Passage I (Questions 66–71)

Resistors and capacitors are two of the elementary components of an electronic circuit. A circuit containing a "black box" element is shown in Figure 1 below. In a "black box" circuit, a variety of different connections can be made between two arbitrary points. In the diagrammed circuit, a battery, B, sets up a current, I. The black box contains two points, a and b, which are connected to either resistors or capacitors. This experimental setup, diagrammed below, was used to carry out two experiments.

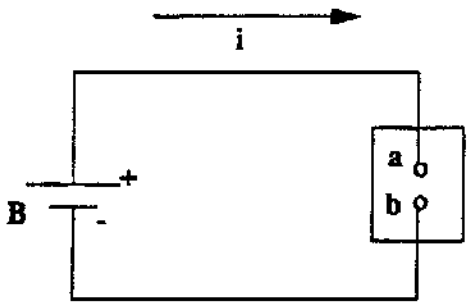


Figure 1. A circuit containing a "black box" element.

Experiment I

Points a and b were attached to two resistors with resistances of R and $2R$, respectively.

Experiment II

Points a and b were attached to two capacitors with capacitances of C, and $2C$, respectively.

66. In experiment I, the two resistors were connected in parallel. The current through the resistor with resistance $2R$ is what fraction of the current through the resistor with resistance R?

A. ½
B. 1
C. 2
D. 4

67. Based on experiment II, in which the two capacitors were connected in parallel, which one of the following statements is FALSE?

A. The potential difference across each capacitor is the same.
B. The magnitude of charge on each plate is the same.
C. The effective capacitance of the two capacitors is proportional to the total charge on the combination of capacitors.
D. The charge on each capacitor is proportional to the total voltage drop across a and b.

68. Consider experiment II. A dielectric slab, with dielectric constant k, is placed between the plates of one of the capacitors in the circuit. In which capacitor must the dielectric slab be placed, and what must be its value so that the two capacitors have equal capacitance?

A. C capacitor; k – ½
B. C capacitor; k = 2
C. 2C capacitor; k = ½
D. 2C capacitor; k – 2

69. The battery in experiment I is replaced by an alternating current source. The time dependence of the current source can be described by the following equation:

$$I - I_{max}\sin\omega t$$

In this equation, I is the instantaneous current at time t, I_{max} is the maximum current, and ω is the angular frequency of the oscillation. Which one of the following statements does NOT correctly describe the behavior of this circuit?

A. The average power delivered over one cycle is 0.
B. The root-mean-square (rms) current is equal to 0.707 times the maximum current.
C. For the resistors of unit resistance and in a series configuration, the maximum current is equal to 0.707 times the rms voltage.
D. The current averaged over one cycle is 0.

70. The resistor of resistance $2R$ in experiment I is replaced with a capacitor of capacitance C. These two elements are attached in series and allowed to reach equilibrium under the influence of the battery. After equilibrium has been reached, the battery is replaced by a resistance free wire. The resulting circuit is now referred to as an RC circuit. Which one of the following statements is NOT an accurate description of an RC circuit?

- **A.** The direction of current flow in the RC circuit is opposite to the current flow that occurs in the presence of the battery.
- **B.** The sum of the voltage drop across the resistor and capacitor is 0.
- **C.** At a time equal to RC after the battery has been removed, the capacitor charge is reduced to 1/e of its initial charge, where $e = 2.718$.
- **D.** The time required for the charge on the capacitor in an RC circuit to fall to a given fraction of its value depends on the value of the initial applied EMF.

71. Suppose that a single capacitor is present in a simple circuit. The plates of the capacitor are found to have a potential difference of 800 V. If the capacitance is found to be 1×10^{-11} farads, how much charge is stored on each plate?

- **A.** 8×10^{-9} C
- **B.** 1.25×10^{9} C
- **C.** 8×10^{8} C
- **D.** 1.25×10^{-8} C

Passage II (Questions 72–77)

The 1890s marked the beginning of the serious study of radioactivity. Radiation is the transmission of energy through space in the form of waves. Radioactive substances will spontaneously decay to emit radiation. This is not, however, the only way in which radiation can be produced. Radiation can also be produced when a cathode ray strikes various substances.

Radioactive substances can produce three different types of rays, which have been classified as alpha, beta, and gamma rays. Figure 1 demonstrates the different behavior of these types of rays when traveling in an electric field.

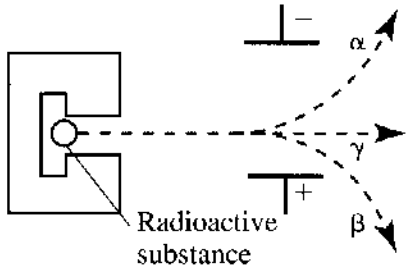


Figure 1

It is known now that an alpha ray is a helium ion (He^{2+}), and a beta ray is an electron. Elements that release alpha particles as they decay tend to change atomic number because they lose two protons as demonstrated by the following equation:

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

Elements that release beta particles also change atomic number because the source of the beta particle is the nucleus rather than an orbital. A beta particle is released when a neutron is converted to a proton. An example reaction follows:

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta$$

These two types of radiation are observed for elements that vary from a stable ratio of neutrons to protons. Stable elements of low atomic mass tend to have an equal or nearly equal number of protons and neutrons. Stable elements of higher atomic mass (i.e., more than 24 protons) tend to have a greater number of neutrons than protons. The unstable elements tend to undergo radioactive decay to approach these stable ratios of neutrons to protons.

