how minor changes in the ocean could have a major influence on climate.

  C. highlight the importance of continental run-off in increasing the ocean's salinity.

  D. describe atmospheric conditions in the North Atlantic.

80. It can be inferred from the passage that scientific analysis of which of the following would be most relevant to questions concerning the possibility of future climate change?

  A. the cascade of waters off the continental shelf

  B. precipitation totals for the North Atlantic

  C. the ways anatomically modern humans dealt with climate change

  D. how changes in the heat-salt balance of the ocean could cause a reorganization of the thermohaline circulation

81. According to the passage, all of the following are factors that influence the density of North Atlantic waters EXCEPT:

  A. prevailing wind patterns.

  B. influx of warm waters from the north.

  C. loss of heat to the atmosphere.

  D. continental runoff.

82. Based on the information provided in the passage, the author could be most reasonably expected to agree that:

  A. oceanographers should devote their research efforts solely on the creation of deep water in the Southern Ocean.

  B. increased tidal action could lead to less mixing of the thermocline.

  C. thermohaline circulation is a secondary issue in the role of climate change.

  D. decreased density of the North Atlantic Deep Water poses a threat to thermohaline circulation and world climate.

83. The author mentions the high salinity of Atlantic waters (line 29) in order to:

  A. stress the importance of the atmosphere's absorption of heat.

  B. highlight the importance of the Atlantic's salinity in thermohaline circulation.

  C. call attention to deficits in the global salt budget.

  D. discuss the factors involved in wind patterns and their effect on evaporation rates.

Passage II (Questions 84–90)

National science standards are beginning to be set for school curricula around the country in an effort to ensure that graduating students have been taught certain concepts and possess an established minimum of knowledge in the
5 sciences. Curriculum guidelines are extremely important, particularly in science classrooms, yet there are many obstacles to establishing these guidelines on a federal or even local level in the United States. A major issue to contend with as national science standards are instituted is
10 whether the nation's science teachers are qualified and competent enough to teach at a level that would meet the new requirements.

Because standards for the teaching of science in high schools are so important and their implementation is
15 indeed inevitable, it is essential that science teachers gain the knowledge of content and methods necessary to teach effectively before attempts are made to set guidelines for what has to be taught. Although national science standards may be easily put in place in many school systems, their
20 presence does not guarantee their use. Many schools do not have the laboratory equipment, for example, to run labs or demonstrate necessary lab concepts; and, they do not have the means to acquire current textbooks to supplement classroom science instruction.

25 It appears that a large number of the science teachers in high schools around the country have neither an adequate knowledge of science nor the skills necessary to impart that knowledge to the children they teach. Because of the importance of national standards, those developing the
30 standards must focus on how to ensure quality teaching in the classroom. All of the national science standards in the world do no good if science teachers do not understand the content of their subject area or do not have appropriate teaching methods at their disposal. In what ways can we
35 make our nation's science teachers better? What kinds of incentives would help? Where do graduate schools of education and other means of continuing education fit in to ensure a high level of science teaching in schools?

First, it is necessary that science teachers develop a 40 large enough knowledge base so that they have a foundation upon which to build throughout their teaching experience. It has been suggested that those teachers with an expert knowledge of their subject area have a much easier time acquiring new knowledge and looking at old information in new ways. Many science teachers currently
45 avoid teaching certain material because they do not know enough about it or do not know how to teach it in a way that would enable their students to grasp it.

Second, higher beginning salaries and higher salaries for veteran teachers would help attract new, young science
50 teachers and retain older, more experienced ones. Many would-be science teachers are diverted into the more lucrative fields of medicine, biotechnology, or pharmaceuticals, and there is the risk that the population of established science teachers will age rapidly without hope for competent
55 replacement.

Third, teacher training and continuing education must be a requisite aspect of teaching in our nation's schools. Doctors, lawyers, and businessmen across the country are required to take recertification tests or to accumulate con-
60 tinuing education credits to maintain their status, yet teachers are not. In the absence of formal coursework, or even as a supplement to it, science teachers should be required to demonstrate that they are periodically reading current journals or magazines dealing with topics in science, much
65 in the same way doctors are asked to keep current in their fields of expertise. If these changes are not instituted in the way that our teachers are trained, national standards alone can only increase frustration and failure in our nation's classrooms.

84. By comparing teachers to doctors and lawyers, the author is trying to show that:

A. teachers should be on the same pay scale as doctors and lawyers.

B. teachers should be held to the same high standards as other professions require.

C. teachers deserve the same level of respect that doctors and lawyers have in society.

D. teachers need to stay current with new research and ideas in all scientific fields.

85. Suppose that national science standards were piloted in the classrooms of several teachers holding advanced degrees in their fields, and students in those classes showed great improvements in test scores relative to previous years with the *same* teachers. This finding would most likely *strengthen* the author's assertion that:

A. teachers with advanced degrees have a much easier time acquiring new knowledge and looking at old information in new ways.

B. national science standards are extremely necessary and important.

C. national science standards are most useful when complemented by teachers that have strong science backgrounds.

D. national science standards help to build crucial foundations for teachers.

86. According to the passage, obstacles to instituting effective national science standards include all of the following EXCEPT:

A. science teachers are aging and fewer young teachers are entering the teaching field.

B. many science teachers avoid teaching particular topics out of ignorance.

C. schools lack equipment and materials that can be used in science classrooms.

D. most science teachers are not required to demonstrate that they are current in their field of science knowledge.

87. According to the passage, graduate schools of education might be able to:

A. retrain current science educators.

B. push unions to increase teacher salaries.

C. encourage those with science backgrounds to enter the teaching profession.

D. improve lab equipment and access to materials needed for teaching.

88. What does the author mean when he states that the "presence" of national standards "does not guarantee their use"?

A. The presence of national standards may cause teachers to back away from teaching certain material.

B. Teachers do not have to abide by national standards until they are present in every school system.

C. Teachers may be limited as to how many of the required topics they can teach.

D. National standards allow individual teachers to determine the extent to which they follow particular requirements and teach certain topics.

89. The author of the passage would be most likely to support a law which:

A. requires teachers to undergo a certain number of hours of continuing education every year.

B. allows teachers to be paid comparably to doctors and lawyers.

C. permits teachers to skip the teaching of portions of national standards which they are not familiar with.

D. immediately institutes national standards across the nation in order to rapidly improve science education.

90. In order to follow up on how well teachers are using national standards in their classrooms, a new generation of achievement tests has been proposed to measure students' performance after standards have taken hold. The author would:

A. support these new tests, since they would help to enforce strict adherence to the national standards.

B. support these new tests, since they would press teachers to remain current in their fields and to improve their content knowledge.

C. not support the new tests unless national standards are backed up by improvements in teacher education.

D. not support the new tests unless teachers themselves were also tested with these tests.

GO ON TO THE NEXT PAGE.

Passage III (Questions 91–98)

Academics and collectors consider the distinction between "folk art" and "fine art" necessary to guide study, appreciation and display of artistic work. However, when the first cave paintings were made, language probably did not distinguish between "fine" and "folk" art. Furthermore, whether there was even a word for "art," in the broadest sense, remains unknown.

As "art" matured into "fine arts" (sophisticated disciplines taught in cosmopolitan centers) its devotees undoubtedly adopted a superior attitude. Mark Twain once said, "when I was fourteen, my father was so ignorant I could hardly stand to have him around. But when I was twenty-one, I was astonished at how much the old man had learned." Like the young Twain, fine art went through a period of disparaging its parent. J. Russell Harper recalls that the first exhibition of Canadian folk painting hung in the National Gallery (in 1927) was greeted with a mixture of disapproval, questioning, and cynicism.

Primitive art (folk art dating from prehistoric periods), having a claim to representing part of art's history, gained appreciation sooner than naive art. The latter suffered from being viewed as if it were the product of an unfortunate, backward relative. The growth of anthropology, nurturing cultural relativism and counteracting ethnocentrism, was significant in increasing the value attributed to naive art.

In the broadest sense, folk art is the art of the people of a region, springing naturally from their customary way of life and beliefs. This definition places appreciation of folk art within the context of appreciation of culture, indicating that applying standards appropriate to sophisticated arts taught in urban centers is problematic. But, is all art that violates accepted standards folk art? Blake McKendry has argued that folk artists are neither conscious nor aware of contemporary rules of the fine arts (hence, "naive art"), but that modern artists *choose* to disregard these conventions. Thus, Picasso's *Les Demoiselles d'Avignon*, which used forms from African masks to reveal the aggressive nature of ladies in a brothel, is modern art. The original masks, however, are folk art.

Different styles can also be recognized in fine arts. However, the term "school" is generally used in identifying such styles, differentiating the conscious choice of training of fine artists from the traditional direction of folk artists. An innovative style, while it may originate in a particular area, may draw artists from afar to study with its masters, and then diffuse, flourishing in other areas.

Some propose that fine art differs most sharply from folk art in lacking practical purpose. This view emphasizes that fine art exists solely for its aesthetic qualities but that folk art, while pleasurable to view, is usually a decoration to an object that has another function, such as a walking stick or bed cover. This distinction, however, may overemphasize the economic constraints in the life of the artist. Both folk and fine art are used to commemorate events, relationships, and people. Thus, a village may commission a sculpture to commemorate its war dead; friends may give a bride and groom a collage containing their wedding invitation.

Degree of mastery of materials and technique, inventiveness, level of cognitive abstraction, and ability to transform the viewer's understanding of the world are accepted criteria for evaluation of fine art. Folk art, by contrast, is best appreciated for its direct appeal and simple charm. However, there is much overlap. While folk artists tend to use readily available materials and simpler techniques, they are nevertheless capable of considerable creativity. While fine art and folk art differ, many fine artists admire and, at times, imitate folk art.

91. It can be inferred from the passage that if several works of folk art were today displayed along with several works of fine art, the former would be more likely to be:

A. misunderstood by viewers.

B. derived from traditional culture.

C. without practical value.

D. of less aesthetic value.

92. Based solely on information in the passage it can be inferred that academics and collectors today consider the first cave paintings to be:

    I. folk art.

    II. primitive art.

    III. naive art.

A. I only

B. I and II only

C. I, II and III

D. II and III only

93. It can be inferred from the passage that the most significant factor responsible for the reaction to the 1927 exhibition at the National Gallery (line 17) was:

A. invalid assessment by the exhibit's curators of the artistic value of the works selected for display.

B. lack of a mature sense of the standards appropriate in appreciating folk art among those who attended the exhibit.

C. undue influence of devotees of the fine arts on the national gallery.

D. those attended the exhibit had experience with folk art executed to serve a practical purpose, but were unused to appreciating folk painting on canvas.

94. Considering how the terms are used in the passage, some of today's modern art, fifty years from now, could be classified as:

A. naive art.

B. primitive art.

C. fine art.

D. folk art.

95. In paragraph 4 the author distinguishes fine art from folk art by focusing primarily on:

    I. social context in which the artist's skill was developed.

    II. the intention of the artist.

    III. the country of origin.

A. I only

B. I and II only

C. II only

D. I, II and III

96. The author of the passage would most probably agree with which of the following statements?

A. Folk art and fine art are more different than they are similar.

B. Fine art is folk art grown up.

C. Whether a work is folk or fine art is mostly in the eye of the beholder.

D. Folk art and fine art share a common origin.

97. According to the passage, which of the following is probably more typical of folk art than of fine art?

A. Younger artists learn from skilled adults.

B. Older practitioners encourage younger artists to test boundaries.

C. Stylistic similarity is correlated to geographic proximity.

D. Utilization of common materials and sophisticated techniques.

98. By "economic constraints in the life of the artist," (lines 53) the passage most nearly means whether artists:

A. can afford objects to serve solely as a surface on which art is executed.

B. are able to support themselves solely from their artwork.

C. have time to devote to creating a significant number of artistic works.

D. can afford to obtain professional training.

In representative democracies, citizens vote to elect representatives, who then make decisions. Voting is intended to give citizens influence in how society is governed. However, even assuming that every citizen has an
5 equal vote, varying the system of how citizens express their preference and how their preferences are tabulated can have great impact not only on the results of elections, but also on how many candidates tend to run for office and to what degree those in serious contention will tend to rep-
10 resent minority points of view.

