Chapter 30: Atomic Physics

# 30.1 Discovery of the Atom

|  |  |
| --- | --- |
| 1. | *Using the given charge-to-mass ratios for electrons and protons, and knowing the magnitudes of their charges are equal, what is the ratio of the proton’s mass to the electron’s? (Note that since the charge-to-mass ratios are given to only three-digit accuracy, your answer may differ from the accepted ratio in the fourth digit.)* |
| Solution | Since  and  The actual mass ratio is  so to three digits, the mass ratio is correct. |
| 2. | *(a) Calculate the mass of a proton using the charge-to-mass ratio given for it in this chapter and its known charge. (b) How does your result compare with the proton mass given in this chapter?* |
| Solution | (a)  (b) It is the same. |
| 3. | *If someone wanted to build a scale model of the atom with a nucleus 1.00 m in diameter, how far away would the nearest electron need to be?* |
| Solution |  |

# 30.2 Discovery of the Parts of the Atom: Electrons and Nuclei

|  |  |
| --- | --- |
| 4. | *Rutherford found the size of the nucleus to be about* *. This implied a huge density. What would this density be for gold?* |
| Solution |  |
| 5. | *In Millikan’s oil-drop experiment, one looks at a small oil drop held motionless between two plates. Take the voltage between the plates to be 2033 V, and the plate separation to be 2.00 cm. The oil drop (of density ) has a diameter of* *. Find the charge on the drop, in terms of electron units.* |
| Solution |  |
| 6. | *(a) An aspiring physicist wants to build a scale model of a hydrogen atom for her science fair project. If the atom is 1.00 m in diameter, how big should she try to make the nucleus? (b) How easy will this be to do?* |
| Solution | (a)  (b) It is not hard to make one of approximately this size. It would be harder to make it exactly . |

# 30.3 Bohr’s Theory of the Hydrogen Atom

|  |  |
| --- | --- |
| 7. | *By calculating its wavelength, show that the first line in the Lyman series is UV radiation.* |
| Solution | so that  UV Radiation |
| 8. | *Find the wavelength of the third line in the Lyman series, and identify the type of EM radiation.* |
| Solution | so that  UV radiation |
| 9. | *Look up the values of the quantities in , and verify that the Bohr radius  is .* |
| Solution |  |
| 10. | *Verify that the ground state energy*  *is 13.6 eV by using* |
| Solution |  |
| 11. | *If a hydrogen atom has its electron in the*  *state, how much energy in eV is needed to ionize it?* |
| Solution | Therefore  is needed to ionize. |
| 12. | *A hydrogen atom in an excited state can be ionized with less energy than when it is in its ground state. What is  for a hydrogen atom if 0.850 eV of energy can ionize it?* |
| Solution | Using, .  (Remember that must be an integer.) |
| 13. | *Find the radius of a hydrogen atom in the  state according to Bohr’s theory.* |
| Solution |  |
| 14. | *Show that  (Rydberg’s constant), as discussed in the text.* |
| Solution |  |
| 15. | *What is the smallest-wavelength line in the Balmer series? Is it in the visible part of the spectrum?* |
| Solution | smallest corresponds to largest  Ultraviolet |
| 16. | *Show that the entire Paschen series is in the infrared part of the spectrum. To do this, you only need to calculate the shortest wavelength in the series.* |
| Solution | All allowable transitions to  with the shortest wavelength occurring for a very large .    This corresponds to the shortest wavelength for IR waves. |
| 17. | *Do the Balmer and Lyman series overlap? To answer this, calculate the shortest-wavelength Balmer line and the longest-wavelength Lyman line.* |
| Solution |  |
| 18. | *(a) Which line in the Balmer series is the first one in the UV part of the spectrum? (b) How many Balmer series lines are in the visible part of the spectrum? (c) How many are in the UV?* |
| Solution | (a) We know that the UV range is from to approximately Using , where  for the Balmer series, we can solve for. Finding a common denominator gives: so that  or . The first line will be for the lowest energy photon, and therefore the largest wavelength, so setting  gives:  will be first.  (b) Setting  allows us to calculate the smallest value for  in the visible range:  so are visible, or 7 lines are in the visible range.  (c) The smallest  in the Balmer series would be for , which corresponds to a value of: , which is in the ultraviolet. Therefore, there are an infinite number of Balmer lines in the ultraviolet. All lines from  fall in the ultraviolet part of the spectrum. |
| 19. | *A wavelength of  is observed in a hydrogen spectrum for a transition that ends in the  level. What was  for the initial level of the electron?* |
| Solution |  |
| 20. | *A singly ionized helium ion has only one electron and is denoted . What is the ion’s radius in the ground state compared to the Bohr radius of hydrogen atom?* |
| Solution |  |
| 21. | *A beryllium ion with a single electron (denoted ) is in an excited state with radius the same as that of the ground state of hydrogen. (a) What is  for the  ion? (b) How much energy in eV is needed to ionize the ion from this excited state?* |
| Solution | (a)  (b)  to ionize |
| 22. | *Atoms can be ionized by thermal collisions, such as at the high temperatures found in the solar corona. One such ion is , a carbon atom with only a single electron. (a) By what factor are the energies of its hydrogen-like levels greater than those of hydrogen? (b) What is the wavelength of the first line in this ion’s Paschen series? (c) What type of EM radiation is this?* |
| Solution | (a) factor of  (b)  (c) This is UV radiation. |
| 23. | *Verify Equations  and  using the approach stated in the text. That is, equate the Coulomb and centripetal forces and then insert an expression for velocity from the condition for angular momentum quantization.* |
| Solution | Using  so that  Since  we can substitute for the velocity giving:  so that  where |
| 24. | *The wavelength of the four Balmer series lines for hydrogen are found to be 410.3, 434.2, 486.3, and 656.5 nm. What average percentage difference is found between these wavelength numbers and those predicted by* *? It is amazing how well a simple formula (disconnected originally from theory) could duplicate this phenomenon.* |
| Solution | Using  calculations for  yield wavelengths of  Known wavelengths are 656, 486, 434, and 410 nm, respectively. Percentage differences are making an average error of |