72. Which one of the following equations could represent the loss of a beta particle by zirconium-97?

A. $^{97}_{97}Zr \rightarrow {}^{97}_{96}Zr + {}^{0}_{-1}\beta$
B. $^{97}_{97}Zr \rightarrow {}^{97}_{98}Zr + {}^{0}_{-1}\beta$
C. $^{97}_{40}Zr \rightarrow {}^{97}_{42}Mo + {}^{0}_{1}\beta$
D. $^{97}_{40}Zr \rightarrow {}^{97}_{41}Nb + {}^{0}_{-1}\beta$

73. What ratio of neutrons to protons should a stable isotope of gold have?

A. Greater than 1
B. Equal to 1
C. Less than 1
D. Equal to 0

74. Which of the following equations could represent the loss of an alpha particle by polonium-214?

A. $^{214}_{84}Po \rightarrow {}^{210}_{82}Pb + {}^{4}_{2}He$
B. $^{214}_{84}Po \rightarrow {}^{218}_{86}Rn + {}^{4}_{2}He$
C. $^{214}_{84}Po \rightarrow {}^{210}_{86}Rn + {}^{4}_{2}He$
D. $^{214}_{84}Po \rightarrow {}^{215}_{82}Pb + {}^{4}_{2}He$

75. What type of decay would potassium-40 be expected to undergo?

A. Alpha-particle emission to increase the neutron-to-proton ratio
B. Alpha-particle emission to decrease the neutron-to-proton ratio
C. Beta-particle emission to increase the neutron-to-proton ratio
D. Beta-particle emission to decrease the neutron-to-proton ratio

76. Which of the following is the most likely charge on a gamma ray particle?

A. − 1
B. 0
C. + 1
D. + 2

77. Why do stable elements of high molecular weight have a greater number of neutrons than protons?

A. The neutrons help hold the nucleus together because of attractive forces.
B. The protons are attracted to the neutrons, which holds the nucleus together.
C. The neutrons help separate the protons, which helps decrease the amount of charge repulsion.
D. The extra neutrons help to hold the electrons closer to the nucleus.

Passage III (Questions 78–82)

A simple pendulum can be constructed using a small mass attached to one end of a string of negligible mass. The other end of the string is attached to a solid surface from which it can swing freely. The following experiment was performed to examine some properties of this system under collision and free fall.

Experiment

Two small spheres, A and B, of mass M and 4M, respectively, hang from the ceiling by strings of equal length, L (Figure 1). Sphere A is drawn aside so that it is raised to a height, h_o, as shown in the diagram below. After being drawn aside, sphere A is released and collides with sphere B. Once the spheres collide, they adhere to each other. This system can now be thought of as a simple pendulum system with total mass 5M. The 5M mass now travels to a maximum height, h, on the opposite side of the swing. Once it reaches maximum height, the 5M mass detaches from the string and falls to the floor under the force of gravity.

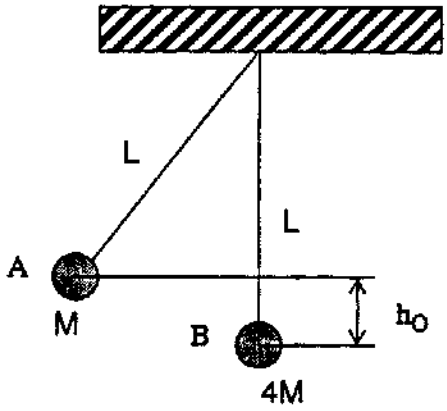


Figure 1. The simple pendulum experiment.

78. Which of the following is the total energy of sphere A just before it is released?

A. Mgh_o
B. $(\frac{1}{2})Mgh_o$
C. $4Mgh_o$
D. $5Mgh_o$

79. As sphere A swings down towards sphere B, the potential energy of sphere A is converted into kinetic energy. If the mass of sphere A was doubled, how would the velocity of sphere A be affected just before it collides with sphere B?

A. It would not change.
B. It would double.
C. It would halve.
D. It would be four times as great.

80. The spheres stick together after the collision. What is the maximum height, h, that they can achieve?

A. $1/2(h_o)$
B. $1/4(h_o)$
C. $1/5(h_o)$
D. $1/25(h_o)$

81. Consider the path of the 5M mass described in the passage. Neglecting air resistance, which of the following statements is NOT a good representation of the ensuing trajectory as the 5M mass falls towards the ground?

A. The velocity along the horizontal direction is 0 throughout the trajectory.
B. The time it takes to fall to the ground is a function of the total height above the ground.
C. If the sphere has a mass of 10M instead of 5M, it would fall to the ground at the same rate.
D. None of the above, because statements A through C all are true.

82. Two important principles for analysis of collisions between idealized bodies are the conservation of energy and momentum. Considering these principles, all of the following statements are true EXCEPT:

A. conservation of energy holds whenever the work done by the nonconservative forces is 0.
B. when the resultant external force acting on a system is 0, the total vector momentum is conserved.
C. in a completely elastic collision, both the momentum and the kinetic energy are conserved.
D. in a completely elastic collision, the final velocities of the two colliding bodies are equal.

Passage IV (Questions 83–87)

The sulfur oxide compounds are important in both atmospheric science and industry. There are numerous sulfur oxide compounds and reactions to consider. Sulfur dioxide (SO_2) and sulfur trioxide (SO_3) react with water to give sulfurous acid (H_2SO_3) and sulfuric acid (H_2SO_4). When these compounds are present in the atmosphere, the pH of rainfall drops from approximately 5.5 to 4.0. Sulfur dioxide comes from several sources, both natural and synthetic. Natural SO_2 is emitted during volcanic eruptions. Synthetic SO_2 is given off during smelting and other industrial processes.

Smelting begins by heating metal sulfides in air as shown in reaction 1. Metal oxides are more easily reduced to the free metal.

Sulfur dioxide can be oxidized to sulfur trioxide by the path outlined in reaction 2, or by that outlined in reactions 3 through 5. Note that reactions 3 through 5 demonstrate the various steps of a mechanism. A third pathway requires dust or another solid particle to act as a catalyst for reaction 6.