A common system of voting entitles each citizen to one vote, and the candidate who receives the most votes is elected. This is known as a *plurality* system, and is used almost exclusively in national elections in the U.S.
15 Notwithstanding the possibility of a tie, if there are two choices, a *plurality system* produces an outcome in accord with the preference of the majority of voters. In races with more than two choices, however, the outcome may be other than what most voters think it should be. If two of three
20 candidates are similar to each other and if these two candidates are, collectively, more popular than a third, the third candidate may nevertheless garner the most votes and win. In such a situation, the two similar candidates are often said to have "split" the vote that either one, if opposed only
25 by the third, could have received. In the 1912 U.S. presidential election, for example, Roosevelt and Taft (former and incumbent Republican presidents) split a majority of the popular vote, allowing the Democrat (Wilson) to win. Such situations have provoked discussion of the merits of
30 alternative voting systems. Under the *plurality system*, in a race between more than two candidates a sophisticated voter who fears his first choice will be unable to win may vote his second choice.

The *Borda count* is a voting system proposed in the late
35 eighteenth century by a French mathematician, Jean-Charles de Borda. In this system, each voter ranks candidates from first to last preference. Each candidate is awarded a number of points from a particular voter equal to the number of candidates that the voter ranked lower. 40 For example: the candidate a voter ranked first in a group of five choices would get four points, thecandidate ranked second would get three points, and so on. The candidate with the most points from all voters would be the winner. The French Royal Academy of Science adopted *Borda*
45 *count* and used it until the early 1800s.

A system more recently developed is *approval* voting, in which each voter can vote for more than one candidate. A voter might vote for only a single, favored candidate, or for all candidates except one (of whom he or she strongly

50 disapproves). The secretary general of the United Nations is elected by *approval* voting. The system is also currently used by a number of scientific and engineering societies.

Given the well-known potential problems associated with use of the *plurality* system when more than two can-
55 didates run for a single office, it seems inevitable that alternatives will continue to be discussed. If adopted, an alternative system could free voters from the fear of "wasting" their votes if they vote their sincere first choice.

99. In concluding that Wilson won the 1912 U.S. Presidential election because Taft and Roosevelt "split" a majority of the popular vote, the author assumes that:

    I. party affiliation is a major determinant of which candidate a voter will prefer.
    II. Taft and Roosevelt, collectively, received fewer votes than Wilson.
    III. individuals who voted for either Taft or Roosevelt would generally not have considered Wilson an appropriate second choice.

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

100. Which of the following concepts does the author illustrate with an example?

A. A *plurality system* of voting can produce an outcome which is not in accord with the preference of the majority of voters.
B. Varying the voting system can have an impact on which candidate is elected.
C. In a race between more than two candidates a sophisticated voter may vote his second choice.
D. Varying the voting system can have an impact on what candidates run for office and what viewpoints they represent.

101. The passage implies that the results of the 1912 election would have been different if:

    I. Taft had not run.

    II. voters had been more sophisticated.

    III. the *Borda count* had been used instead of the plurality system.

A. I only

B. I and II only

C. I and III only

D. I, II and III

102. The argument in the passage that Wilson was allowed to win because Roosevelt and Taft split a majority of the popular vote (line 27) would be *weakened* by any of the following EXCEPT:

A. most voters in 1912 considered Roosevelt and Wilson to be "progressives" and Taft to be a conservative.

B. in his 1912 campaign, Roosevelt argued Taft had "betrayed" the policies of progressive reform that Roosevelt had followed when Taft was his vice-president.

C. a fourth candidate, Eugene Debbs, received more than 6% of the popular vote in the 1912 election.

D. in 1916, Wilson was re-elected and Hughes, who represented a reunited Republican party, was defeated.

103. As used in the passage, the phrase "in serious contention" (line 9) most nearly means those who are:

A. more likely to win the election.

B. more committed to their principles.

C. more articulate in conveying their positions.

D. more energetic in their campaigning.

104. Assume four candidates are running for class president. If the students in the class are familiar with the information in the passage and some want to use *approval* voting, but others want to use the *plurality system*, what is the most likely reason that some students would favor the *plurality system*?

A. They are generally less receptive to change.

B. They are generally more mathematically inclined.

C. They each strongly prefer a candidate who is markedly different from the other three candidates.

D. They each tend to prefer either of two candidates who are similar to each other.

The dominance of the "New Historicism" in academic circles over the past fifteen years has begun to arouse a backlash in these same circles. New Historicism, which was developed to study the complexities of Renaissance Italian history, swiftly impressed other historians, who used it to gain insights into other cultures. Combining anthropology with textual criticism, its practitioners developed what they termed "thick description", using anecdotes gleaned from cultural practices, and intertwining these anecdotes with general studies of the complexities of the culture. Canonical literature, such as the works of Dante, was studied alongside decidedly inferior works by contemporaries who lacked his literary genius. No text, argued the New Historicists, could be understood outside its culture; thus, a reading of all works necessitated anthropological study and literary criticism.

The result was in part a lively revival of historical study, attracting several brilliant scholars, illuminating several cultural periods, and bringing close study to such marginalized groups as transvestites, sorcerers, orphans, pornographers, and fanatics. Studying such marginalized groups, argued the New Historicists, brought mainstream groups into tighter focus. Not incidentally, such groups also attracted interest by their very strangeness, and heightened both popular and academic curiosity. Not that the New Historicism lacked detractors. Some argued that the study of marginalized groups inevitably entailed the neglect of the dominant cultural figures. And, while many welcomed the study of hitherto unknown texts, others contended, rightly, that this approach often clouded the uniqueness and importance of canonical texts.

The current backlash argues that the great flaw in New Historicism is that it assumes that all cultures have coherence, and that marginalized voices form an essential part of understanding that coherence. If (they reason) cultures do not form a unified entity, but are formed of disparate units in constant conflict, the New Historicist approach is not only valueless, but deceptive. These new scholars (who lack a convenient nomenclature) argue for a return to the study of groups as unique within their societies. Ironically, in so doing, they continue the same study of individuals and marginalized groups pioneered by their predecessors, even while proclaiming the uniqueness of their approach. It could be argued, therefore, that this is no backlash at all, but only a need to proclaim that a backlash exists, and that we are ready to move on to another disciplinary approach.

What we must question is why we constantly feel the need to change our historiographical tactics, or at least to claim that we do so. No other pseudo-scientific discipline feels the need to revolutionize techniques so frequently. Years may pass, but economists continue to pore over numbers; linguists continue to study words. In history, however, the "great man theory" shifts to "the progressive theory"; progressives swiftly shift techniques and train social historians; social historians shift from studying social conflicts to cultural studies; cultural historians embrace the literary theory of deconstructionism, and proceed to dismantle earlier work. Instead of studying history, we study its process, creating generations of students more interested in the techniques of historical writing than in history itself. We refrain from making historical or literary judgements, focusing only on how we create words, not on how we create meaning. I oversimplify, of course; other disciplines have shifted gears and developed new insights. But none seems to do so at the same rate as the historians, who in a twenty-year period have developed – and now appear to be wrecking – the very technique they termed "The New Historicism." If such historical techniques can be so easily vitiated, what does that say about their initial value?

105. Regarding the New Historicists, the author asserts that:

A. their work was responsible for sparking new interest in history.

B. their approach clarified many problems in Renaissance Italy studies.

C. by assuming that all cultures form themselves into a coherent unit, their work misinterpreted the place of marginalized groups.

D. its practitioners focus more on the words they create, and less on the meaning behind these words.

106. The author's primary argument in the fourth paragraph would be most *weakened* by:

A. proof that other pseudo-scientific disciplines frequently change their techniques.

B. evidence that New Historicists do not hesitate to make moral judgements upon historical events.

C. proof that new historical techniques amplify, not diminish, previous historical judgements.

D. evidence that New Historicism has not been weakened at all, but remains a vibrant force in historical studies.

107. According to the passage, which of the following would be of the LEAST interest to a New Historicist?

A. A textual study comparing the works of the minor poet Aemilia Lanyer to the works of her contemporary, William Shakespeare

B. An analysis of the power structure of a ruling town elite

C. an essay contrasting the literary work to the music of the same era

D. A pornographic work from the generally puritanical Victorian era

108. The author probably uses the term "pseudo-scientific" in order to:

A. draw a contrast between historical research and that done in true scientific disciplines such as physics.

B. critique economists, anthropologists, and historians for not using stringent scientific methods.

C. urge historians to reject New Historicism and other historical techniques in favor of a more scientific, objective approach.

D. note that the study of history by its very nature lacks a straightforward scientific approach.

109. Which of the following can be inferred about the backlash towards New Historicism?

    I. Its scholarly texts may include studies of marginalized groups.

    II. It suffers from the same flaw that New Historicism does.

    III. It has provided no new insights into historical periods.

A. I only

B. I and II only

C. II and III only

D. I, II and III

110. If the author of the passage admired the work of a new scholar criticizing an earlier work comparing Dante to a previously unknown Italian poet, this admiration would be most inconsistent with the claim that:

A. the backlash against the New Historicism has no claim to originality.

B. the work of the New Historicists unfairly concealed the uniqueness of Dante.

C. the New Historicists' work provided new insights into understudied poets.

D. the constant cycle of changing historical approaches is potentially dangerous to the field of history.

Passage VI (Questions 111–116)

Any theory of spatial representation must assume a moving animal. In other words, when thinking about cognitive maps, we should first ask ourselves what information would most help a motile animal navigate. Here, I think we need to consider two classes of objects: those that move and those that do not. When constructing spatial maps, animals will rely on stationary objects in their environments.

There are two reasons why animals are more likely to use objects in their environments and not themselves as a focal point on a map. First, if an animal used information generated by its own body movements, navigational errors would rapidly multiply because small body movements would throw the system off. Second, an animal's location is only important relative to other objects, such as its nest or burrow. Thus, while an animal might make use of other regularities (e.g., angle of the sun, polarization of light, etc.), especially for large-scale migrations, they will also need to use landmarks to orient themselves or to recalibrate their position.

For example, one desert ant (*Cataglyphis fortis*) searches for food by making a winding path across the desert. Then, once it has found food, it makes a relatively straight path back to its nest. The ant makes use of a number of cues about the sun, and about its body movements as it winds across the desert. In addition to these cues, which are sufficient to get the ant back to the general vicinity of its nest, the ant uses landmark cues to actually zero in on its nest. If one moves the landmarks to a new location, the ants will persist in going to this new location, even after they do not find their nest. There is evidence that bees use similar cues.

While this skill is impressive, the ants do not seem to have a true map, however. They do not show transitivity. The might be able to get from A to B, and A to C, but they cannot get from B to C.

Other animals that store food use landmarks in order to find their food. In a series of experiments, many scientists have discovered that birds do not find their stores of food by following a regular pattern (e.g., first visit the tree with the knob, then the tree with the missing bark), by scent, or by seeing the food; instead, they used landmarks.

Since the location of one landmark is highly uninformative, animals will determine where they relative to the configuration of a number of landmark objects. For example, some scientists tested rats in an eight-arm radial maze. By manipulating the position of cues, they discovered that the rats knew which arms they had visited by examining where they were relative to the configuration of landmarks outside the maze. Experiments with pigeons and black-capped chickadees produced similar results. In one experiment, black-capped chickadees were trained to find food in one of four feeders on a wall. After the animals learned the task, the researcher wanted to see what cues the birds used to find the food. So, he first changed the location of the feeder with the food; in a second manipulation, he changed the location within the array of the feeder with food; finally, in a third experiment, he changed the appearance of the feeders. He found that the chickadees usually returned to location of the feeder, then to the location within the array. This, and experiments with many other animals, support the idea that the identifying features of an object are of less importance than its absolute or relative location.

111. Presumably, an animal could get back to its original starting point by making all its movements in reverse. According to the author, why might this system not actually work?

   A. Since the animal would have to integrate all its body movements into a system of where it was, small body movements could throw its computations off.

   B. It is impossible to use this information since such information is not detailed enough.

   C. Body kinesthetic information is inherently subject to large errors from such sources as the sun.

   D. There is no evidence to suggest that kinesthetic maps could not actually work as well as other types of maps.

112. Based on the information in the passage, why might animals use a configuration of landmarks instead of a single landmark?

    A. It is easier to remember where many objects are versus just one object.

    B. It is easier to identify many objects versus one object.

    C. It is less likely that the position of many objects would change than that the position of one object would change.

    D. It is more likely that the position of many objects would change than that the position of one object would change.

113. For what purpose did the researcher on black-capped chickadees manipulate the location of the food, the location within the array, and the appearance of the feeders separately?