# 30.4 X Rays: Atomic Origins and Applications

|  |  |
| --- | --- |
| 25. | *(a) What is the shortest-wavelength x-ray radiation that can be generated in an x-ray tube with an applied voltage of 50.0 kV? (b) Calculate the photon energy in eV. (c) Explain the relationship of the photon energy to the applied voltage.* |
| Solution | (a)  (b)  (c) The photon energy is just the applied voltage times the electron charge, so the value of the voltage in volts is the same as the value of the energy in electron volts. |
| 26. | *A color television tube also generates some x rays when its electron beam strikes the screen. What is the shortest wavelength of these x rays, if a 30.0-kV potential is used to accelerate the electrons? (Note that TVs have shielding to prevent these x rays from exposing viewers.)* |
| Solution | , so |
| 27. | *An x ray tube has an applied voltage of 100 kV. (a) What is the most energetic x-ray photon it can produce? Express your answer in electron volts and joules. (b) Find the wavelength of such an X–ray.* |
| Solution | (a)  (b) |
| 28. | *The maximum characteristic x-ray photon energy comes from the capture of a free electron into a  shell vacancy. What is this photon energy in keV for tungsten, assuming the free electron has no initial kinetic energy?* |
| Solution | This exercise is like Example 30.2 with |
| 29. | *What are the approximate energies of the  and  x rays for copper?* |
| Solution | For copper, . Thus,  and |

