Chapter 31: Radioactivity and Nuclear Physics

# 31.2 Radiation Detection and Detectors

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| 1. | *The energy of 30.0*  *is required to ionize a molecule of the gas inside a Geiger tube, thereby producing an ion pair. Suppose a particle of ionizing radiation deposits 0.500 MeV of energy in this Geiger tube. What maximum number of ion pairs can it create?* |
| Solution |  |
| 2. | *A particle of ionizing radiation creates 4000 ion pairs in the gas inside a Geiger tube as it passes through. What minimum energy was deposited, if 30.0*  *is required to create each ion pair?* |
| Solution |  |
| 3. | *(a) Repeat Exercise 31.2, and convert the energy to joules or calories. (b) If all of this energy is converted to thermal energy in the gas, what is its temperature increase, assuming  of ideal gas at 0.250-atm pressure? (The small answer is consistent with the fact that the energy is large on a quantum mechanical scale but small on a macroscopic scale.)* |
| Solution | (a)  (b)  Assume |
| 4. | *Suppose a particle of ionizing radiation deposits 1.0 MeV in the gas of a Geiger tube, all of which goes to creating ion pairs. Each ion pair requires 30.0 eV of energy. (a) The applied voltage sweeps the ions out of the gas in . What is the current? (b) This current is smaller than the actual current since the applied voltage in the Geiger tube accelerates the separated ions, which then create other ion pairs in subsequent collisions. What is the current if this last effect multiplies the number of ion pairs by 900?* |
| Solution | (a)  (b) |

# 31.3 Substructure of the Nucleus

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| 5. | *Verify that a  mass of water at normal density would make a cube 60 km on a side, as claimed in Example 31.1. (This mass at nuclear density would make a cube 1.0 m on a side.)* |
| Solution |  |
| 6. | *Find the length of a side of a cube having a mass of 1.0 kg and the density of nuclear matter, taking this to be .* |
| Solution |  |
| 7. | *What is the radius of an  particle?* |
| Solution |  |
| 8. | *Find the radius of a  nucleus.  is a manufactured nuclide that is used as a power source on some space probes.* |
| Solution |  |
| 9. | *(a) Calculate the radius of , one of the most tightly bound stable nuclei. (b) What is the ratio of the radius of  to that of , one of the largest nuclei ever made? Note that the radius of the largest nucleus is still much smaller than the size of an atom.* |
| Solution | (a)  (b) |
| 10. | *The unified atomic mass unit is defined to be . Verify that this amount of mass converted to energy yields 931.5 MeV. Note that you must use four-digit or better values for  and .* |
| Solution |  |
| 11. | *What is the ratio of the velocity of a  particle to that of an  particle, if they have the same nonrelativistic kinetic energy?* |
| Solution |  |
| 12. | *If a 1.50-cm-thick piece of lead can absorb 90.0% of the  rays from a radioactive source, how many centimeters of lead are needed to absorb all but 0.100% of the  rays?* |
| Solution | If there is a 90.0% reduction for each 1.50 cm, then  will remain, where  number of distances of 1.50 cm |
| 13. | *The detail observable using a probe is limited by its wavelength. Calculate the energy of a -ray photon that has a wavelength of , small enough to detect details about one-tenth the size of a nucleon. Note that a photon having this energy is difficult to produce and interacts poorly with the nucleus, limiting the practicability of this probe.* |
| Solution |  |
| 14. | *(a) Show that if you assume the average nucleus is spherical with a radius , and with a mass of  u, then its density is independent of . (b) Calculate that density in  and , and compare your results with those found in Example 31.1 for .* |
| Solution | (a)  (b)  . The answer is the same as Example 31.1. |
| 15. | *What is the ratio of the velocity of a 5.00-MeV  ray to that of an  particle with the same kinetic energy? This should confirm that s travel much faster than s even when relativity is taken into consideration. (See also Exercise 31.11.)* |
| Solution | , since,, or  For the  particle: , so that  or . Thus,  For the  particle:  so that . Thus, . Finally, the ratio of the velocities is given by |
| 16. | *(a) What is the kinetic energy in MeV of a  ray that is traveling at ? This gives some idea of how energetic a  ray must be to travel at nearly the same speed as a  ray. (b) What is the velocity of the  ray relative to the  ray?* |
| Solution | (a)  (b)  (4 significant figures used to show difference) |