    A. If he did them all at the same time, the birds could have quickly flown to the new location of the food.

    B. He wanted to remove external cues, such as how many days have passed since they ate last.

    C. He had to manipulate them separately to isolate the most important cue.

    D. He wanted to remove kinesthetic information from the birds' memory of how far they had flown.

114. What are the implications of the fact that many animals use similar cues when finding objects?

    A. There may be something about the brain that requires them to use similar cues.

    B. They may be something in the muscles that are similar across animals.

    C. It is probably random that animals use similar cues.

    D. It has not been shown that animals use similar cues.

115. Animals that use configuration cues are most likely to rely on what sensory organ?

    A. Hearing, because sounds are usually specific to one location.

    B. Sight, because this allows configurations to be detected at a distance.

    C. Sight, because objects always look the same from any orientation.

    D. Touch, because this is the only sense that allows animals to identify objects unambiguously.

116. If we discovered a new animal, and we trained it to expect food at a location we selected, what cues might it use to find the food if we released it?

    A. There is no way to tell what cues it might use.

    B. It would probably use kinesthetic cues to find food.

    C. It would probably use properties of landmarks to find food.

    D. It would probably use configurations of landmarks to find food.

The dominant culture wishes to pretend, particularly where children are concerned, that the dark side of humanity does not exist. Psychoanalysis itself is viewed as having the purpose of making life easy. But psychoanalysis

5 was created to enable humans to accept the problematic nature of life without being defeated by it, or giving in to escapism. Freud's prescription is that only by struggling against what seem like overwhelming odds can individuals find meaning in their existence. This is exactly the mes-

10 sage that traditional fairy tales get across to the child: that a struggle against severe difficulties is an intrinsic part of existence. Modern stories written for children mainly avoid these existential problems, although they are crucial issues. The child needs to be given suggestions in symbolic

15 form about how to deal with these issues and grow safely into maturity. "Safe" stories mention neither death nor aging, the limits to our existence, nor the wish for eternal life. The fairy tale, by contrast, confronts the child with basic predicaments.

20 It is characteristic of fairy tales to state an existential dilemma briefly and pointedly. This permits the child to grapple with the problem in its essential form. Figures are clearly drawn; details, unless important, are eliminated; characters are typical rather than unique. Contrary to what

25 takes place in many modern children's stories, in fairy tales evil is as omnipresent as virtue. Good and evil are embodied in figures and their actions, as good and evil are omnipresent in life and the propensities for both are present in everyone. But the figures in fairy tales are not ambivalent. Since polar-

30 ization dominates the child's mind, it also dominates fairy tales. A person is either good or bad, nothing in between. Presenting the polarities of character permits the child to comprehend differences, which the child could not do as readily were the figures drawn more true to life.

35 Although subject to desperate feelings of loneliness, iso-lation, and anxiety, the child is usually unable to express these feelings in words, or can do so only by indirection: fear of the dark, of some animal, anxiety about his or her body. Since it creates discomfort or anxiety in a parent to

40 recognize these emotions in the child, the parent tends to overlook or belittle them, believing this will cover over the child's fears. The fairy tale, however, addresses itself directly to anxieties and fears. Further, it offers solutions in ways that the child can grasp. For example, fairy tales pose

45 the dilemma of wishing to live eternally by occasionally concluding: "If they have not died, they are still alive." The other ending—"And they lived happily ever after"—does not for a moment fool the child that eternal life is possible. But it does indicate that which alone can take the sting out

50 of our existence: forming a truly satisfying bond to another.

117. According to the passage, one of the primary con-trasts between fairy tales and modern children's sto-ries is that:

A. fairy tales are full of mythical characters whose personalities are complex and ambiguous.

B. modern stories give children a more thorough understanding of the difficult issues of life and death.

C. anxieties related to human existence are clearly addressed in fairy tales.

D. parents are more comfortable with traditional fairy tales because of their simplistic plots.

118. The author mentions Freud's theories in the first paragraph in order to:

A. demonstrate that applying psychoanalytic theo-ries to literature is an invalid manner of examin-ing children's stories.

B. support the thesis that the structure and content of traditional fairy tales can show children how to overcome obstacles and struggles.

C. argue that modern children's stories have been founded upon the refutation of the human strug-gle against overwhelming odds.

D. provide support for the claim that the essential nature of humans is good rather than evil.

119. The concluding paragraph of the passage relies on which of the following assumptions?

A. Successful interpersonal relationships are the only source of meaning in human lives.

B. Children are capable of distinguishing between fiction and reality on a semantic level.

C. Parents' desires to protect their children from the harsh realities of life are undermined by the classic fairy tale plot.

D. Vague childhood fears are always indirect proof of negative feelings that are difficult to articu-late.

120. All of the following are presented as positive effects of the inherent polarization of good and evil in fairy tales EXCEPT:

A. fairy tales permit children to struggle with difficult issues in their most simple forms.

B. both good and evil are constantly in evidence so that children can draw parallels between the story and what they experience in life.

C. simplistic characters allow children to understand differences between polar opposites more readily than complex or ambiguous characters.

D. the triumph of good over evil imparts important moral lessons and values to children.

121. Which of the following, if true, would most strengthen the author's assertion in Paragraph 1 that a child "needs to be given suggestions in symbolic form about how to deal with these issues and grow safely into maturity"?

A. Parents cannot always provide their offspring with appropriate models for confronting challenges.

B. Results of early education studies have shown that children in elementary school prefer fictional representations of difficult issues.

C. Children respond instinctively to their experiences in ways that do not allow them to develop meaningful responses to life and death situations.

D. Young children are not capable of comprehending the underlying meaning of the predicaments presented in fairy tales.

122. It can be inferred from the passage that the author would agree with which of the following?

A. Authors of children's stories are well-intentioned but misguided in their re-structuring of classic fairy tales to make them more palatable to parents.

B. Modern children's literature has deviated from the traditional fairy tale in ways that are detrimental to the development of children's evolution into adulthood.

C. Although traditional fairy tales often include evil and malignant characters, these negative forces have no impact on children's understanding of basic human nature.

D. Fairy tales represent goals and standards that may discourage children once they realize that such perfect lives are impossible to achieve.

123. Based on the information in the passage, the author would consider a story a "safe story" only if it was one in which:

A. problems are constructively solved.

B. life is viewed without a "dark side".

C. virtue often triumphs over evil.

D. people are portrayed with compassion.

124. The author refers to "Freud's prescription" in discussing psychoanalysis (line 7) primarily in order to:

A. reconcile opposing positions.

B. expose a contradiction.

C. provide an analogy.

D. clarify a view.

The United States has less than half of the 215 million acres of wetlands that existed at the time of European settlement. Wetland conversion began upon the arrival of European immigrants with their traditional antipathy to
5 wetlands and with the will and technology to dry them out. In the mid-19th century the federal government awarded nearly 65 million acres of wetlands to 15 states in a series of Swamp Land Acts. But the most rapid conversion occurred between the mid-1950s and mid-1970s, when an
10 estimated 450,000 acres per year were lost, primarily to agriculture.

This conversion has meant the loss of a wide range of important wetland functions. Wetlands inhibit downstream flooding, prevent erosion along coasts and rivers, and help
15 remove or assimilate pollutants. They support scores of endangered birds, mammals, amphibians, plants, and fishes. Wetlands provide aesthetic and open space benefits, and some are critical groundwater exchange areas. These and other public benefits have been lost to agricultural
20 forestry and development enterprises of all kinds, despite the fact that most of the conversion goals might have been obtained with far less wetland loss through regional planning, stronger regulation, and greater public understanding of wetland values.

25 At best, existing wetland laws and programs only slow the rate of loss. Despite the growing willingness of government to respond, wetland protection faces significant obstacles. Acquisition as a remedy will always be limited by severe budget constraints. The Emergency Wetlands
30 Resources Act allocates only $40 million per year in federal funds, supplemented by relatively modest state funds, for wetland purchase. Ultimately, the wetlands that are protected will be a small percentage of the approximately 95 million acres remaining today. Wetland acquisition by
35 private environmental groups and land trusts adds qualitatively important but quantitatively limited protection. Government incentives to induce wetland conservation through private initiatives are limited and poorly funded. Some private developers have recognized that business can protect
40 selected wetlands and still profit. Recreational developments in Florida have benefited from wetland and habitat protection that preserves visual amenities. It is doubtful, however, that these business decisions to save wetlands would have occurred without strong government regula-
45 tion; the marketplace does not generally recognize the public benefits of wetlands for flood control, fish and wildlife, and other long-term values.

One possible strategy (and the one presently being implemented) is to protect each and every wetland in

50 threatened areas according to stringent permit guidelines that do not distinguish by wetland types or values. This approach may be environmentally desirable, but it has not worked. About 300,000 acres of wetlands are lost each year. An alternative strategy is to develop a regional man-
55 agement approach focused on valuable wetlands in selected areas that are under intense pressure. Broad regional wetland evaluations could identify critical wetland systems that meet particular local and national needs and avoid abandonment of any wetlands without careful
60 review of the tradeoffs. Cooperating federal, state, and local interests can then anticipate and seek ways to prevent wetland losses, and can guide future development in areas where alternative options exist. There is no general federal authority to conduct such planning for wetland system pro-
65 tection. But there are several authorities under which a program to anticipate and prevent wetland losses on an areawide basis can be developed.

125. The author mentions the Emergency Wetlands Resources Acts in order to:

   A. emphasize the important role of governmental willingness to preserve wetlands.

   B. prove that federal funding is sufficient for the preservation of wetlands.

   C. advocate passage of new legislation to protect America's wetlands.

   D. show how fiscal constraints affect purchase of wetlands.

126. According to the passage, all of the following contributed to the rapid loss of wetlands in the United States EXCEPT:

   A. technological innovations implemented by European settlers.

   B. development of commercial and residential real estate complexes.

   C. increased rezoning for the purposes of agricultural and industrial operations.

   D. conversion of wetlands for agricultural uses.

GO ON TO THE NEXT PAGE.

127. In the final paragraph, the author's primary purpose is to:

A. present several potentially effective strategies for protecting wetlands and preventing additional losses of these important conservation areas.

B. criticize current methods of protecting wetlands for their inefficiency and disregard of strict governmental guidelines.

C. argue that collaboration between regional, local, and federal organizations is the only way to establish effective wetlands conservation methods.

D. suggest that the present approach to protection of wetlands has been ineffective and advocate a different method.

128. It can be inferred from the conclusion of the passage that the author assumes which of the following?

A. Non-federal organizations across the country would be willing to cooperate in order to develop standards for wetlands protection and conservation.

B. Federal funding programs for environmental protections will never establish a national committee with the authority to develop a comprehensive wetlands protection plan.

C. Only additional guidelines that increase the already-stringent permit requirements for developers would effectively end the loss of wetlands.

D. Identification of critical wetlands systems should be conducted on a case-by-case basis in order to determine which areas could be exempt from wetlands protection regulations.

129. The passage suggests that which of the following could be helpful for the protection of wetlands systems in the United States?

I. increased acquisition by private environmental groups and land trusts

II. recognition of the myriad benefits to the public by developers and agricultural interests

III. stricter supervision of commercial zoning by governmental agencies

A. I only

B. II and III only

C. I and II only

D. I, II, and III

130. Which of the following best describes the author's attitude toward government acquisition of wetlands, acquisition by private environmental groups, and protection by private developers?

A. All three are limited in their potential for slowing wetland loss.

B. Acquisition by government and private groups offers some protection for wetlands, while actions by private developers will speed wetland loss.

C. All three strategies are promising, and more study is needed to determine which is best.

D. A combination of all three strategies, in conjunction with regional management, can potentially reverse the trend toward wetland conversion.

131. The author mentions the Emergency Wetlands Resources Act (line 29–30) in order to:

A. illustrate the need for legislation to save wetland areas in the United States.

B. argue that the federal government prevents various state governments from protecting valuable wetland areas.

C. give an example of the severe financial obstacles limiting federal acquisition of wetland areas.

D. indicate how widespread is the perception that wetlands are not worth saving.

Among the several hundred million binary systems estimated to lie within 3,000 light-years of the solar system, and thus to be theoretically detectable on sky-survey photographs, a tiny fraction, no more than a few hundred, belong to a curious subclass whose radiation has a wavelength distribution so peculiar that it long defied explanation. Binary systems radiate strongly in the visible region of the spectrum, but some of them do so even more strongly at both shorter and longer wavelengths: in the ultraviolet region and in the infrared and radio regions.

This odd distribution of radiation is best explained by the pairing of a cool red-giant star and an intensely hot small star that is virtually in contact with its larger companion as the two travel around a common center. Such objects have become known as symbiotic stars. On photographic plates only the giant star can be discerned, but evidence for the existence of the hot companion has now been supplied by satellite-borne instruments capable of detecting ultraviolet radiation at wavelengths that are absorbed by the earth's atmosphere (and therefore cannot be detected by instruments on the ground). Recently two symbiotic-star systems, the first to be detected outside our galaxy, have been observed in the Large Cloud of Magellan, one of the satellite galaxies associated with ours.