# 30.5 Applications of Atomic Excitations and De-Excitations

|  |  |
| --- | --- |
| 30. | *Figure 30.39 shows the energy-level diagram for neon. (a) Verify that the energy of the photon emitted when neon goes from its metastable state to the one immediately below is equal to 1.96 eV. (b) Show that the wavelength of this radiation is 633 nm. (c) What wavelength is emitted when the neon makes a direct transition to its ground state?* |
| Solution | (a)  (b)  (c) |
| 31. | *A helium-neon laser is pumped by electric discharge. What wavelength electromagnetic radiation would be needed to pump it? See Figure 30.39 for energy-level information.* |
| Solution |  |
| 32. | *Ruby lasers have chromium atoms doped in an aluminum oxide crystal. The energy level diagram for chromium in a ruby is shown in Figure 30.64. What wavelength is emitted by a ruby laser?* |
| Solution | (metastable to next level) |
| 33. | *(a) What energy photons can pump chromium atoms in a ruby laser from the ground state to its second and third excited states? (b) What are the wavelengths of these photons? Verify that they are in the visible part of the spectrum.* |
| Solution | (a) From Figure 30.64, we see that it would take 2.3 eV photons to pump chromium atoms into the second excited state. Similarly, it would take 3.0 eV photons to pump chromium atoms into the third excited state.  (b) , which is yellow-green.  , which is blue-violet. |
| 34. | *Some of the most powerful lasers are based on the energy levels of neodymium in solids, such as glass, as shown in Figure 30.65. (a) What average wavelength light can pump the neodymium into the levels above its metastable state? (b) Verify that the 1.17 eV transition produces  radiation.* |
| Solution | (a)  (b) |

# 30.8 Quantum Numbers and Rules

|  |  |
| --- | --- |
| 35. | *If an atom has an electron in the  state with , what are the possible values of ?* |
| Solution | are possible since and . |
| 36. | *An atom has an electron with . What is the smallest value of  for this electron?* |
| Solution | is smallest possible . |
| 37. | *What are the possible values of  for an electron in the  state?* |
| Solution | are possible. |
| 38. | *What, if any, constraints does a value of  place on the other quantum numbers for an electron in an atom?* |
| Solution |  |
| 39. | *(a) Calculate the magnitude of the angular momentum for an  electron. (b) Compare your answer to the value Bohr proposed for the  state.* |
| Solution | (a)  (b) |
| 40. | *(a) What is the magnitude of the angular momentum for an  electron? (b) Calculate the magnitude of the electron’s spin angular momentum. (c) What is the ratio of these angular momenta?* |
| Solution | (a)  (b)  (c) |
| 41. | *Repeat Exercise 30.40 for .* |
| Solution | (a)  (b)  (c) |
| 42. | *(a) How many angles can  make with the -axis for an  electron? (b) Calculate the value of the smallest angle.* |
| Solution | (a)  (b) |
| 43. | *What angles can the spin  of an electron make with the -axis?* |
| Solution | so |