# 31.4 Nuclear Decay and Conservation Laws

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| 17. | *decay of  (tritium), a manufactured isotope of hydrogen used in some digital watch displays, and manufactured primarily for use in hydrogen bombs.* |
| Solution |  |
| 18. | *decay of , a naturally occurring rare isotope of potassium responsible for some of our exposure to background radiation.* |
| Solution |  |
| 19. | *decay of .* |
| Solution |  |
| 20. | *decay of .* |
| Solution |  |
| 21. | *Electron capture by .* |
| Solution |  |
| 22. | *Electron capture by .* |
| Solution |  |
| 23. | *decay of , the isotope of polonium in the decay series of  that was discovered by the Curies. A favorite isotope in physics labs, since it has a short half-life and decays to a stable nuclide.* |
| Solution |  |
| 24. | *decay of , another isotope in the decay series of , first recognized as a new element by the Curies. Poses special problems because its daughter is a radioactive noble gas.* |
| Solution |  |
| 25. | *decay producing . The parent nuclide is a major waste product of reactors and has chemistry similar to potassium and sodium, resulting in its concentration in your cells if ingested.* |
| Solution |  |
| 26. | *decay producing . The parent nuclide is a major waste product of reactors and has chemistry similar to calcium, so that it is concentrated in bones if ingested ( is also radioactive.)* |
| Solution |  |
| 27. | *decay producing . The parent nuclide is nearly 100% of the natural element and is found in gas lantern mantles and in metal alloys used in jets ( is also radioactive).* |
| Solution |  |
| 28. | *decay producing . The parent nuclide is in the decay series produced by , the only naturally occurring isotope of thorium.* |
| Solution |  |
| 29. | *When an electron and positron annihilate, both their masses are destroyed, creating two equal-energy photons to preserve momentum. (a) Confirm that the annihilation equation  conserves charge, electron family number, and total number of nucleons. To do this, identify the values of each before and after the annihilation. (b) Find the energy of each  ray, assuming the electron and positron are initially nearly at rest. (c) Explain why the two  rays travel in exactly opposite directions if the center of mass of the electron-positron system is initially at rest.* |
| Solution | (a)  (b)  (c) The two  rays must travel in exactly opposite directions to conserve momentum, since initially there is zero momentum if the center of mass is initially at rest. |
| 30. | *Confirm that charge, electron family number, and the total number of nucleons are all conserved by the rule for  decay given in the equation . To do this, identify the values of each before and after the decay.* |
| Solution |  |
| 31. | *Confirm that charge, electron family number, and the total number of nucleons are all conserved by the rule for  decay given in the equation . To do this, identify the values of each before and after the decay.* |
| Solution |  |
| 32. | *Confirm that charge, electron family number, and the total number of nucleons are all conserved by the rule for  decay given in the equation . To do this, identify the values of each before and after the decay.* |
| Solution |  |
| 33. | *Confirm that charge, electron family number, and the total number of nucleons are all conserved by the rule for electron capture given in the equation . To do this, identify the values of each before and after the capture.* |
| Solution |  |
| 34. | *A rare decay mode has been observed in which  emits a  nucleus. (a) The decay equation is . Identify the nuclide . (b) Find the energy emitted in the decay. The mass of  is 222.015353 u.* |
| Solution | (a) The decay is , so we know that:  and  so from the periodic table the element is lead and  (b) |
| 35. | *(a) Write the complete  decay equation for . (b) Find the energy released in the decay.* |
| Solution | (a)  (b) |
| 36. | *(a) Write the complete  decay equation for . (b) Find the energy released in the decay.* |
| Solution | (a)  (b) |
| 37. | *(a) Write the complete  decay equation for the neutron. (b) Find the energy released in the decay.* |
| Solution | (a)  (b) |
| 38. | *(a) Write the complete  decay equation for , a major waste product of nuclear reactors. (b) Find the energy released in the decay.* |
| Solution | (a)  (b) |
| 39. | *Calculate the energy released in the  decay of , the equation for which is given in the text. The masses of  and  are 21.994434 and 21.991383 u, respectively.* |
| Solution |  |
| 40. | *(a) Write the complete  decay equation for . (b) Calculate the energy released in the decay. The masses of  and  are 11.011433 and 11.009305 u, respectively.* |
| Solution | (a)  (b) |
| 41. | *(a) Calculate the energy released in the  decay of . (b) What fraction of the mass of a single  is destroyed in the decay? The mass of  is 234.043593 u. (c) Although the fractional mass loss is large for a single nucleus, it is difficult to observe for an entire macroscopic sample of uranium. Why is this?* |
| Solution | (a)  (b)  (c) Since  is a slowly decaying substance, only a very small number of nuclei decay on human timescales; therefore, although those nuclei that decay lose a noticeable fraction of their mass, the change in the total mass of the sample is not detectable for a macroscopic sample. |
| 42. | *(a) Write the complete reaction equation for electron capture by . (b) Calculate the energy released.* |
| Solution | (a)  (b) The energy released in electron capture is given by , so |
| 43. | *(a) Write the complete reaction equation for electron capture by . (b) Calculate the energy released.* |
| Solution | (a)  (b) |