The spectra of symbiotic stars indicate that the cool red giant is surrounded by a very hot ionized gas. The existence of the ionized gas marked such objects as being peculiar several decades before satellite observations finally identified the ionizing source as the radiation from an invisible hot companion. Symbiotic stars also flare up in outbursts indicating the ejection of material in the form of a shell or a ring, reminiscent of the recurrent outbursts of a nova. Symbiotic stars may therefore represent a transitory phase in the evolution of certain types of binary systems in which there is a substantial transfer of matter from the larger partner to the smaller.

The exact evolutionary course that turns a binary system into a symbiotic one is a matter of conjecture. The comparatively small number of known symbiotics in our galaxy suggests that if all binaries of modest mass normally pass through a symbiotic phase in their evolution, the phase must be extremely brief, perhaps as short as a million years. It is suspected that the evolutionary course of a binary system is predetermined by the initial mass and angular momentum of the gas cloud within which binary stars are born. Since red giants and Mira variables are thought to be stars with a mass of one or two suns, it seems plausible that the original cloud from which a symbiotic system is formed can consist of no more than a few solar masses of gas.

132. According to the passage, the true nature of symbiotic stars was long a matter of speculation because:

A. such formations have a relatively short life span.

B. unstable pairings of hot and cool stars are undetectable by the human eye.

C. scientific researchers did not possess the capability to properly study these stars.

D. other binary stars are more numerous and readily available for study.

133. In Paragraph 4, the author's purpose in mentioning "red giants and Mira variables" is primarily to:

A. support the argument that symbiotic stars exist outside of our galaxy.

B. provide evidence for a theory about the origins of symbiotic stars.

C. refute the thesis that symbiotic stars are larger than other binary stars.

D. show that the evolution of giant stars is predetermined.

134. According to the passage, all of the following are true about symbiotic stars EXCEPT:

A. symbiotic stars consist of a cool star and an intensely hot star that orbit each other.

B. some of the radiation emitted by symbiotic stars falls outside the visible spectrum.

C. the ionized gas surrounding the red giant star was identified by researchers as coming from its companion.

D. evolution of a symbiotic pair has yet to be clearly determined.

135. With which of the following statements is the author of the passage most likely to agree?

   A. Symbiotic stars are a recent discovery that casts doubt on the usefulness of photographic plates for astronomical research.

   B. The high levels of radiation given off by the intensely hot star in the symbiotic pair represent a potential hazard for other stars and planets in the galaxy.

   C. All binary systems must pass through an extensive symbiotic phase that is predetermined by their relative masses.

   D. The development of some binary systems may include a symbiotic stage that marks a transition in their evolution.

136. The author's discussion of novas in Paragraph 3 apparently is intended to:

   A. contrast the development of symbiotic stars with that of other celestial formations.

   B. compare a characteristic of a newer discovery to that of an older one.

   C. prove that symbiotic stars engage in matter transfer as part of their evolution.

   D. suggest that binary systems emit flares to eject material in a shell-like form.

137. According to the passage, which of the following is true about binary star systems?

   A. They begin their development inside of a substantial and mobile gas cloud.

   B. They engage in an equal exchange of matter during their evolution.

   C. All binary systems of average mass pass through a brief symbiotic stage.

   D. Several hundred million binary systems are detectable by photographic instruments on the ground.

STOP. IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK. YOU MAY GO BACK TO ANY QUESTION IN THIS SECTION ONLY.

Biological Sciences

Time: 100 Minutes
Questions 138–214

DO NOT BEGIN THIS SECTION UNTIL YOU ARE TOLD TO DO SO.

BIOLOGICAL SCIENCES

DIRECTIONS: Most of the questions in the Biological Sciences test are organized into groups, with a descriptive passage preceding each group of questions. Study the passage, then select the single best answer to each question in the group. Some of the questions are not based on a descriptive passage; you must also select the best answer to these questions. If you are unsure of the best answer, eliminate the choices that you know are incorrect, then select an answer from the choices that remain. Indicate your selection by blackening the corresponding circle on your answer sheet. A periodic table is provided below for your use with the questions.

PERIODIC TABLE OF THE ELEMENTS

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 *** 138.9	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 †** 227.0	104 **Rf** (261)	105 **Ha** (262)	106 **Unh** (263)	107 **Uns** (262)	108 **Uno** (265)	109 **Une** (267)									

	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)

Passage I (Questions 138–143)

Vitamin B$_{12}$, also known as cobalamin, is a substance that cannot be synthesized by the human body and must be supplied in the diet. Bacteria produce cobalamin, and humans obtain cobalamin by ingesting animal products. The absorption of cobalamin from dietary sources is a multi-step process. First, cobalamin is released from food in the acidic environment of the stomach and binds R-binder, a substance which is found in human saliva and gastric juice. The alkaline pH of the duodenum allows the dissociation of the cobalamin-R-binder complex, and cobalamin is then available to bind intrinsic factor (IF). IF is produced by parietal cells in the stomach, in parallel with parietal cell secretion of HCl. The new cobalamin-IF complex, resistant to proteolytic digestion, travels safely to the ileum, where the complex is bound and taken-up by a specific receptor on the lining cells. Here, the IF is destroyed, and the cobalamin is transferred to a transport protein, transcobalamin, which carries it to the liver for storage and to certain cell types for use.

Cobalamin is an essential cofactor for two enzymes in human cells: methionine synthase and methylmalonyl-CoA synthase. The former catalyzes a reaction that is required for proper metabolism of folate, and folate is required for successful DNA synthesis, specifically in red blood cells. Thus, a major effect of cobalamin deficiency is a form of anemia. This type of anemia is characterized by a decreased concentration of red blood cells (RBCs), that is also seen with folate deficiency; both are characterized by larger than normal RBCs.

Both methionine synthase deficiency and methyl-malonyl-CoA synthase deficiency may contribute to the neurologic complications seen in cobalamin deficiency by interfering with the production of lipids that make up neuronal membranes and myelin sheaths. The neurologic manifestations involve both the peripheral and central nervous systems and reflect progression from demyelination, to degeneration of axons and eventual neuronal death.

The most common cause of cobalamin deficiency is pernicious anemia, caused by the absence of IF. This could be the consequence of an inherited condition or, more commonly, of an autoimmune attack on the parietal cell or IF.

138. Based on the passage, all of the following could lead to cobalamin deficiency EXCEPT:

  A. use of medication that inhibits the production of gastric acid.
  B. blockage of pancreatic secretions.
  C. blockage of bile tract secretions.
  D. removal of a part of the GI tract from the distal jejunum to the colon.

139. Which of the following patients would likely still suffer from cobalamin deficiency despite daily treatment with supplemental cobalamin-IF complex?

  A. A patient with pernicious anemia.
  B. A patient with an inherited deficiency of transcobalamin.
  C. A patient who does not produce R-binder.
  D. A patient with a resected stomach.

140. A scientist performing electrical stimulation tests on a patient with advanced symptoms of cobalamin deficiency finds that, relative to a normal subject, it takes longer for stimuli of afferent sensory neurons at the wrist to cause depolarization at the shoulder of the same arm. This most likely reflects which of the following defects associated with cobalamin deficiency?

  A. Defective oligodendrocytes
  B. Defective Schwann cells
  C. Defective nodes of Ranvier
  D. Defective dendrites

141. Involuntary smooth muscle groups, such as the sphincters controlling the outlets of the bladder and rectum, may be affected in more severe cases of cobalamin deficiency, indicating possible involvement of all of the following EXCEPT:

  A. the peripheral nervous system.
  B. the autonomic nervous system.
  C. the efferent neurons of the nervous system.
  D. the somatic nervous system.

142. Folate is important for purine synthesis in red blood cells. Transcription of which of the following segments of DNA will be most affected by cobalamin deficiency?

    A. TTCAGTCCC

    B. AAGTCAGGG

    C. UATTCCTTU

    D. CCCGGGGAA

143. Though cobalamin is one of the water-soluble vitamins, vitamins A, D, E, and K are fat-soluble, requiring all of the following organs for processing EXCEPT:

    A. the liver.

    B. the small intestine.

    C. the pancreas.

    D. the stomach.

Passage II (Questions 144–149)

Semiochemicals are naturally-occurring, message-bearing biochemicals used by insects and other organisms for communication and perception of their environment. Many of these compounds are esters which are small enough to be volatile and therefore odorous. For example, bees release isoamyl acetate (3-methylbutyl acetate) b.p. = 142.5°C in their stingers to signal danger.

Isoamyl acetate is commonly synthesized in organic class laboratories through an esterification reaction of a carboxylic acid with an alcohol in the presence of a catalyst (see below). In order to drive this reaction to completion, an excess of acetic acid (b.p. = 118°C) is used. During the work-up, the reaction mixture is extracted with aqueous sodium bicarbonate and dried over anhydrous sodium sulfate.
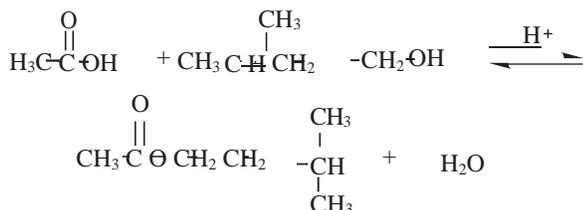
Equation 1

An alternative method to synthesizing isoamyl acetate is shown in Equation 2. This method involves reaction of acetyl chloride with isopentyl alcohol (b.p. = 132°C). This reaction goes to completion without adding excess reactant and with no acid catalysis. An organic base is usually added.
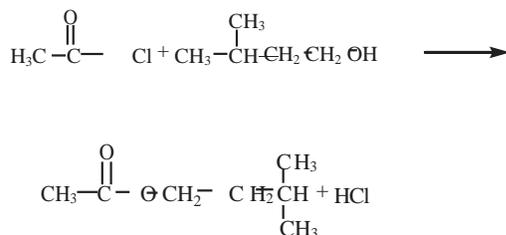
Equation 2

Shown in Equation 3, a third method commonly used to synthesize isoamyl acetate involves reaction of an acid anhydride and an alcohol. Yields of nearly 100% can be obtained by using little or no excess anhydride. The reaction is usually catalyzed by a strong acid. The reaction is so fast and exothermic that care must be taken to control it.
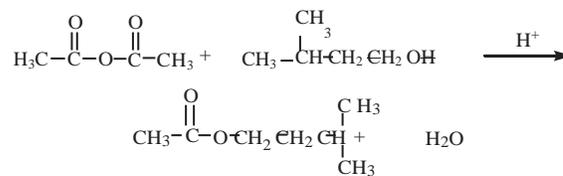
Equation 3

144. A student attempted this synthesis, but forgot to dry the solution after she extracted the reaction mixture with sodium bicarbonate. She checked her product by infrared spectroscopy, and obtained peaks at 1735 cm^{-1} (sharp, intense), 2800 cm^{-1} (sharp, intense), 3200 cm^{-1} (broad, medium intensity), and several peaks in the fingerprint region. She determined the boiling point of her product to be 140–145°C. Did the student most likely obtain isoamyl acetate?

- **A.** No, isoamyl acetate should not contain a peak at 3200 cm^{-1}.
- **B.** Yes, she obtained pure isoamyl acetate.
- **C.** Yes, but the isoamyl acetate is contaminated with acetic acid
- **D.** Yes, but the isoamyl acetate is contaminated with water

145. Excess reactant is used in the Fischer esterification synthesis of isoamyl acetate (Equation 1) in order to shift the equilibrium to product. What is an alternative way to drive the reaction to the formation of isoamyl acetate?

- I. use distillation to remove water as it forms
- II. use distillation to remove isoamyl acetate as it forms
- III. use a dehydrating agent to remove water as it forms

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

146. Why is aqueous sodium bicarbonate used to extract the reaction mixture?

    A. addition of water shifts the equilibrium to the right and drives the reaction to completion.

    B. the sodium bicarbonate deprotonates the excess acetic acid, thereby removing it to the aqueous layer and separating it from the product.

    C. the sodium bicarbonate deprotonates the isopentyl alcohol, thereby removing it to the aqueous layer and separating it from the product.

    D. the aqueous solution solvates the isoamyl acetate, separating it from the hydrophobic reactants.

147. Equation 2 shows the synthesis of isoamyl acetate by reaction of acetyl chloride with isopentyl alcohol. This reaction proceeds to completion without adding excess reactant and requires no acid catalyst. Why?