# 30.9 The Pauli Exclusion Principle

|  |  |
| --- | --- |
| 44. | *(a) How many electrons can be in the  shell? (b) What are its subshells, and how many electrons can be in each?* |
| Solution | (a)  (b) |
| 45. | *(a) What is the minimum value of l for a subshell that has 11 electrons in it? (b) If this subshell is in the  shell, what is the spectroscopic notation for this atom?* |
| Solution | (a) can havefor 11 electrons  (b) |
| 46. | *(a) If one subshell of an atom has 9 electrons in it, what is the minimum value of* *? (b) What is the spectroscopic notation for this atom, if this subshell is part of the*  *shell?* |
| Solution | (a) We know that the  subshell can have  electrons. The  subshell can have  electrons. So,  will be the minimum value of  to have 9 electrons in it.  (b) Using the spectroscopic notation where  and the number of electrons is 9, we have: |
| 47. | *(a) List all possible sets of quantum numbers  for the*  *shell, and determine the number of electrons that can be in the shell and each of its subshells. (b) Show that the number of electrons in the shell equals*  *and that the number in each subshell is* *.* |
| Solution | (a)  (b) |
| 48. | *Which of the following spectroscopic notations are not allowed? (a)  (b)  (c)  (d)  (e) . State which rule is violated for each that is not allowed.* |
| Solution | (a) and (e) are allowed; the others are not allowed.  (b)  not allowed for  (c) Cannot have 3 electrons in s subshell since  (d) Cannot have 7 electrons in p subshell (max=6) |
| 49. | *Which of the following spectroscopic notations are allowed (that is, which violate none of the rules regarding values of quantum numbers)? (a)*  *(b)*  *(c)*  *(d)*  *(e)* |
| Solution | (a), (c), and (e) are allowed; the others are not allowed.  (b)  not allowed  (d) |
| 50. | *(a) Using the Pauli exclusion principle and the rules relating the allowed values of the quantum numbers , prove that the maximum number of electrons in a subshell is 2(2l + 1). (b) In a similar manner, prove that the maximum number of electrons in a shell is 2n2.* |
| Solution | (a) The number of different values of  is  for each . That gives  values plus one for , which gives a total of . Then there is an additional factor of 2 since each  can have equal to either  or  . Therefore, the total number is .  (b) For each value of  you have  electrons, from part (a). The values of  run from 0 to . The total number is then  .  To see that the expression in the box is imagine taking  from the last term and adding it to the first term  Now take  from the penultimate term and add it to the second term. |
| 51. | ***Integrated Concepts*** *Estimate the density of a nucleus by calculating the density of a proton, taking it to be a sphere 1.2 fm in diameter. Compare your result with the value estimated in this chapter.* |
| Solution | The chapter estimate was . |
| 52. | ***Integrated Concepts*** *The electric and magnetic forces on an electron in the CRT in Figure 30.7 are supposed to be in opposite directions. Verify this by determining the direction of each force for the situation shown. Explain how you obtain the directions (that is, identify the rules used).* |
| Solution | The electric force on the electron is up (toward the positively charged plate). The magnetic force is down (by the RHR). |
| 53. | *(a) What is the distance between the slits of a diffraction grating that produces a first-order maximum for the first Balmer line at an angle of ? (b) At what angle will the fourth line of the Balmer series appear in first order? (c) At what angle will the second-order maximum be for the first line?* |
| Solution | (a)  (b)  (c) |
| 54. | ***Integrated Concepts*** *A galaxy moving away from the earth has a speed of . What wavelength do we observe for an  to  transition for hydrogen in that galaxy?* |
| Solution |  |
| 55. | ***Integrated Concepts*** *Calculate the velocity of a star moving relative to the earth if you observe a wavelength of 91.0 nm for ionized hydrogen capturing an electron directly into the lowest orbital (that is, a  to , or a Lyman series transition).* |
| Solution | We will use the equation  to determine the speed of the star, since we are given the observed wavelength. We first need the source wavelength: , so that  Therefore, using we have  so that  and thus,  So, . Since  is negative, the star is moving toward the earth at a speed of |
| 56. | ***Integrated Concepts*** *In a Millikan oil-drop experiment using a setup like that in Figure 30.9, a 500-V potential difference is applied to plates separated by 2.50 cm. (a) What is the mass of an oil drop having two extra electrons that is suspended motionless by the field between the plates? (b) What is the diameter of the drop, assuming it is a sphere with the density of olive oil?* |
| Solution | (a)  (b) |
| 57. | ***Integrated Concepts*** *What double-slit separation would produce a first-order maximum at  for 25.0-keV x rays? The small answer indicates that the wave character of x rays is best determined by having them interact with very small objects such as atoms and molecules.* |
| Solution |  |
| 58. | ***Integrated Concepts*** *In a laboratory experiment designed to duplicate Thomson’s determination of , a beam of electrons having a velocity of  enters a  magnetic field. The beam moves perpendicular to the field in a path having a 6.80-cm radius of curvature. Determine  from these observations, and compare the result with the known value.* |
| Solution | , which is close to |
| 59. | ***Integrated Concepts*** *Find the value of , the orbital angular momentum quantum number, for the moon around the earth. The extremely large value obtained implies that it is impossible to tell the difference between adjacent quantized orbits for macroscopic objects.* |