Reaction 1

$$2\ ZnS(s) + 3\ O_2(g) \rightarrow 2\ ZnO(s) + 2\ SO_2(g)$$

Reaction 2

$$SO_2(g) + O_3(g) \rightarrow SO_3(g) + O_2(g)$$

Reaction 3

$$SO_2(g) + h\nu \rightarrow SO_2^{+}(g)$$

Reaction 4

$$SO_2(g) + O_2(g) \rightarrow SO_4(g)$$

Reaction 5

$$SO_4(g) + SO_2(g) \rightarrow 2\ SO_3(g)$$

Reaction 6

$$2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$$

83. Which of the following reactions has a negative entropy change?

A. Reaction 1
B. Reaction 2
C. Reaction 3
D. Reaction 5

84. Which of the following reactions is endothermic?

A. Reaction 2
B. Reaction 3
C. Reaction 4
D. Reaction 5

85. Which of the following species is a reactive intermediate?

A. SO_2^-
B. SO_3
C. SO_x
D. H_2SO_4

86. Why is reaction 1 an important step in the production of metals?

A. Metal sulfides are easier to reduce.
B. Metal sulfides are easier to oxidize.
C. Metal oxides are easier to reduce.
D. Metal oxides are easier to oxidize.

87. What is the difference in hydrogen ion concentration between normal rain and acid rain?

A. -9.7×10^{-5}
B. 9.7×10^{-5}
C. 1.5
D. -1.5

Questions 88 through 91 are **NOT** based on a descriptive passage.

88. An object initially at rest is dropped from a height, h. The ratio of its velocity after it has fallen half of the distance to the ground over the final velocity when it reaches the ground is:

A. 0.25
B. 0.50
C. 0.71
D. 0.87

89. A vessel is filled with a gaseous mixture of ammonia, hydrogen, and nitrogen at equilibrium. An analysis of the gases shows that $[NH_3] = 0.1M$, $[N_2] = 0.2M$, and $[H_2] = 0.3M$. The equilibrium constant for the decomposition of ammonia gas to nitrogen and hydrogen gas is best given by:

A. $(0.2)(0.3)^2/(0.1)$.
B. $(0.1)^2/(0.2)(0.3)^3$.
C. $(0.1)/(0.2)^2(0.3)^3$.
D. $(0.2)(0.3)^3/(0.1)^2$.

90. Two objects of identical mass and radius, a solid sphere and a hollow sphere, are released from rest at the top of an incline. At the base of the incline, which will have the larger linear velocity, and which will have the larger rotational kinetic energy, respectively?

A. Solid sphere, solid sphere
B. Solid sphere, hollow sphere
C. Hollow sphere, solid sphere
D. Hollow sphere, hollow sphere

91. Catalysts speed the rates of chemical reactions by lowering the activation energy associated with the reactions. Which of the following statements accurately describes an additional feature of catalysts?

A. They may alter equilibrium concentrations.
B. They favor the forward reaction.
C. The equilibrium is displaced to the more energetically favorable product.
D. The forward and backward reaction rates are accelerated equally.

Passage V (Questions 92–97)

Ammonia is a valuable raw material in the manufacturing of fertilizers and explosives. Ammonia consists of nitrogen and hydrogen atoms, and the synthesis from nitrogen and hydrogen gas is desirable and inexpensive. This synthesis was completed in 1905 by Fritz Haber and is known as the Haber process (Reaction 1).

Reaction 1

$$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$$

Haber discovered the optimal temperature and pressure for the reaction. Table 1 summarizes some of the data he collected.

Table 1. Variation with temperature of the equilibrium constant for the synthesis of ammonia.

Temperature (°C)	Equilibrium constant (K_c)
25	6.0×10^5
200	0.65
300	0.011
400	6.2×10^{-4}
500	7.4×10^{-5}

Figure 1 shows the yield of ammonia according to temperature. Figure 2 shows the mole percent of ammonia as a function of the total pressure of the system.

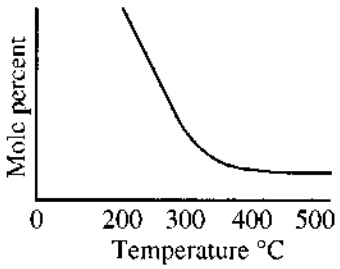


Figure 1. Mole percent of ammonia at equilibrium as a function of temperature.

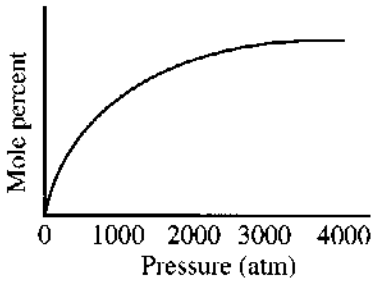


Figure 2. Mole percent of ammonia at equilibrium as a function of pressure.

Table 2 gives the boiling points for ammonia, nitrogen, and hydrogen.

Table 2. Physical properties for hydrogen, nitrogen, and ammonia.

Compound	Boiling point (°C)
Hydrogen	−252.8
Nitrogen	−195.8
Ammonia	−33.5

92. Which of the following statements regarding the entropy of reaction 1 is true?

- **A.** The entropy of the reaction is positive.
- **B.** The entropy of the reaction is negative.
- **C.** The entropy of the reaction is 0.
- **D.** No conclusions about the entropy can be made.

93. Evaluation of the data in Figure 1 leads to the conclusion that:

- **A.** the yield increases with decreasing temperature because the reaction is endothermic.
- **B.** the yield increases with decreasing temperature because the reaction is exothermic.
- **C.** the yield increases with increasing temperature because the reaction is endothermic.
- **D.** the yield increases with increasing temperature because the reaction is exothermic.