    A. The carbonyl carbon of acetyl chloride is more electrophilic than the carbonyl carbon of acetic acid.

    B. The carbonyl carbon of acetyl chloride is more nucleophilic than the carbonyl carbon of acetic acid.

    C. The carbocation intermediate of the acetyl chloride is more stable than the carbocation intermediate of acetic acid.

    D. The chloride ion provides a better leaving group for the S_N1 reaction.

148. Another student attempted the synthesis in Figure 3. He performed an nmr to determine if he had obtained the correct product. He found all the characteristic peaks of isoamyl acetate, in addition to a singlet at 11.2 ppm. To what compound does the extra peak likely belong?

    A. Water

    B. Isopentyl alcohol

    C. Acetic anhydride

    D. Acetic acid

149. A student is trying to separate a isoamyl acetate from a mixture which includes octane and n-octyl alcohol. If the student is trying to separate the compounds by distillation, in what order should they distill (from first to last)?

    A. Isoamyl acetate, octane, and n-octyl alcohol

    B. Octane, isoamyl acetate, and n-octyl alcohol

    C. Octane, n-octyl alcohol, and isoamyl acetate

    D. n-Octyl alcohol, octane, and isoamyl acetate

Membranes play a central role in communication between the inside and outside of the cell. They are composed mainly of lipids and proteins, and provide a highly selective permeability barrier to a variety of ions and small molecules that are important for normal cell function. Eukaryotic cells also contain a number of internal membranes that define specific internal compartments of the cell. Many membrane proteins (and some lipids) function as receptors that recognize and initiate cellular responses to external stimuli. The movement of bacteria towards food, the response of target cells to hormones and the detection of odor by olfactory cells are examples of processes which require the detection of a stimulus by a corresponding receptor in the cell membrane.

Biological membranes are not rigid structures, but are constantly in lateral motion. The rapid movement of membrane lipids and proteins can be quantified using the technique of fluorescence photobleaching recovery. In this method, cell surface components are first chemically modified with a fluorescent component such as fluorescein. A small fraction of the cell surface is then illuminated briefly with an intense light pulse from a laser to destroy (or "photobleach") the fluorescent molecules in that region, producing a "hole" in the fluorescent cell. If the labeled component is mobile, bleached molecules leave and unbleached molecules enter the illuminated region, which restores fluorescence intensity in that region. This technique has made it possible to measure the rates of diffusion of labeled components by measuring the time required for the return to uniform fluorescence. The diffusion rates of proteins have been found to be significantly lower than the diffusion rates of lipids.

150. A hormone is a substance that serves as a chemical message between cells of a multicellular organism. Which of the following hormones requires a membrane receptor to signal cells?

   A. Aldosterone
   B. Glucagon
   C. Testosterone
   D. Estrogen

151. The Na^+/K^+ pump is a glycoprotein built into the membranes of all animal cells. It uses the energy of an ATP molecule to import two K^+ ions into the cell and export three Na^+ ions out of the cell. Which of the following will decrease the rate of ATP consumption by the Na^+/K^+ pump?

   A. Placement of the cell into a hypertonic environment
   B. Placement of the cell into a hypotonic environment
   C. A defect in the sodium channel that allows more ions to leak into the cell
   D. A defect in the potassium channel that facilitates leakage of potassium out of the cell

152. In the fluorescence photobleaching experiments, recovery time is defined as the amount of time it takes the bleached area to regain its fluorescence. The recovery time for a cell with fluorescently labeled membrane proteins is:

   A. greater than the recovery time for a cell with fluorescently labeled lipids because lipids diffuse faster than proteins.
   B. smaller than the recovery time for a cell with fluorescently labeled lipids because proteins diffuse faster than lipids.
   C. equal to the recovery time for a cell with fluorescently labeled lipids because proteins and lipids diffuse at the same rate.
   D. smaller than the recovery time for a cell with fluorescently labeled lipids because lipids diffuse faster than proteins.

GO ON TO THE NEXT PAGE.

153. Although lateral diffusion of lipid molecules is common, transverse diffusion, the transfer of a lipid molecule from one layer of the bilayer to the other, is extremely rare. However, when enzymes known as flippases are added, the rate at which phospholipids flip back and forth between the two layers of the bilayer is significantly increased. Which of the following best explains the mode of action of flippases?

A. Flippases stabilize lipid molecules following their transfer across a bilayer.

B. Flippases destabilize lipid molecules prior to their transfer across a bilayer.

C. Flippases lower the free energy change corresponding to the transfer of lipids from one layer to another.

D. Flippases lower the potential energy of lipids during their transfer from one layer to another.

154. Valinomycin is an antibiotic that functions as a K^+ carrier, allowing its passive transport across a biological membrane. If the concentration of K^+ is 150 mM inside a neutral, membrane-enclosed vesicle, and 1.5 mM outside, what will occur after the addition of valinomycin to the vesicles?

A. K^+ will be transported into the vesicle, resulting in a net positive charge inside the vesicle.

B. K^+ will be exported out of the vesicle, resulting in a net negative charge inside the vesicle.

C. K^+ will be transported into the vesicle without affecting the charge inside the vesicle.

D. K^+ will be exported out of the vesicle, resulting in a net positive charge inside the vesicle.

The sensation of pain is in many ways similar to the sensation of other stimuli such as light, sound and odor. It has its own specialized receptors, afferent pathways, brain centers, and control mechanisms. However, unlike other sensations, pain can be evoked by a variety of external stimuli of chemical, mechanical, thermal or electrical nature as well as by endogenous stimuli that activate specialized sensory afferent neurons.

Endogenously occurring chemical agents capable of causing or augmenting pain include ions, small molecules, lipids and bioactive peptides that are often released during tissue injury. These stimuli are recognized by specialized afferent neurons called nociceptors that are capable of transmitting the information to the central nervous system. Adenosine triphosphate (ATP) and protons, for example, can trigger a sensation of pain when applied to sensory terminals of nociceptors. ATP is present at high concentrations within the cytoplasm of all cells and is readily released upon cell damage. Protons, on the other hand, accumulate locally when tissues are deprived of adequate circulation that removes metabolically generated carbon dioxide. Protons can also accumulate during infection, when neutrophils undergo anaerobic respiration. Below pH 7, protons can augment nociceptor activation by thermal, chemical or mechanical stimuli, whereas below pH 6, protons can directly activate nociceptors.

There are two main classes of receptors found in nociceptor terminals: ion channels and G protein-coupled receptors. Activation of ion (cation) channels by many pain producing chemical substances directly depolarizes the nociceptor terminal by allowing an influx of cations into the cell. G protein-coupled receptors, on the other hand are not channels and cannot depolarize the nociceptor terminal. Instead, they activate an intracellular cascade involving second messengers and protein kinases that alters the behavior of cation channels described above, thereby dampening nociceptive signaling.

155. G protein-coupled receptors are transmembrane protein molecules that participate in a number of different signaling pathways. During synthesis, G protein-coupled receptors would be primarily found in association with which of the following intracellular compartments?

   A.   Nucleus
   B.   Endoplasmic reticulum
   C.   Golgi apparatus
   D.   Lysosome

156. Bradykinin is a short peptide that can cause the sensation of pain and enhance the responsiveness of nociceptive neurons to thermal or mechanical stimuli. Selective bradykinin antagonists can block the pain mediated by bradykinin by:

   A.   enhancing the ion flow into the nociceptive neurons.
   B.   activating an intracellular enzyme involved in the G protein-coupled cascade.
   C.   binding to and inhibiting bradykinin receptors present on nociceptors.
   D.   inhibiting the generation of second messengers involved in the G protein-coupled cascade.

157. Adenylyl cyclase is an intracellular enzyme that becomes active when endogenous stimuli bind to G protein-coupled receptors present on nociceptors. Based on the information presented in the passage, which of the following is a likely consequence of having a mutant form of adenylyl cyclase that is continually active even in the absence of endogenous stimuli?

   A.   Cation channels will continually remain open and sensation of pain will occur in the absence of endogenous pain stimuli.
   B.   Cation channels will continually remain closed and sensation of pain will be diminished in the presence of endogenous pain stimuli.
   C.   Cation channels will continually remain closed and sensation of pain will occur in the absence of endogenous pain stimuli.
   D.   Cation channels will continually remain open and sensation of pain will be diminished in the presence of endogenous pain stimuli.

158. Which of the following is likely to occur if an actively respiring muscle lowers the acidity of the environment in the vicinity of a nociceptive neuron to a pH value of 6.9?

    A. Protons will generate action potentials in the nociceptive neuron by binding and activating ion channels.

    B. Protons will generate action potentials in the nociceptive neuron by binding and activating G protein-coupled receptors.

    C. Protons will facilitate the generation of action potentials in the nociceptive neurons in response to the heat generated by the muscle.

    D. Protons will delay the generation of action potentials in the nociceptive neurons in response to noxious stimuli.

159. Nociceptors present in the peripheral tissues form synapses with neurons in the dorsal horn of the spinal cord. When nociceptors are stimulated, they release excitatory neurotransmitters that activate postsynaptic neurons in the spinal cord. One class of compounds known as opiates can exert analgesic effects by blocking the stimulation of postsynaptic neurons in the spinal cord. Which of the following may be the mechanism of action of opiates?

    A. Opiates inhibit enzymatically catalyzed cleavage of neurotransmitters secreted by the nociceptors.

    B. Opiates stimulate the release of neurotransmitters into the synaptic cleft.

    C. Opiates bind to G protein-coupled receptors on the postsynaptic neurons and generate an intracellular cascade that leads to inhibition of calcium channels.

    D. Opiates bind to G protein-coupled receptors on the postsynaptic neurons and generate an intracellular cascade that leads to activation of sodium channels.

160. Transmission of pain signals by nociceptors can be inhibited by all of the following EXCEPT:

    A. drugs that inhibit the release of ATP following tissue injury.

    B. drugs that improve the circulation and delivery of oxygen to the tissues.

    C. drugs that block ion channel receptors.

    D. drugs that block G protein-coupled receptors.

Questions 161 through 164 are **NOT** based on a descriptive passage.

161. What molecule is regenerated at the end of the citric acid cycle (or Krebs cycle)?

    A. Acetyl CoA

    B. Citrate

    C. Malate

    D. Oxaloacetate

162. A cell that normally has 2N chromosomes has what number of chromosomes at the end of the S phase of the cell cycle?

    A. 1N

    B. 2N

    C. 4N

    D. 8N

163. The structure of the organic intermediate in the propagation steps of the following reaction is:

$$CH_3CH_2CH\text{—}CH_2 + HBr \xrightarrow{\text{Peroxides}}$$

    A. $CH_3CH_2CH_2\overset{\bullet}{C}HBr$

    B. $CH_3CH_2\overset{\bullet}{C}HCH_3$

    C. $CH_3CH_2\overset{Br}{\underset{|}{C}}H\overset{\bullet}{C}H_2$

    D. $CH_3CH_2\overset{\bullet}{C}HCH_2Br$

164. Which of the following processes requires the presence of uracil?

    A. Transcription

    B. Translation

    C. Mitosis

    D. Conjugation

Passage V (Questions 165–170)

Electrophilic aromatic substitution (EAS) is a reaction in which there is substitution of an electrophile for a hydrogen on an aromatic ring. As shown in Figure 1, the reaction proceeds in two basic steps:

Step 1: Attack of the electrophile (E^+) upon the aromatic ring affording a resonance-stabilized carbocation called an arenium ion. The energy of activation for this step is high because aromaticity is lost.

Step 2: The arenium ion is deprotonated by a weak base (:B). The energy of activation for this deprotonation is exceptionally low as aromaticity is regained.
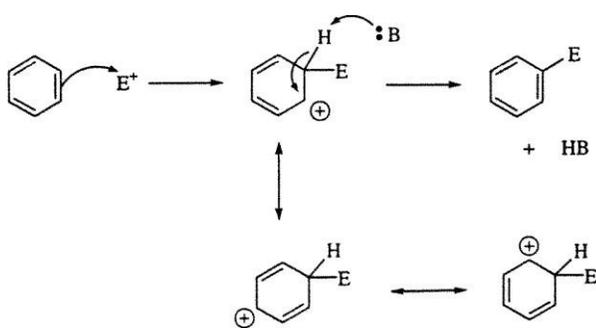
Figure 1

A student investigated the bromination of toluene, shown by Equation 1.
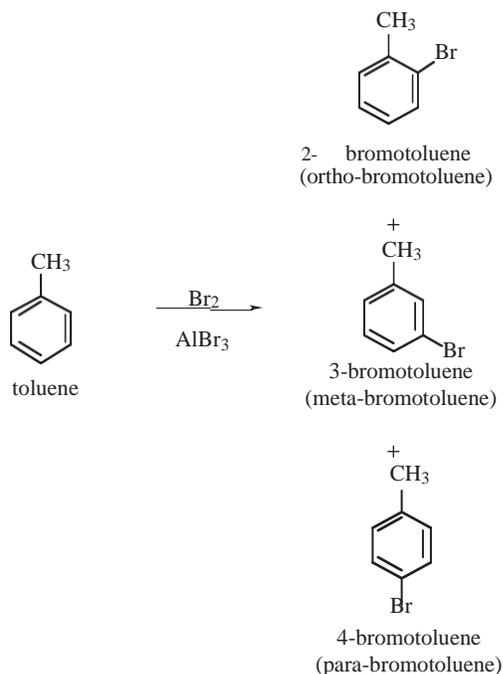
Equation 1

In the reaction, a solution of Br_2 in HNO_3 (5% in H_2O) was treated with toluene and the mixture was vigorously stirred for 15 min. Care was taken to exclude light by wrapping the flask in aluminum foil. The flask was uncovered and sodium sulfite (Na_2SO_3) was added to destroy excess Br_2. The mixture was extracted with diethyl ether, treated with Na_2CO_3, and dried over Mg_2SO_4. The products were analyzed directly by gas chromatography (GC).