| Solution | From the definition of velocity, , we can get an expression for the velocity in terms of the period of rotation of the moon: . Then, from  for a point object we get the angular momentum:  . Substituting for the velocity and setting equal to  gives: . Since  is large :  , so |
| 60. | ***Integrated Concepts*** *Particles called muons exist in cosmic rays and can be created in particle accelerators. Muons are very similar to electrons, having the same charge and spin, but they have a mass 207 times greater. When muons are captured by an atom, they orbit just like an electron but with a smaller radius, since the mass in  is 207 .(a) Calculate the radius of the  orbit for a muon in a uranium ion (**). (b) Compare this with the 7.5-fm radius of a uranium nucleus. Note that since the muon orbits inside the electron, it falls into a hydrogen-like orbit. Since your answer is less than the radius of the nucleus, you can see that the photons emitted as the muon falls into its lowest orbit can give information about the nucleus.* |
| Solution | (a)  (b)  of the nuclear radius. |
| 61. | ***Integrated Concepts*** *Calculate the minimum amount of energy in joules needed to create a population inversion in a helium-neon laser containing  moles of neon.* |
| Solution |  |
| 62. | ***Integrated Concepts*** *A carbon dioxide laser used in surgery emits infrared radiation with a wavelength of . In 1.00 ms, this laser raised the temperature of  of flesh to  and evaporated it. (a) How many photons were required? You may assume flesh has the same heat of vaporization as water. (b) What was the minimum power output during the flash?* |
| Solution | (a) If flesh has the same density as water then    (b) |
| 63. | ***Integrated Concepts*** *Suppose an MRI scanner uses 100-MHz radio waves. (a) Calculate the photon energy. (b) How does this compare to typical molecular binding energies?* |
| Solution | (a)  (b) Typical binding energies are on the order of , so this energy is seven orders of magnitude smaller. |
| 64. | ***Integrated Concepts*** *(a) An excimer laser used for vision correction emits 193-nm UV. Calculate the photon energy in eV. (b) These photons are used to evaporate corneal tissue, which is very similar to water in its properties. Calculate the amount of energy needed per molecule of water to make the phase change from liquid to gas. That is, divide the heat of vaporization in kJ/kg by the number of water molecules in a kilogram. (c) Convert this to eV and compare to the photon energy. Discuss the implications.* |
| Solution | (a)  (b)  (c) .  Therefore, each photon will evaporate approximately 1500 molecules of tissue. This gives the surgeon a rather precise method of removing corneal tissue from the surface of the eye. |
| 65. | ***Integrated Concepts*** *A neighboring galaxy rotates on its axis so that stars on one side move toward us as fast as 200 km/s, while those on the other side move away as fast as 200 km/s. This causes the EM radiation we receive to be Doppler shifted by velocities over the entire range of ±200 km/s. What range of wavelengths will we observe for the 656.0-nm line in the Balmer series of hydrogen emitted by stars in this galaxy. (This is called line broadening.)* |
| Solution | For motion away:    For motion toward:    So the range is |
| 66. | ***Integrated Concepts*** *A pulsar is a rapidly spinning remnant of a supernova. It rotates on its axis, sweeping hydrogen along with it so that hydrogen on one side moves toward us as fast as 50.0 km/s, while that on the other side moves away as fast as 50.0 km/s. This means that the EM radiation we receive will be Doppler shifted over a range of . What range of wavelengths will we observe for the 91.20-nm line in the Lyman series of hydrogen? (Such line broadening is observed and actually provides part of the evidence for rapid rotation.)* |
| Solution | We will use the Doppler shift equation to determine the observed wavelengths for the Doppler shifted hydrogen line. First, for the hydrogen moving away from us, we use  so that:    Then, for the hydrogen moving towards us, we use  so that:    The range of wavelengths is from |
| 67. | ***Integrated Concepts*** *Prove that the velocity of charged particles moving along a straight path through perpendicular electric and magnetic fields is . Thus crossed electric and magnetic fields can be used as a velocity selector independent of the charge and mass of the particle involved.* |
| Solution | The two forces  must be equal in magnitude. |
| 68. | ***Unreasonable Results*** *(a) What voltage must be applied to an X-ray tube to obtain 0.0100-fm-wavelength X-rays for use in exploring the details of nuclei? (b) What is unreasonable about this result? (c) Which assumptions are unreasonable or inconsistent?* |
| Solution | (a)  (b) The voltage is much larger than any achievable voltage.  (c) The assumption that you get an x-ray with such a short wavelength from this method is unreasonable. |
| 69. | ***Unreasonable Results*** *A student in a physics laboratory observes a hydrogen spectrum with a diffraction grating for the purpose of measuring the wavelengths of the emitted radiation. In the spectrum, she observes a yellow line and finds its wavelength to be 589 nm. (a) Assuming this is part of the Balmer series, determine  the principal quantum number of the initial state. (b) What is unreasonable about this result? (c) Which assumptions are unreasonable or inconsistent?* |
| Solution | (a) , so that  Since  (b)  is not an integer.  (c) The wavelength must not be correct. Since  , the assumption that the line was from the Balmer series is possible, but the wavelength of the light did not produce an integer value for . If the wavelength is correct, then the assumption that the gas is hydrogen is not correct; it may be sodium instead. |