94. Based on the data in Figure 2, what conclusion can be made?

A. The yield increases with increasing pressure because of the favorable enthalpy change.
B. The yield decreases with increasing pressure because of the unfavorable enthalpy change.
C. The yield increases with increasing pressure because of the number of moles of gas produced.
D. The yield decreases with increasing pressure because of the number of moles of gas produced.

95. If the reaction were run at 50°C, which of the following statements would be true?

A. The ammonia would liquefy as it forms, pulling the equilibrium to the left.
B. The ammonia would liquefy as it forms, pulling the equilibrium to the right.
C. The gases would liquefy as it forms, stopping the reaction before reaching equilibrium.
D. The ammonia would liquefy as it forms, having no effect on the equilibrium.

96. Why is the reaction run at 500°C, rather than 25°C, in the industrial process?

A. A higher yield results.
B. A faster reaction occurs.
C. A higher yield results, and the reaction occurs faster.
D. A slower, more controllable reaction occurs.

97. If a mixture of 1 mole H_2, 2 moles N_2, and 3 moles NH_3 were placed in an airtight container at 25°C, what changes would occur as the system reaches equilibrium?

A. The concentration of ammonia would increase, and the concentrations of hydrogen and nitrogen would remain the same.
B. The concentrations of hydrogen and nitrogen would increase, and the concentration of ammonia would remain the same.
C. The concentration of ammonia would increase, and the concentrations of hydrogen and nitrogen would decrease.
D. The concentrations of nitrogen and hydrogen would increase, and the concentration of ammonia would decrease.

Passage VI (Questions 98–102)

Light can be defined as that part of the electromagnetic spectrum that can stimulate photoreceptors in the eye. The typical range of the normal human vision corresponds to electromagnetic radiation ranging from 400 nm (violet) to 700 nm (red). This constitutes the visible part of the electromagnetic spectrum.

There are several features of the electromagnetic spectrum that are important in understanding the properties of light. Electromagnetic radiation can be propagated through a vacuum in the form of electromagnetic waves. The energy of an electromagnetic wave is equally divided between an electric field and a mutually perpendicular magnetic field. Both of these fields are perpendicular to the direction of propagation.

All electromagnetic waves travel through a vacuum with the same speed, $c = 3.0 \times 10^8$ m/s, called the speed of light. When electromagnetic radiation travels through a transparent physical medium, it no longer travels at the speed of light. It obeys the dispersion relation, $\lambda f = v$, where λ is the wavelength, f is the frequency, and v is the speed of light. Differences in the optical density of various physical materials give rise to a value known as the index of refraction. By definition, the index of refraction, n, is the speed of light, c, through a vacuum divided by the speed of light, v, in a transparent substance.

The difference in the speed of light in different media gives rise to a phenomenon known as refraction. In refraction, bending of light occurs as it crosses obliquely from one medium to another.

98. A plane-polarized electromagnetic wave propagates in free space. This is an example of what type of wave?

A. Standing wave
B. Longitudinal wave
C. Transverse wave
D. Mechanical wave

99. Light can be piped from one point to another with little loss by allowing it to enter one end of a transparent fiber. The light undergoes total internal reflection at the boundary of the fiber and will follow its contour, emerging at its far end. Bundles of such fibers form the basis of fiber optics techniques. If one fiber with refractive index n is operated in air, what relation must the incident angle of the transported light, θ_i, satisfy in order to achieve transmission of the light along the optical fiber?

A. $\sin\theta_i \geq 1/n$
B. $\sin\theta_i \geq n$
C. $\sin\theta_i \leq 1/n$
D. $\sin\theta_i = 1/n$

100. An observer is able to measure the wavelength of a light ray as it goes from air into a medium of unknown index of refraction. The incident light ray is red, whereas the wavelength of the light in the medium is consistent with violet light. What must be the value of n?

A. 4/7
B. 7/4
C. 4
D. 7

101. In addition to waves, electromagnetic radiation can be described in terms of massless particles called photons. For an electromagnetic wave whose electric and magnetic fields oscillate at frequency, f_w, how will the frequency of its constituent photons, f_p, vary if f_w is increased?

A. It would increase.
B. It would decrease.
C. It would stay the same.
D. It is not possible to determine, because f_w and f_p are not related.

102. White light strikes a glass prism. On exiting the prism, the light beam is dispersed into a typical rainbow spectrum. The spectrum of light is then projected onto a viewing screen, such that the most refracted component of the white light is at the top of the screen. Which of the following *incorrectly* describes the behavior of the exiting and entering light rays as they related to the viewing screen?

A. Highest wavelength light at bottom; lowest wavelength light at top
B. Lowest energy light at bottom; highest energy light at top
C. Light waves bent away from the normal on entering the prism; light waves bent toward the normal on exiting the prism
D. None of the above

Passage VII (Questions 103–109)

The efficient use of solar energy relies upon efficient conversion of light energy into heat energy. One method for performing this conversion involves two types of energy exchange. First, the light energy is used to drive an endothermic reaction. This converts the light energy to chemical energy. The reverse of the endothermic reaction then occurs, releasing heat.

One such chemical system that can be used for this type of energy conversion sequence is the decomposition of sulfur trioxide. The reactions involved are shown in reactions 1 and 2.

Reaction 1

$$2\ SO_3(g) \rightarrow 2\ SO_2(g) + O_2(g)$$
$$\Delta H = 198\ kJ$$

Reaction 2

$$2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$$

One key feature for this type of solar energy conversion is that it can be a closed system. No reagents need to be added or removed. A second benefit is that reaction 2 requires the presence of a platinum catalyst. This allows the system to be used to store light energy until it is needed. Figure 1 shows how this system might be implemented.