In a second experiment, the student investigated the relative rates of bromination of benzene and toluene. The above experiment was repeated except a 2:1 mole ratio of benzene:toluene was substituted for the pure toluene. GC analysis of the product mixture showed approximately equimolar amounts of bromobenzene to bromotoluene.

A third experiment was performed in order to study the effect of changing the nature of the electrophile. The bromination of toluene was performed as described in Experiment 1 with the exception of the addition of an aqueous solution of silver nitrate $(AgNO_3)$ to the reaction mixture. The addition of silver ion changes the electrophile in this reaction from Br_2 to H_2OBr^+.

165. What product distribution is expected in Experiment 1?

    A. 2-bromotoluene (most) > 3-bromotoluene > 4-bromotoluene (least)

    B. 3-bromotoluene (most) > 4-bromotoluene > 2-bromotoluene (least)

    C. 4-bromotoluene (most) > 2-bromotoluene > 3-bromotoluene (least)

    D. All will be formed in equal amounts

166. What is the purpose of the $AlBr_3$ in the reaction?

    A. To generate a carbocation through electrophilic attack on the benzene ring

    B. To enhance the electrophilicity of Br_2 by strongly polarizing the Al-Br bond

    C. To enhance the electrophilicity of Br_2 by strongly depolarizing the Al-Br bond

    D. To act as a hydride acceptor following substitution of bromide for hydride on the benzene ring

GO ON TO THE NEXT PAGE.

167. Rank the following compounds in order of relative rate of EAS from fastest to slowest:

OCH$_3$

I. Anisole

CH$_3$

II. Toluene

NO$_2$
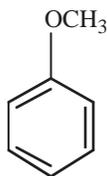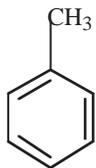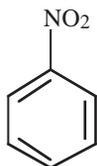
III. Nitrobenzene
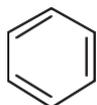
IV. Benzene

    A. IV > I > III > IV
    B. II > I >III > IV
    C. III > IV > II > I
    D. I > II > IV > III

168. Another student repeated Experiment 2 but forgot to cover the reaction flask with foil. How might this have affected the outcome?

    A. Bromotoluene would have been the major product because bromobenzene is sensitive to UV light and readily decomposes.

    B. Bromobenzene would have been the major product because UV light catalyzes the formation of dibromotoluene from bromotoluene and Br$_2$.

    C. Bromobenzene would have been the major product because UV light catalyzes the side-chain bromination of toluene through a radical mechanism.

    D. The product ratio would have been unaffected; however, the concentrations of both products would have decreased due to photodecomposition.

169. Compared to Experiment 1, the yield of bromo-toluene in Experiments 3 would be:

    A. greater because H$_2$OBr$^+$ is a stronger elec-trophile than Br$_2$.

    B. less because H$_2$OBr$^+$ is a weaker electrophile than Br$_2$.

    C. the same because the rate-limiting step is depro-tonation of the aromatic ring.

    D. less because of the lower solubility of H$_2$OBr$^+$ in H$_2$O compared with Br$_2$.

170. What is the representative potential energy diagram for the reaction in Experiment 1?

  A.

Reaction coordinate

  B.

Reaction coordinate

  C.

Energy

Reaction coordinate

  D.

Energy
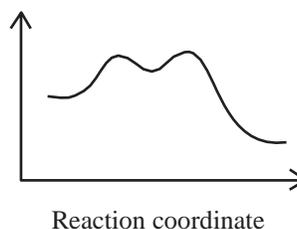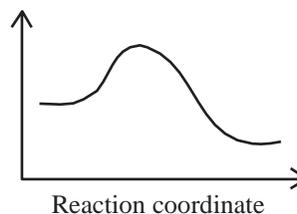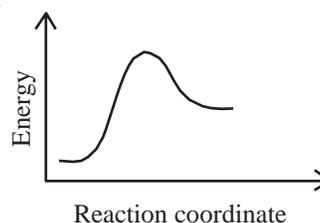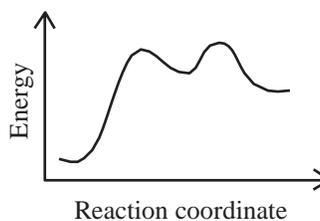
Reaction coordinate

Passage VI (Questions 171–175)

A patient's blood glucose concentration can often provide important information on diseases of glucose homeostasis, making glucose one of the most commonly measured components of blood. A continuing problem in the accurate measurement of glucose is the loss of glucose from specimens because of glycolysis by erythrocytes during transport and processing. The best method of preserving plasma glucose concentration long enough to be measured in a centralized laboratory must yield a specimen that is suitable for analysis of many other common analytes as well, so that separate collections are unnecessary.

To obtain an accurate measurement of glucose concentration several approaches have been proposed including refrigeration during transport, addition of antiglycolytic agents such as iodoacetate, fluoride or mannose, and near-patient glucose analyzers. The efficacy of such methods is limited by high cost, incomplete inhibition of glycolysis, interference in testing for co-analytes (i.e. electrolytes, creatinine, and urea) and disruption of plasma membrane integrity.

Glyceraldehyde (GA), known for its antiglycolytic properties, was among the compounds tested for the ability to preserve blood glucose concentration and its interference with measurement of various co-analytes. Whole blood specimens were collected in tubes containing sodium heparin as anticoagulant and either D,L-glyceraldehyde (D,L-GA) or an equal volume of saline. Figure 1 shows the course of glucose disappearance in the absence and presence of 10 mmol/L of D,L-GA.
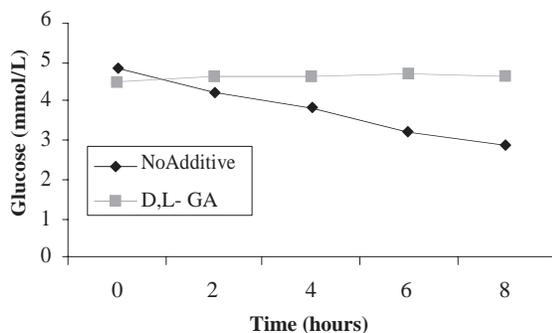
Figure 1

The potential for D,L-GA to interfere in testing for glucose and common co-analytes was explored by drawing blood from patients and adding 10 mmol/L D,L-GA or the same volume of saline. Table 1 lists the concentrations of co-analytes obtained in the presence and absence of D,L-GA.

Analyte	No additive	D,L-GA
Glucose mmol/L	11	10.9
Sodium mmol/L	142	142
Potassium mmol/L	4.5	4.6
Chloride mmol/L	110	110
Creatinine mmol/L	80	120
Calcium mmol/L	2.1	2.1
Urea mmol/L	6.4	6.5

Table 1 Effect of D,L-GA on glucose and other analytes

The racemic mixture of glyceraldehyde (D,L-GA) preserved glucose concentration for up to 8 hours at room temperature. Trials of the D and L stereoisomers individually indicated that the L isomer (L-GA) was responsible for all or most of the antiglycolytic activity of the racemic mixture.

171. Fluoride is a commonly used antiglycolytic agent used to preserve blood glucose concentration when a significant delay between collection and analysis is anticipated. However, fluoride can cause red blood cells to lyse, thus affecting plasma concentration of co-analytes. Plasma concentrations of which of the following analytes will be most significantly affected after addition of fluoride into blood specimens?

   A. Sodium ion
   B. Albumin
   C. Potassium ion
   D. Bicarbonate ion

172. Which of the following is the best approximation of the average rate of disappearance of glucose without addition of D,L-glyceraldehyde?

   A. 0.25 mmol/L per hour
   B. 0.50 mmol/L per hour
   C. 1 mmol/L per hour
   D. 5 mmol/L per hour

GO ON TO THE NEXT PAGE.

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173. A possible mechanism through which D,L-glycer-aldehyde exerts its effects on blood glucose concen-tration may involve:

    A. a decrease in insulin secretion that lowers the use of glucose by erythrocytes.

    B. an increase in the rate of glycolysis through stimulation of a glycolytic enzyme.

    C. an increase in the rate of gluconeogenesis in erythrocytes.

    D. inhibition of a glycolytic enzyme in erythro-cytes.

174. According to the information presented in the pas-sage, blood samples containing D,L-glyceraldehyde may yield reliable concentration values for all of the following EXCEPT:

    A. urea.

    B. calcium.

    C. creatinine.

    D. potassium.

175. If 30 mmol/L of racemic D,L-glyceraldehyde solu-tion is required to maintain constant plasma glucose concentration for a period of 12 hours, what concen-tration of L-glyceraldehyde is required to maintain glucose concentration for the same amount of time?

    A. 15 mmol/L

    B. 30 mmol/L

    C. 60 mmol/L

    D. 75 mmol/L

Passage VII (Questions 176–180)

Paralytics are a class of medications that selectively paralyze skeletal muscle. The most commonly used agents are succinylcholine chloride and vecuronium bromide. One reason these agents are preferred is that both vecuronium and succinylcholine molecules are quaternary amines with permanent positive charges. This permanent positive charge prevents them from crossing the blood brain barrier; therefore CNS side effects are avoided.

Paralytics that act at the neuromuscular junction may be classified as either depolarizing or non-depolarizing agents. Succinylcholine is a depolarizing agent. Acting at the acetylcholine binding site on the receptor, succinylcholine binds to the acetylcholine receptor in the neuromuscular junction, activating the receptor channel; this results in depolarization of the muscle cell. Acetylcholinesterase, the enzyme that degrades acetylcholine, does not degrade succinylcholine. Subsequently the receptor channel remains open and the muscle cell is unable to repolarize to respond to the next stimulus.

In contrast, vecuronium is a non-depolarizing agent. When vecuronium binds to the acetylcholine receptor, it prevents ACh from binding and activating the receptor channel. The binding of vecuronium itself does not activate the receptor so the target cell remains polarized and ready to contract. One advantage of vecuronium is that its effects can be rapidly reversed by administering an acetylcholinesterase inhibitor such as edrophonium. Inactivating acetylcholinesterase leads to a decrease in the breakdown of acetylcholine; this increases the acetylcholine concentration in the synaptic cleft. This increased concentration is more readily able to displace vecuronium from the acetylcholine receptor and stimulate a normal depolarization.

Great care must be taken when reversing the effects of vecuronium. Because acetylcholine and acetylcholinesterase are also found in the synapses of the parasympathetic nervous system, administering edrophonium may result in severe unwanted parasympathetic side effects. These side effects may be prevented or minimized by administering a parasympathetic blocker such as atropine sulfate before administering edrophonium.

176. The relationship of succinylcholine to acetylcholine and the acetylcholine receptor may best be described by stating that succinylcholine is a:

   A. competitive inhibitor of the ACh receptor channel.
   B. non-competitive inhibitor of the ACh receptor channel.
   C. competitive activator of the ACh receptor channel.
   D. non-competitive activator of the ACh receptor channel.

177. If a physician neglected to administer atropine sulfate prior to reversing vecuronium with edrophonium, the patient would most likely experience:

   A. increased heart rate and sweating.
   B. persistent paralysis.
   C. pupil dilation and decreased gastric motility.
   D. decreased heart rate and increased salivary secretion.

178. Botulinum toxin utilizes a different mechanism to induce chemical paralysis. Instead of acting on the receptor, Botulinum toxin induces paralysis by preventing the manufacture and release of acetylcholine in the axonal end bulb. Other possible mechanisms for inducing paralysis would include all of the following EXCEPT:

   A. destruction or loss of the acetylcholine receptors.
   B. severing the motor neural axons.
   C. preventing the release of Ca^{2+} from the sarcoplasmic reticulum.
   D. downregulation of the acetylcholinesterase gene.