# Test Prep For AP® Courses

|  |  |
| --- | --- |
| 1. | *In an experiment, three microscopic latex spheres are sprayed into a chamber and become charged with +3e, +5e, and −3e, respectively. Later, all three spheres collide simultaneously and then separate. Which of the following are possible values for the final charges on the spheres? Select two answers.*   1. +4*e*, −4*e*, +5*e* 2. −4*e*, +4.5*e*, +4.5*e* 3. +5*e*, −8*e*, +7*e* 4. +6*e*, +6*e*, −7*e* |
| Solution | (a), (d) |
| 2. | *In Millikan’s oil drop experiment, he experimented with various voltage differences between two plates to determine what voltage was necessary to hold a drop motionless. He deduced that the charge on the oil drop could be found by setting the gravitational force on the drop (pointing downward) equal to the electric force (pointing upward):*  ,  *where  is the mass of the oil drop, g is the gravitational acceleration (9.8 m/s2), q is the net charge of the oil drop, and E is the electric field between the plates. Millikan deduced that the charge on an electron, e, is 1.6 × 10−19 C.*  *For a system of oil drops of equal mass (1.0 × 10−15 kilograms), describe what value or values of the electric field would hold the drops motionless.* |
| Solution | The maximum possible electric field can be found by assuming the minimum possible charge, which is the charge on an electron:  .  Since the charge on an oil drop is quantized and can be any integer multiple of *e*, the possible values for the electric field can be given by:  ,  where *N* is a positive integer. |
| 3. | *A hypothetical one-electron atom in its highest excited state can only emit photons of energy 2E, 3E, and 5E before reaching the ground state. Which of the following represents the complete set of energy levels for this atom?*   1. 0, 3*E*, 5*E* 2. 0, 2*E*, 3*E* 3. 0, 2*E*, 3*E*, 5*E* 4. 0, 5*E*, 8*E*, 10*E* |
| Solution | (a) |
| 4. | *The Lyman series of photons each have an energy capable of exciting the electron of a hydrogen atom from the ground state (energy level 1) to energy levels 2, 3, 4, etc. The wavelengths of the first five photons in this series are 121.6 nm, 102.6 nm, 97.3 nm, 95.0 nm, and 93.8 nm. The ground state energy of hydrogen is −13.6 eV. Based on the wavelengths of the Lyman series, calculate the energies of the first five excited states above ground level for a hydrogen atom to the nearest 0.1 eV.* |
| Solution | The energy of each photon can be calculated using the formula    and then converting the energy from Joules to eV. This energy is equal to the difference between levels of the hydrogen atom.  For a wavelength of 121.6 nm,      So based on the difference between levels, we can find the energy of level 2.        Similarly, for the other levels:  For 102.6 nm,  For 97.3 nm,  For 95.0 nm,  For 93.8 nm, |
| 5. | *The ground state of a certain type of atom has energy –E0. What is the wavelength of a photon with enough energy to ionize an atom in the ground state and give the ejected electron a kinetic energy of 2E0?*  a)  b)  c)  d) |
| Solution | (a) |
| 6. | *An electron in a hydrogen atom is initially in energy level 2 (). (a) What frequency of photon must be absorbed by the atom in order for the electron to transition to energy level 3 ()? (b) What frequency of photon must be emitted by the atom in order for the electron to transition to energy level 1 ()?* |
| Solution | (a) In absorption, the electron must gain energy equal to the difference between energy levels. In this case, the gain is    To find the frequency, use        (b) In emission, the electron loses energy equal to the difference between energy levels and releases that energy in the form of a photon. The energy loss is    The frequency can then be found as above: |
| 7. | *A sample of hydrogen gas confined to a tube is initially at room temperature. As the gas is heated, the observer notices that the gas begins to glow with a pale pink color. Careful study of the spectrum shows that the light spectrum is not continuous. Instead, the hydrogen gas is only emitting visible wavelength photons of four specific colors, which combine to form the overall color to the human eye. What is the best way to explain this behavior?*   1. As the gas heats up, atoms have more and more collisions and close approaches, so frictional heating causes the gas to glow. 2. As the gas heats up, the electrons within the hydrogen atoms are excited to high energy levels. As the electrons transition to lower energies, they emit light of specific colors. 3. As the gas heats up, more and more collisions occur, and the energy lost in these inelastic collisions is converted into light. 4. As the gas heats up, the turbulence of the gas within the tube causes friction between the gas and the walls of the container, causing the gas to glow. |