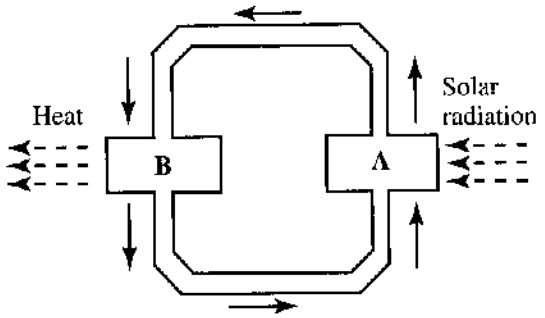


Figure 1. Closed system for energy conversion.

103. Which of the following reactions would occur in Figure 1 at region A?

A. Reaction 1 only
B. Reaction 2 only
C. Reactions 1 and 2
D. Neither reaction 1 nor reaction 2

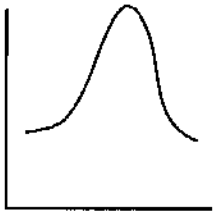
104. Which of the following reactions would occur in Figure 1 at region B?

A. Reaction 1 only
B. Reaction 2 only
C. Reactions 1 and 2
D. Neither reaction 1 nor reaction 2

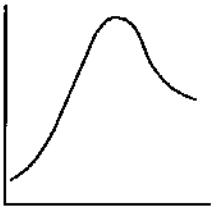
105. The change in enthalpy, ΔH, for reaction 2 is closest to:

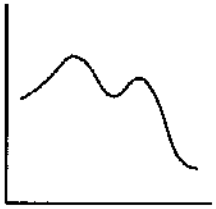
A. 198 kJ.
B. 396 kJ.
C. −198 kJ.
D. −396 kJ.

106. Which of the following diagrams is most likely to represent the energy of reaction 1 as the reaction proceeds?

A.


B.

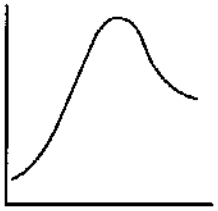

C.


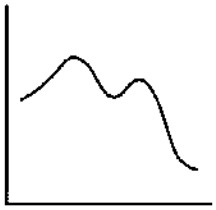
D.


107. Which of the following diagrams is most likely to represent the energy of reaction 2 without the presence of platinum?

A.


B.

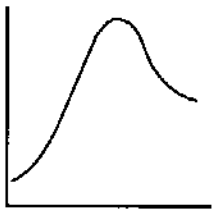

C.


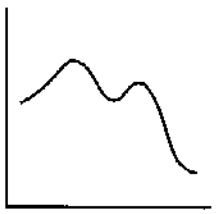
D.


108. Which of the following diagrams is most likely to represent the energy of reaction 2 with platinum present?

A.


B.


C.


D.


109. Which of the following statements best describes how light can drive a reaction?

A. Light is actually used to heat up the reaction chamber, which allows the reaction to proceed.
B. Light bounces off the molecules, pushing them together more energetically.
C. Some molecules absorb light of certain wavelengths, becoming more energetic.
D. Molecules all absorb light, becoming more energetic.

Passage VIII (Questions 110–114)

In 1921, Albert Einstein received the Nobel Prize for his contributions to theoretical physics, and especially for his discovery of the law of the photoelectric effect. This phenomenon, first discovered by Heinrich Hertz in 1887 and later painstakingly investigated experimentally by R. A. Millikan, refers to the observation that when light of sufficiently high energy is incident on a metal in a vacuum, the metal emits electrons.

Figure 1 depicts the apparatus used to study the photoelectric effect.

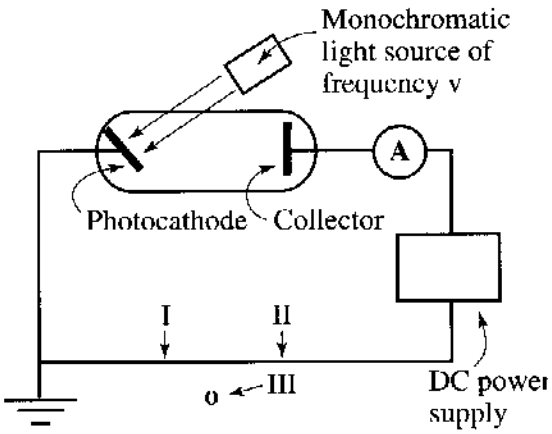


Figure 1. Apparatus used to study the photoelectric effect.

In this apparatus, the photocathode is induced to release electrons by the application of photons of frequency, ν. The potential of the collector, V, measured relative to ground, can be varied continuously. The effect is described by Einstein's photoelectric equation:

$$eV = h\nu - W,$$

where W is the work function of the metal, and e is the charge of an electron. The work function equals the minimum energy required to eject an electron, and e has a value of 1.6×10^{-19} Coulombs. Other constants of importance are h and c: $h = 4.14 \times 10^{-15}$ eVsec, and $c = 3.00 \times 10^{8}$ m/s.

110. The photoelectric effect is derived under the assumption that:

- **A.** electrons are restricted to orbits of angular momentum $nh/2\pi$ where n is an integer and h is Planck's constant.
- **B.** electrons are associated with waves of wavelength $\lambda = h/p$, where p is the momentum.
- **C.** light behaves like a wave.
- **D.** light is absorbed in quanta of energy, where $E = h\nu$.

111. The quantity, W, in the photoelectric equation is the:

- **A.** energy difference between the two lowest electron orbits in the atoms of the photocathode.
- **B.** total light energy absorbed by the photocathode during the measurement.
- **C.** minimum energy a photon must have to be absorbed by the photocathode.
- **D.** minimum energy required to free an electron from its binding to the cathode material.