179. Fasciculations are short-lived uncoordinated isolated contractions of individual skeletal muscle cells that are often described as a "bag of worms" because of the way they cause the skin to ripple. Would fasciculations be expected following administration of succinylcholine?

A. Yes, because succinylcholine binds to the receptor channel and this binding causes depolarization of the skeletal myocytes.

B. Yes, because succinylcholine binding causes a structural change in the receptor that allows ACh to bind and depolarize the myocytes.

C. No, because succinylcholine prevents ACh from binding, therefore no depolarization is possible.

D. No, because succinylcholine would suppress brain activity enough to prevent any random depolarizations.

180. Curare is a paralytic arrow poison used by South American Indian tribes and is made from the skin of certain species of frog. An early observation in curare research was that even when the injected animals were paralyzed, muscle contractions could still be stimulated with an external electrical impulse applied to the muscle itself. This finding suggests that curare acts on the:

    I. motor neural axon.
   II. acetylcholine receptor.
  III. myosin binding site on the actin filament.

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

Passage VIII (Questions 181–186)

A substitution reaction is one in which one atom or group of atoms is replaced by another atom or group of atoms. In a nucleophilic substitution, a nucleophile reacts with a compound displacing another nucleophile. A reaction for which the rate-determining step is unimolecular is an S_N1 reaction while S_N2 reactions involve a bimolecular rate-determining step. In an elimination reaction, portions of a molecule are lost, usually resulting in the formation of a new π-bond. If the mechanism is unimolecular it is termed E1 and if it is bimolecular it is termed E2.

Because the reactive part of a nucleophile or a base is an unshared electron pair, all nucleophiles are potential bases and all bases are potential nucleophiles. As such, nucleophilic substitution and elimination reactions often compete with one another.

For example, since the first step of an E1 reaction, formation of a carbocation, is the same as that of an S_N1 reaction, E1 and S_N1 reactions compete. E1 reactions are important when tertiary halides are subjected to solvolysis in polar solvents, especially at higher temperatures. The steps in the E1 reaction of tert-butyl chloride are the following:

Step 1:
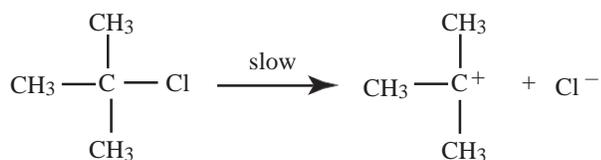
Step 2:
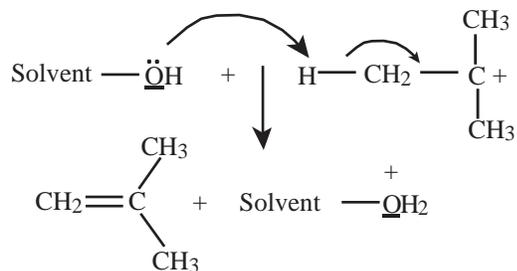
Similarly, E2 biomolecular elimination reactions often compete with S_N2 reactions. E2 reactions are favored by the use of a high concentration of a strong, bulky, and slightly polarizable base. The mechanism of an E2 reaction involves a single step:
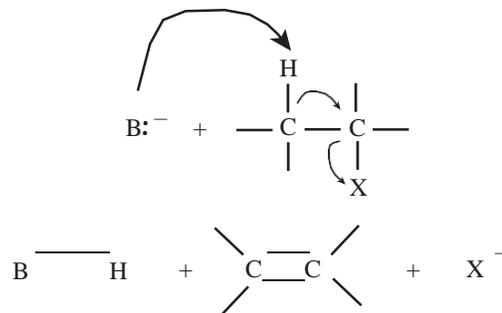
A chemistry student wishes to investigate the relationship between substitution and elimination by reacting a series of alkyl halides with various nucleophiles. Her results are shown in Table 1.

Table 1

Reactant	Conditions	Products
A	EtOH, 25ºC	
B	EtO⁻Na⁺, EtOH, 25ºC	
C	MeO⁻Na⁺ MeOH, 65ºC 12h	
D	tBuO⁻K⁺, tBuOH, 80ºC 20h	

181. In Reaction A, which elimination product is thermo-dynamically favored?
    A. $(CH_3)_2C=C(CH_3)_2$
    B. $Et(CH_3)C=CH_2$
    C. Both alkenes will be formed in equal amounts
    D. Product distribution can only be determined by experiment

182. In Reaction A, the elimination products are:
    A. configurational isomers.
    B. constitutional isomers.
    C. conformers.
    D. diastereomers.

183. The products of Reactions C and D are formed via:
    A. S_N1 and E1 mechanisms, respectively.
    B. S_N1 and E2 mechanisms, respectively.
    C. S_N2 and E1 mechanisms, respectively.
    D. S_N2 and E2 mechanisms, respectively.

184. The product distribution outcome in reactions C and D can be explained by:
    A. the low basicity of the *tert*-butoxide ion versus the methoxide ion
    B. the bulkiness of the *tert*-butoxide ion versus the methoxide ion
    C. the increased time and temperature of Reaction D compared to Reaction C
    D. All of the above

185. *n*-Butyl bromide reacts with sodium cyanide to give *n*-Butyl cyanide. Which solvent should be used to afford the fastest reaction rate?
    A. Water
    B. Methanol
    C. Dimethylformamide
    D. Formamide

186. Substitution reactions occur when nucleophiles react with electrophilic centers. A species Y is more nucle-ophilic than species Z when:
    A. Y is more electronegative than Z.
    B. Y is the negatively-charged conjugate base of the uncharged conjugate acid Z.
    C. Y is a smaller atom than Z.
    D. Y is less polarizable than Z.

187. What cells synthesize the components of cartilage?

    A. Chondrocytes
    B. Epiphyses
    C. Osteoblasts
    D. Osteoclasts

188. T lymphocyte-derived effector cells have all of the following roles EXCEPT:

    A. activation of B and T cells.
    B. destruction of antigens.
    C. downregulate B and T cell activity against antigens.
    D. recognition of an antigen upon secondary exposure to it.

189. In humans, hemophilia is an X-linked recessive allele. Affected males inherited the recessive allele from their mother. If a female who is a carrier for hemophilia mates with a male who is a hemophiliac, what percentage of their female children will be hemophiliacs?

    A. 0%
    B. 25%
    C. 50%
    D. 75%

190. Which of the following is an imine?

    A. $CH_3CH_2NHCH_3$

    B. $CH_3CH_2CH=NCH_3$

    C. $CH_3CH=CHN(CH_3)_2$

    D.
                 OH
                  |
    $CH_3CH_2CHNHCH_3$

191. Rank the following in order of decreasing acidity (most acidic first).

             Cl
             |
    $CH_3CH_2CHCO_2H$ $CH_3CH_2CHCO_2H$ $CH_3CHCH_2CO_2H$ (Cl above middle)
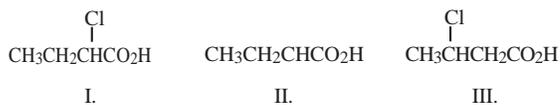
           I.   II.   III.

    A. II > I > III
    B. III > I > II
    C. I > III > II
    D. II > III > I

Passage IX (Questions 192–196)

The human eye perceives light through specialized photoreceptor cells in the retina. These photoreceptors are classified as either rod cells or cone cells. Rods are more abundant and are more sensitive to light at low light levels. However, they are monochrome and cannot distinguish between different colors. Cones, on the other hand, come in three varieties: red, blue, and green. Differential activation of these three kinds of cone cells allows the eyes to distinguish light of varying frequencies. Unlike rod cells, cones are less abundant and are active predominantly under relatively bright conditions.

Both rods and cones have the ability to undergo dark adaptation, the phenomenon by which a person's vision increases in sensitivity when he moves from a bright area into a dark room. However, due to the distinct characteristics of the two kinds of photoreceptors, rods and cones undergo dark adaptation in a different manner. An experiment was conducted to study this difference in effect.

A human subject sitting in a dark room was first asked to gaze at a pre-adapting white light for 5 minutes. Immediately afterwards, the light was shut off, putting the subject in complete darkness. After a specified period of time, a small light spot on the wall of the chamber was slowly brightened until the subject acknowledges its presence. This is known as the threshold intensity, the minimum level of luminance that is required for the subject to perceive the light. The same task is then repeated with the threshold intensity measured at different times after the onset of darkness. Four sets of these experiments were conducted, each with a different value for the intensity of the pre-adapting light. The results are plotted in Figure 1 shown below, with pre-adapting light intensity increasing from curve D to curve A.
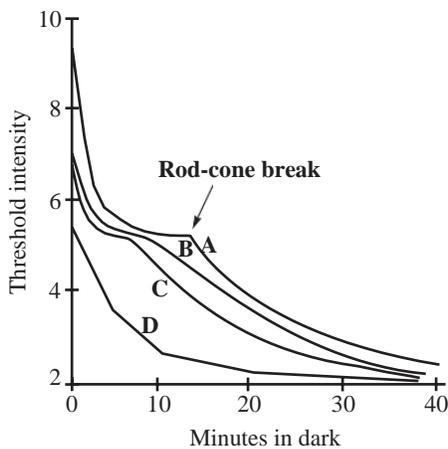

Figure 1

The investigator noted two-phases of dark adaptation, which he attributed to the two types of photoreceptors dominating the adaptation process at different levels of luminance. The point of inflection is termed the "rod-cone break", which divides the two phases of dark adaptation into the initial cone phase followed by the subsequent rod phase.

192. On which curve do the photoreceptors experience the greatest INCREASE in sensitivity during the first 40 minutes in the dark?

- **A.** Curve A
- **B.** Curve B
- **C.** Curve C
- **D.** Curve D

193. According to the experiment, at light intensities above the "rod-cone break" as shown in Figure 1:

- **A.** rod cells are no longer responsive to light.
- **B.** cone cells are no longer responsive to light.
- **C.** rod cells become more sensitive than cones.
- **D.** cone cells become more sensitive than rods.

194. Which of the following statements is supported by the results of this set of experiments?

- **A.** Cone adaptation occurs earlier at lower pre-adapting intensities.
- **B.** Rod adaptation occurs earlier at lower pre-adapting intensities.
- **C.** Cone adaptation does not occur at lower pre-adapting intensities.
- **D.** Rod adaptation does not occur at lower pre-adapting intensities.

195. A monochromatic color-blind subject (one who lacks all color vision) will always produce a dark-adaptation curve most similar to which curve?

    A. Curve A

    B. Curve B

    C. Curve C

    D. Curve D

196. Which of the following conclusions drawn from the experimental results is INCORRECT?

    A. Rods are always more sensitive than cones.

    B. Rods can achieve greater sensitivity than cones.

    C. Cones adapt faster than rods.

    D. An absolute threshold is reached by about 40 minutes following the onset of darkness.

Passage X (Questions 197–202)

A chemist is examining forensic evidence for a court case and needs to identify an analgesic (pain killer). A coffee cup containing a white, powdery substance has been submitted to her for drug analysis. She is told the drug is likely to be one of acetylsalicylic acid, ibuprofen, acetaminophen or phenacetin.

In order to identify the compound, it will be necessary to first separate the white drug from the coffee sludge at the bottom of the coffee cup. A quantity of hot, deionized water is added to a sample of the impure material and the suspension is stirred to dissolve the drug. The suspension is left to settle and the solution is decanted into a second flask. The undissolved material is washed with a second quantity of warm water and decanted into the flask containing the unknown. The flask is placed in an ice bath and colorless crystals accumulate. The crystals are filtered, washed with cold water, and dried. The melting point of the isolated material is determined to be 154–156°C. Addition of $FeCl_3$ to a $CHCl_3$ solution of the unknown confirms the presence of phenol (color change to violet).

The chemist performs a qualitative *Hinsberg Test* to determine the presence of secondary amine in the unknown drug. She dissolves a sample of the pure unknown in 10% KOH solution. Benzenesulfonyl chloride is added and the mixture is shaken vigorously. The solution separates into two phases and the organic layer is treated with 10% HCl. The absence of precipitate upon addition of HCl indicates the absence of 2° amine functionality in the unknown compound.