| Solution | (b) |
| 8. | *A rock is illuminated with high energy ultraviolet light. This causes the rock to emit visible light. Explain what is happening in the atomic substructure of the rock that causes this effect, which we call fluorescence.* |
| Solution | The individual atoms contain electrons which are excited to very high energy states by the ultraviolet light. These electrons return to the ground state via a series of smaller steps (lower energies than that found in ultraviolet light), some of which cause the emission of photons of the visible region of the spectrum. |
| 9. | *Which of the following is the best way of explaining why the leaves on a given tree are green?*   1. The molecules in the leaves absorb all visible light but strongly reflect green light. 2. The molecules in the leaves absorb green light and reflect other visible light. 3. The molecules are excited by external light sources, and their electrons emit green light when they are de-excited to a lower energy level within the molecules. 4. The molecules glow with a characteristic green energy in order to balance the absorption of energy due to light and heat from their surroundings. |
| Solution | (a) |
| 10. | *Explain what phosphorescence is and how it differs from fluorescence. Which process typically takes longer and why?* |
| Solution | Both processes involve some external source of energy exciting electrons in atoms out of their ground state. With fluorescence, the atoms return to the ground state via a more complicated path (rather than a single step), releasing several lower energy photons in response to the absorption of one higher energy photon. In phosphorescence, an electron is excited to a metastable state, and it takes a significantly longer time than usual for the electron to leave this state and transition downward, emitting energy. This “afterglow” effect lasts much longer due to the extra time it takes for the electron transitions. |
| 11. | *An electron is excited from the ground state of an atom (energy level 1) into a highly excited state (energy level 8). Which of the following electron behaviors represents the fluorescence effect by the atom?*   1. The electron remains at level 8 for a very long time, then transitions up to level 9. 2. The electron transitions directly down from level 8 to level 1. 3. The electron transitions from level 8 to level 1 and then returns quickly to level 8. 4. The electron transitions from level 8 to level 6, then to level 5, then to level 3, then to level 1. |
| Solution | (d) |
| 12. | *Describe the process of fluorescence in terms of the emission of photons as electrons transitions between energy states. Specifically, explain how this process differs from ordinary atomic emission.* |
| Solution | An electron is excited from the ground state into a high energy level. Under ordinary circumstances, the most likely next step is that the electron will transition back to the ground. This is the most probable outcome for most atoms. The fluorescence effect involves the electron transitioning from the high energy level to a series of intermediate energy levels before returning to the ground state, thus emitting a series of lower energy photons instead of a single highly energetic photon (e.g., visible light vs. ultraviolet light). |
| 13. | *For an electron with a de Broglie wavelength , which of the following orbital circumferences within the atom would be disallowed? Select two answers.*   1. 0.5 3. 1.5 4. 2 |
| Solution | (a), (c) |
| 14. | *We have discovered that an electron’s orbit must contain an integer number of de Broglie wavelengths. Explain why, under ordinary conditions, this makes it impossible for electrons to spiral in to merge with the positively charged nucleus.* |
| Solution | The integer multiple condition means that electrons can only exist in orbits in which their wavelike path interferes constructively with itself. If an electron were to move closer to the nucleus than the ground state (which has an orbital circumference equal to the de Broglie wavelength), it would begin to destructively interfere with itself. |

This file is copyright 2015, Rice University. All Rights Reserved.