112. A metal with the work function of 3.00 eV, is used for the construction of the photocathode and collector. If violet light of wavelength 400 nm is used, will there be photoejection of electrons? [Assume 1 eV = 1.6×10^{-19} joules.]

- **A.** Yes, because the energy of the incident photons is higher than the work function.
- **B.** Yes, because the energy of the incident photons equals the work function.
- **C.** No, because the energy of the incident photons is lower than the work function.
- **D.** There is not enough information to determine an answer.

113. Electrons liberated from the metal by the photoelectric effect produce a net charge flow per unit time, or a current. Consider Figure 1 shown in the passage. Assume that the portion of the diagram lying between points I and II can be treated as an isolated wire carrying current. Which of the following statements best describes the direction of the current and the induced magnetic field at point III?

- **A.** Current flows from point I to point II, whereas the magnetic field is directed out of the page at point III.
- **B.** Current flows from point I to point II, whereas the magnetic field is directed into the page at point III.
- **C.** Current flows from point II to point I, whereas the magnetic field is directed into the page at point III.
- **D.** Current flows from point II to point I, whereas the magnetic field is directed out of the page at point III.

114. Assume that the work function of the metal and the incident frequency are matched such that there is a steady current caused by the flow of the ejected electrons. How will the intensity of the incident light beam (i.e., the number of photons per unit time that fall on the cathode) relate to the system?

A. The induced current will be proportional to the intensity of the incident light beam.
B. The induced current will be inversely proportional to the intensity of the incident light beam.
C. The kinetic energy of the photoejected electrons will be higher if the intensity of the incident light beam is increased.
D. An increase in the intensity of the incident light will decrease the work function of the metal.

Questions 115 through 118 are **NOT** based on a descriptive passage.

115. A ray of light travels from medium A into medium B. Medium B has a higher refractive index than A. Which one of the following best describes the refracted ray?

A. The ray will bend away from the normal.
B. The ray will continue along the same path as in medium A.
C. The ray will bend towards the normal.
D. The ray will not exist if the angle of incidence is greater than the critical angle.

116. A negative test charge is to be sent, moving in the vicinity of a current carrying wire. For the charge to experience a force in the same direction as the current, the motion of the charge must be directed:

A. toward the wire.
B. away from the wire.
C. opposite the current.
D. with the current.

117. Two unknown salt compounds, XY_2 and WY_2, are studied in a chemistry laboratory. Both compounds are found to have the same solubility product (K_{sp}), and both are found to dissociate completely into their respective ions when dissolved in water. Element X has a higher atomic weight than element W. Which one of the following is the best statement regarding the solubilities of these compounds?

A. More grams of XY_2 than WY_2 would dissolve at K_{sp}.
B. More grams of WY_2 than XY_2 would dissolve at K_{sp}.
C. Equal gram quantities of XY_2 and WY_2 would dissolve at K_{sp}.
D. There is not enough data to compare these two compounds.

118. Two spheres of putty, A and B, have masses M and 2M, respectively. They are hung from equal lengths of string. Sphere A is then drawn aside and raised to a height, h. It is then released and swings down, undergoing a completely inelastic collision with sphere B. The two spheres will rise to a maximum height of:

A. (1/9)h
B. (1/3)h
C. (1/2)h
D. (2/3)h

Passage IX (Questions 119–123)

Aluminum cans are the source of as much as 3 billion pounds of aluminum discarded annually. The loss of aluminum as a result of the one-time use of aluminum cans is considered by many as a waste of both precious natural resources and energy.

Aluminum is ideal for use by the beverage industry because it is nontoxic, odorless, tasteless, thermally conducting, and lightweight. Aluminum does react with strong acids and bases, which could otherwise be a problem when storing strongly acidic beverages such as carbonated sodas. However, aluminum is easily oxidized in air to Al_2O_3. A thin layer of this oxide protects the aluminum from the contents of the can.

Aluminum can be produced from bauxite by the Hall process, which is shown in Reaction 1. The ΔH for the Hall process is 1340 kJ and the ΔS is 586 J/K.

Reaction 1

$$Al_2O_3 + 3\ C(s) \rightarrow 2\ Al(l) + 3\ CO(g)$$

Figure 1 shows the type of reactor used in the Hall process.

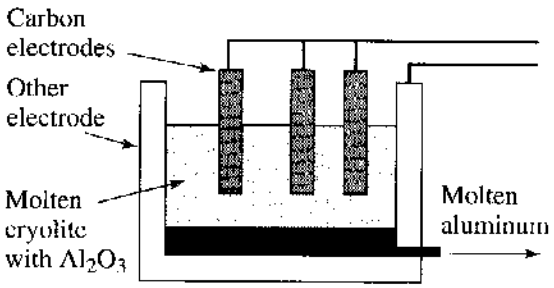


Figure 1

The recycling of aluminum requires only that the metal be heated to its melting point (660°C) with enough additional heat to melt the metal. The heat of fusion for aluminum is 10.7 kJ/mol, and the specific heat of aluminum is 0.900 J/(g°C).

119. What is the ΔG for the Hall process run at 1000°C?

A. 1340 − (1000)(586)
B. 1340 − (1000)(586)(1/1000)
C. 1340 − (1273)(586)
D. 1340 − (1273)(586)(1/1000)

120. What is the total energy required to recycle 1 mole of aluminum?

- **A.** (27)(0.900)(600) + 10.7
- **B.** (27)(660)/(0.900) + 10.7
- **C.** (27)(0.900)(660 − 25)(1/1000) + 10.7
- **D.** (0.900)(660 − 25)

121. Which of the following would result in the most favorable ΔG for the Hall process?

- **A.** Running the reaction below 0°C
- **B.** Running the reaction at room temperature
- **C.** Running the reaction at 1000°C
- **D.** Running the reaction at 1000°F

122. What function does carbon serve in the Hall process reactor?

- **A.** The carbon is the anode.
- **B.** The carbon is the cathode.
- **C.** The carbon is only a reactant.
- **D.** The carbon is the solvent.