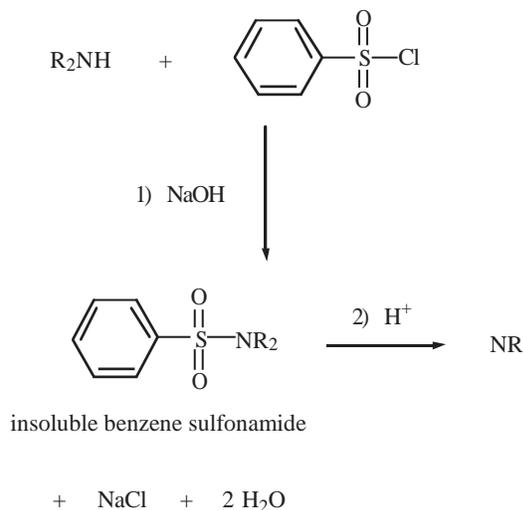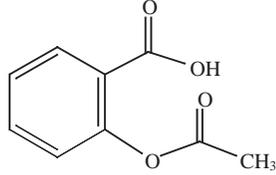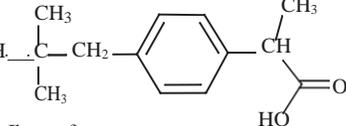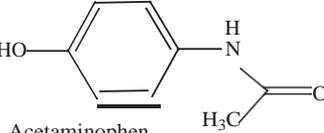The general reaction for the *Hinsberg Test* of a 2° amine is:

insoluble benzene sulfonamide

+ NaCl + 2 H$_2$O

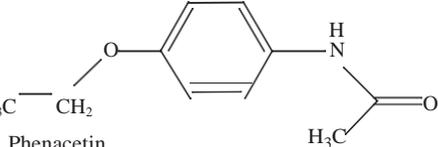**Table 1** Possible Structures of Unknown Drug

Compound	Mp (°C)
Acetylsalicylic acid	135-137
Ibuprofen	75-77
Acetaminophen	169-172
Phenacetin	134-137

197. The melting point and qualitative test results are not consistent with any of the compounds in Table 1. A likely explanation is that:

- **A.** the chemist did not obtain a pure compound.
- **B.** the unknown is the hydrolysis product of acetylsalicylic acid.
- **C.** the unknown is the hydrolysis product of acetaminophen.
- **D.** the unknown is a hygroscopic solid.

198. Acetaminophen is the metabolite of phenacetin. The conversion of acetaminophen into phenacetin is an example of the Williamson ether synthesis using a phenol as the alcohol. The net reaction is:

Acetaminophen

Phenacetin

$$+ \quad KI \quad + \quad KHCO_3$$
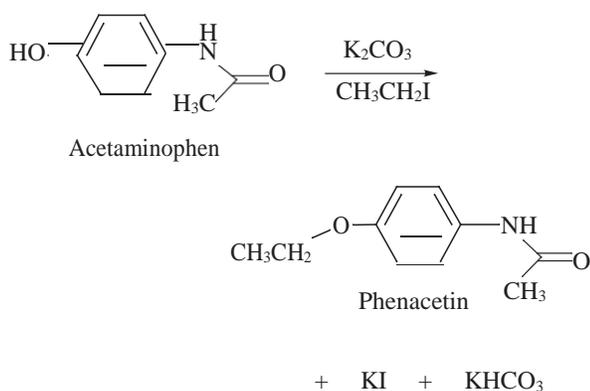
The mechanism for this reaction is:

- I. reaction of acetaminophen with carbonate to form the corresponding phenoxide ion followed by nucleophilic attack of phenoxide on ethyl iodide to form phenacetin
- II. electrophilic attack of ethyl iodide on acetominophen followed by hydride abstraction by carbonate
- III. S_N2
- **A.** I and II only
- **B.** II only
- **C.** III only
- **D.** I and III only

199. Which of the compounds in Table 1 is chiral?

- **A.** Acetylsalicylic acid
- **B.** Ibuprofen
- **C.** Acetaminophen
- **D.** Phenacetin

200. Is the *Hinsberg Test* useful for distinguishing 1°, 2° and 3° amines?

- **A.** No, because 1°, 2°, and 3° amines form insoluble benzene sulfonamides *before* acidification with HCl.
- **B.** No, because only 2° amines form insoluble sulfonamides *after* acidification with HCl.
- **C.** No, because only 2° amines form insoluble sulfonamides *before* acidification with HCl, while 1°, 2°, and 3° amines form insoluble benzene sulfonates *after* acidification with HCl.
- **D.** Yes, because 2° amines form insoluble benzene sulfonates before *before* acidification with HCl, 1° amines form insoluble benzene sulfonates *after* acidification with HCl and 3° amines do not form benzene sulfonates.

201. The Ferric Chloride qualitative test for phenol is carried out in the presence of pyridine (C_5H_5N). The purpose of pyridine in this reaction is to:

- **A.** oxidize Fe(II) to Fe(III).
- **B.** reduce Fe(III) to Fe(II).
- **C.** neutralize the HCl which is formed.
- **D.** abstract a proton from phenol.

202. The IUPAC name for acetaminophen is:

- **A.** N-(4-ethoxyphenyl) acetamide.
- **B.** N-(4-hydroxyphenyl) acetamide.
- **C.** 4-hydroxy benzoic acid.
- **D.** N-(4-hydroxyphenyl) propionic acid.

Passage XI (Questions 203–208)

In mice, an essential step in fertilization is the binding of acrosome-intact sperm to specific O-linked oligosaccharides on an egg's zona pellucida glycoprotein 3 (ZP3). O-linked oligosaccharides are sugar groups that are attached to proteins at serine and threonine residues by specific galactosyl transferases. While there is agreement on the primary role of O-linked oligosaccharides in sperm-ZP3 binding, there is a lack of consensus on the terminal monosaccharide(s) required for a functional binding site and the corresponding protein on the sperm cells surface that recognizes this ligand.

Hypothesis I

One hypothesis claims that O-linked oligosaccharides of ZP3 with a-galactosyl residues at their non-reducing termini mediate sperm binding to egg, and a 56-kDa peptide found on sperm called Sp56 is a complementary sugar-binding protein.

Hypothesis 2

According to another hypothesis, sperm-egg binding is mediated by interaction between sperm surface þ-galactosyltransferase and O-linked sugar chains of ZP3 with non-reducing terminal N-acetyl-glucosaminyl (GlcNAc) residues.

To study the carbohydrate recognition mechanism in fertilization, two experiments were conducted using mutant mice strains a and þ. Strain a has a mutation in the region of DNA coding for a-galactosyltransferase, an enzyme which adds nonreducing terminal a-galactosyl residues to sugars. Strain þ, on the other hand, has a mutation in a gene coding for þ-galactosyltransferase. In both strains, mutations eliminated the functions of affected enzymes.

In the first experiment the fertility of both strains was determined *in vivo* by crossing mutant and wild type mice. The results of this experiment are shown in Table 1.

Strain	Males	Females
a	fertile	fertile
þ	infertile	fertile

Table 1 Fertility of offspring from mutant/wild type cross

The second experiment involved measuring sperm-egg binding *in vitro*. In this experiment, eggs and sperm from the wild type and both mutant strains of mice were mixed in all possible combinations and the average number of sperm bound per egg after a specific, controlled series of washes was measured and recorded. The results are shown in Table 2.

		Sperm		
		Wild type	Strain a	Strain þ
Egg	Wild type	46	45	13
	Strain a	45	44	10
	Strain þ	45	46	11

Table 2 Average number of sperm bound per egg

203. The most reasonable conclusion that can be drawn from the experiments described in the passage is that:

- **A.** strain a can reproduce itself just as effectively as the wild type strain.
- **B.** strain þ males are infertile because their sperm cannot attach to eggs.
- **B.** þ-galactosyltransferase is needed for effective attachment of sperm to an egg.
- **D.** a-galactosyltransferase is unlikely to play a role in fertilization.

204. If a-galactosyl residues were essential for sperm-egg attachment then one would expect:

- **A.** strain a males to be infertile.
- **B.** strain þ males to be infertile.
- **C.** strain a females to be infertile.
- **D.** strain þ females to be infertile.

205. Which of the following findings supports Hypothesis 2?

    A. Sperm derived from strain þ males can fertilize eggs in vitro.

    B. Reagents modifying substrate specificity of þ-galactosyltransferase also inhibit sperm binding to zona pellucida.

    C. Removal of the N-acetyl-glucosaminyl residues from ZP3 does not affect sperm-egg binding.

    D. Placement of excess þ-galactosyltransferases in the medium does not interfere with sperm-egg attachment.

206. Which of the following experimental observations would provide evidence against Hypothesis 1?

    A. Strain a females are less fertile than wild type females.

    B. Strain a males are less fertile than wild type males.

    C. þ-galactosyl residues are involved in sperm-egg recognition.

    D. Removal of a-galactosyl residues from ZP3 does not affect sperm-egg binding.

207. A third experiment was conducted where proteins, isolated from mouse sperm membranes, were passed over a column of beads covalently attached to ZP3. Most of the proteins passed through the column, but one, a 56-kDa peptide, bound to the ZP3-coated beads. This observation will most likely:
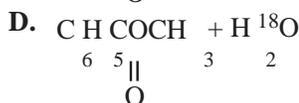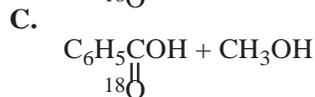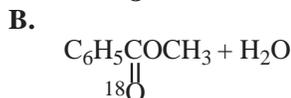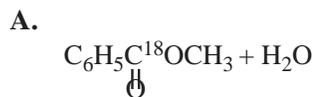
    A. provide evidence for a new model of sperm-egg attachment.

    B. challenge the conception that ZP3 is glycoprotein involved in sperm-egg binding.

    C. provide evidence to support Hypothesis 1.

    D. provide evidence to support Hypothesis 2

208. Based on the information presented in the passage, which of the following molecules will be the best candidate for a competitive inhibitor of sperm-egg interaction in mice?

    A. An oligosaccharide with N-acetyl-glucosaminyl residues

    B. An oligosaccharide with a-galactosyl residues

    C. An antibody to Sp56

    D. An antibody to þ-galactosyltransferase

Questions 209 through 214 are **NOT** based on a descriptive passage.

209. Reaction of benzoic acid ($C_6H_5CO_2H$) with $CH_3{}^{18}OH$ in the presence of an acid catalyst yields: [^{18}O = mass-18 isotope of oxygen]

    A.
$$C_6H_5\overset{\underset{\|}{O}}{C}{}^{18}OCH_3 + H_2O$$

    B.
$$C_6H_5\overset{\underset{\|}{{}^{18}O}}{C}OCH_3 + H_2O$$

    C.
$$C_6H_5\overset{\underset{\|}{{}^{18}O}}{C}OH + CH_3OH$$

    D.
$$C_6H_5\overset{\underset{\|}{O}}{C}OCH_3 + H_2{}^{18}O$$

210. The carbohydrate shown belongs to the D-series because:
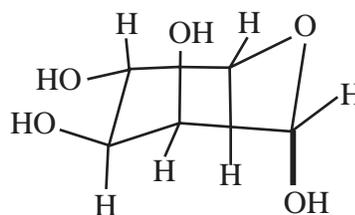
    A. The compound rotates plane-polarized light in the (+) direction

    B. The configuration at the anomeric carbon is analogous to that of D-glyceraldehyde

    C. The OH group at C-4 is to the right in the open-chain Fischer projection

    D. The OH group at C-5 is to the right in the open-chain Fischer projection

211. What is the correct IUPAC name for the compound below?

$$CH_3CHCH_2CH_2CHCH_3$$

$$\quad CH_2CH_3 \qquad CH_2CH(CH_3)_2$$
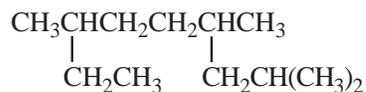
- **A.** 2-ethyl-5-isobutylhexane
- **B.** 5-*sec*-butyl-2-ethylhexane
- **C.** 2,4,7-trimethylnonane
- **D.** 2-ethyl-5,7-dimethyloctane

212. Which of the following strands of DNA, when paired with its complementary strand, would have the highest melting point?

- **A.** ACTACTA
- **B.** TCGATAT
- **C.** CATGTAG
- **D.** GACGACT

213. Which of the following conditions increases the affinity of hemoglobin for oxygen?

- I.   Increased H^+ concentration in the blood
- II. Increased CO_2 concentration in the blood
- III. Increased O_2 concentration in the alveolar capillaries

- **A.** II only
- **B.** III only
- **C.** II and III only
- **D.** I, II, and III

214. Which of the following structures is derived from the same germ layer as muscle?

- **A.** Skin
- **B.** Heart
- **C.** Spinal cord
- **D.** Pancreas

STOP. IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK. YOU MAY GO BACK TO ANY QUESTION IN THIS SECTION ONLY.