123. How does the density of liquid aluminum compare with that of molten cryolite?

- **A.** The densities are equal.
- **B.** The density of aluminum is lower.
- **C.** The density of aluminum is higher.
- **D.** There is no basis to compare the densities of liquid aluminum and molten cryolite.

Passage X (Questions 124–129)

Consider a compound slab consisting of two materials having thickness W_1 and W_2, lengths L_1 and L_2, masses m_1 and m_2, cross-sectional areas A_1 and A_2, thermal conductivity k_1 and k_2, specific heats C_{p1} and C_{p2}, and coefficients of linear expansion α_1 and α_2. A compound slab is shown in Figure 1.

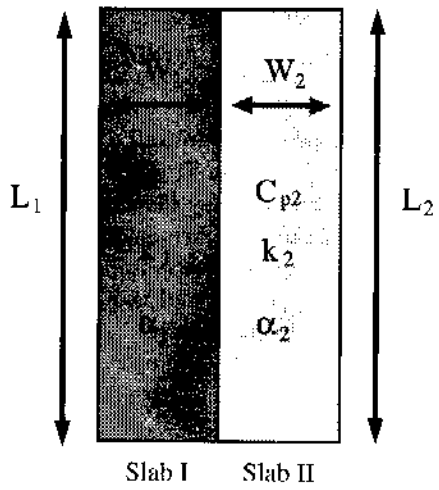


Figure 1. Compound slab of two materials.

The quantities C_p, k, and α are important in characterizing several key thermal features of this system.

The heat capacity per unit mass of a body, called specific heat, or C_p, is the energy that must be added as heat to raise the temperature of an object one degree centigrade. The heat, Q, gained or lost by an object and the change in temperature of that object, ΔT, are related by the equation $Q = mC_p\Delta T$, where m is the mass of the object.

The transfer of energy arising from temperature differences between two adjacent objects is called heat conduction and is characterized by the constant, k. This constant is the proportionality constant in the following equation:

$$\Delta Q/\Delta t \approx (A)(\Delta T/\Delta x),$$

where ΔQ is the heat that flows per unit time Δt across a body that has a cross-sectional area A, width Δx, and a temperature difference of ΔT across its width.

Another common feature of the thermal behavior of materials is the change in size of the materials after a temperature change. In most solids, an increase in temperature is accompanied by an increase in length. This thermal expansion, ΔL, is described by the equation $\Delta L = \alpha L\Delta T$, where α is the coefficient of linear expansion, L is the original length, and ΔT is the change in the temperature.

A series of experiments were conducted. A selected set of experimentally determined values of these three

constants were found and are given in Table 1:

Table 1. Experimentally determined values of α, C_p, and k.

Substance	$\alpha(°C^{-1})$	C_p(cal/g°C)	k(kcal/sm°C)
Aluminum	23×10^{-6}	0.215	4.9×10^{-2}
Copper	17×10^{-6}	0.0923	9.2×10^{-2}
Lead	29×10^{-6}	0.0305	8.3×10^{-3}
Water	51×10^{-6}	1.00(l)	4.0×10^{-4}

124. Consider the two slabs initially at thermal equilibrium with temperatures T_1 and T_2. The slabs are allowed to contact, and they reach a new thermal equilibrium. Using the slab parameters in Figure 1, which of the following quantities is important in determining the final temperature of the slabs after thermal equilibrium has been reached?

A. k_1 and k_2
B. α_1 and α_2
C. W_1 and W_2
D. m_1 and m_2

125. Consider the slabs to be long compared with their width (i.e., L >> W) and to be under a thermal gradient such that the outer surfaces of slab 1 and slab 2 are at temperatures T_1 and T_2, respectively. Which of the following describes the temperature at the interface between the two materials, T_i?

A. Under steady state conditions, the time rate of transfer of heat energy must be equal at the interface.
B. The net heat flow across the boundary must be 0.
C. Under steady state conditions, the net heat flow at the outer surface of slab 1 must be equal to the net heat flow at the boundary.
D. Under steady state conditions, the net heat flow at the outer surface of slab 2 must be equal to the net heat flow at the boundary.

126. Consider a single slab of length L at a specific temperature. Assuming no phase changes occur, which of the following compounds would show the most increase in length upon an equivalent increase in temperature?

A. Aluminum
B. Copper
C. Lead
D. Ice (water)

127. Assuming no phase changes occur, a slab made from which of the following compounds makes the best thermal insulator?

A. Aluminum
B. Copper
C. Lead
D. Ice (water)

128. A slab with a given mass undergoes a temperature increase when a given amount of heat is added. Assuming no phase changes occur, for which of the following compounds is the increase in temperature the greatest?

A. Aluminum
B. Copper
C. Lead
D. Water

129. In isotropic solids, the percent change in length for a given temperature change is the same for all lines within the solid. Every line, whether straight or curved, lengthens in the ratio α per degree temperature rise. Based on this information and the data given in the passage, what is the fractional change in volume of a sphere per degree temperature change for an isotropic solid?

A. 2α
B. 3α
C. $2\pi\alpha$
D. α

Passage XI (Questions 130–136)

The separation of isotopes of the same element is made difficult by the fact that different isotopes have the same chemical properties. A method that can be used to separate isotopes is effusion. Graham's law of effusion demonstrates the rate of effusion of a gas is inversely proportional to the square root of its molecular weight. Graham's law is shown in the following equation:

$$\frac{r_1}{r_2} = \frac{\sqrt{MW_2}}{\sqrt{MW_1}}$$

Based on this equation, a separation factor can be defined as the ratio of the square roots of the molecular weights of the compounds being studied. In addition, the larger molecular weight of the two compounds being considered is always placed in the numerator. This gives a minimum ratio value of 1. A separation factor of 1 indicates that the gases cannot be separated by effusion.

The difference in effusion of compounds with differing molecular weights allows the use of membranes to separate different isotopes. A mixture of isotopes is placed on one side of a membrane, and one of the isotopes will effuse to the other side faster than the other isotope(s). Better separation of the isotopes can be achieved by performing a multistage effusion. In fact, the separation of ^{235}U and ^{238}U to generate fuel for nuclear reactors involves a 2000-stage effusion separation.

130. Which of the following pairs of isotopes would be separated most completely by a single-stage effusion experiment?

- **A.** ^{1}H and ^{2}H
- **B.** ^{1}H and ^{3}H
- **C.** ^{16}O and ^{18}O
- **D.** ^{12}C and ^{13}C

131. Which of the following descriptions explains how the separation is achieved in the purification of uranium isotopes?

- **A.** ^{235}U effuses more slowly than ^{238}U, so ^{238}U collects on the receiving end of the apparatus, and ^{235}U remains at the starting end.
- **B.** ^{235}U effuses more quickly than ^{238}U, so ^{238}U collects on the receiving end of the apparatus, and ^{235}U remains at the starting end.
- **C.** ^{235}U effuses more quickly than ^{238}U, so ^{235}U collects on the receiving end of the apparatus, and ^{238}U remains at the starting end.
- **D.** ^{235}U effuses more slowly than ^{238}U, so ^{235}U collects on the receiving end of the apparatus, and ^{238}U remains at the starting end.

132. What effect would increasing the temperature have on the efficiency of the separation?

- **A.** There would be no effect.
- **B.** It would increase the efficiency of the separation by further slowing the effusion of the slower isotope.
- **C.** It would decrease the efficiency of the separation by slowing both isotopes.
- **D.** It would increase the efficiency of the separation by increasing the speed at which both isotopes effuse.

133. What effect would increasing the pressure on the gas mixture have on the efficiency of the separation?

- **A.** There would be no effect.
- **B.** It would increase the efficiency of the separation by further slowing the effusion of the slower isotope.
- **C.** It would decrease the efficiency of the separation by further slowing both isotopes.
- **D.** It would increase the efficiency of the separation by increasing the speed at which both isotopes effuse.

134. Which of the following statements gives the most reasonable effect on the efficiency of the separation of increasing the pressure on the empty side of the membrane?

- **A.** There would be no effect.
- **B.** It would increase the efficiency of the separation by further slowing the effusion of the slower isotope.
- **C.** It would decrease the efficiency of the separation by slowing both isotopes.
- **D.** It would increase the efficiency of the separation by increasing the speed at which both isotopes effuse.

135. What effect would increasing the temperature have on the speed of the separation?

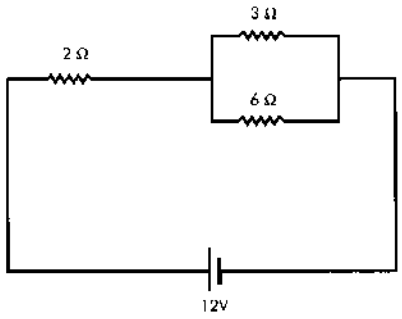
- **A.** There would be no effect.
- **B.** It would increase the speed of the separation by further slowing the slower isotope.
- **C.** It would decrease the speed of the separation by slowing both isotopes.
- **D.** It would increase the speed of the separation by increasing the speed at which both isotopes effuse.

136. What effect would increasing the pressure on the gas mixture have on the speed of the separation?

A. There would be no effect.
B. It would increase the speed of the separation by further slowing the slower isotope.
C. It would decrease the speed of the separation by slowing both isotopes.
D. It would increase the speed of the separation by increasing the speed at which both isotopes effuse.

Questions 137 through 142 are **NOT** based on a descriptive passage.

137. Which of the following values is the current flowing through the 3-ohm resistor for the circuit shown below.



A. 2 amps
B. 3 amps
C. 4 amps
D. 6 amps

138. Which of the following groups of information must be known to determine the power output of a machine?

A. The mass and amount of work performed
B. The time required to perform work and the amount of work performed
C. The force, mass, and time required to apply force
D. The force applied and the distance over which it is applied

139. Buffer solutions are important in both inorganic and organic chemical systems. Buffer solutions resist changes in pH. Which of the following statements most accurately describes an effective buffer solution?

A. Weak acids or bases and their salts
B. Strong acids or bases
C. Strong acids or bases and their salts
D. Weak acids or bases

140. The simple microscope represents a special case of image formation. In the microscope, a converging lens system is used, and the object to be viewed is placed between the lens and the focal point of the lens. The image expected in this system is:

A. real, and on the same side of the lens as the object.
B. real, and on the opposite side of the lens as the object.
C. virtual, and on the same side of the lens as the object.
D. virtual, and on the opposite side of the lens as the object.

141. The process of converting $H_2O(g)$ to $H_2O(l)$ is a nonspontaneous process at a pressure of 1 atm and 373 K. Which of the following best describes why the process is nonspontaneous?

A. ΔH is greater than $T\Delta S$.
B. ΔH is positive.
C. ΔG is negative.
D. ΔH and ΔS are negative.

142. A boat travels on a lake towards the bank of the lake. Above the bank of the lake is a steep cliff. On the cliff stands an observer. As the boat approaches the cliff, it sounds its horn. Who would hear the highest perceived frequency?

A. A person standing on the boat who heard the horn.
B. The observer on the cliff who heard the horn.
C. A person standing on the boat who heard the echo of the horn.
D. All of the perceived frequencies would be the same.

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