# 31.5 Half-Life and Activity

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| 44. | *An old campfire is uncovered during an archaeological dig. Its charcoal is found to contain less than 1/1000 the normal amount of . Estimate the minimum age of the charcoal, noting that .* |
| Solution | 10 half lives would reduce the  (last three digits uncertain). More precisely, , so that |
| 45. | *A  source is labeled 4.00 mCi, but its present activity is found to be  Bq. (a) What is the present activity in mCi? (b) How long ago did it actually have a 4.00-mCi activity?* |
| Solution | (a)  (b) |
| 46. | *(a) Calculate the activity  in curies of 1.00 g of . (b) Discuss why your answer is not exactly 1.00 Ci, given that the curie was originally supposed to be exactly the activity of a gram of radium.* |
| Solution | (a) First we must determine the number of atoms for radium. We use the molar mass of 226 g/mol to get:  Then using the equation , where we know the half life of  is,      (b) The half life of  is more accurately known than it was when the Ci unit was established. |
| 47. | *Show that the activity of the  in 1.00 g of  found in living tissue is 0.250 Bq.* |
| Solution |  |
| 48. | *Mantles for gas lanterns contain thorium, because it forms an oxide that can survive being heated to incandescence for long periods of time. Natural thorium is almost 100% , with a half-life of  y. If an average lantern mantle contains 300 mg of thorium, what is its activity?* |
| Solution |  |
| 49. | *Cow’s milk produced near nuclear reactors can be tested for as little as 1.00 pCi of  per liter, to check for possible reactor leakage. What mass of  has this activity?* |
| Solution |  |
| 50. | *(a) Natural potassium contains , which has a half-life of  y. What mass of  in a person would have a decay rate of 4140 Bq? (b) What is the fraction of  in natural potassium, given that the person has 140 g in his body? (These numbers are typical for a 70-kg adult.)* |
| Solution | (a)  (b) |
| 51. | *There is more than one isotope of natural uranium. If a researcher isolates 1.00 mg of the relatively scarce  and finds this mass to have an activity of 80.0 Bq, what is its half-life in years?* |
| Solution |  |
| 52. | *has one of the longest known radioactive half-lives. In a difficult experiment, a researcher found that the activity of 1.00 kg of  is 1.75 Bq. What is the half-life in years?* |
| Solution | From the periodic table, , so |
| 53. | *You can sometimes find deep red crystal vases in antique stores, called uranium glass because their color was produced by doping the glass with uranium. Look up the natural isotopes of uranium and their half-lives, and calculate the activity of such a vase assuming it has 2.00 g of uranium in it. Neglect the activity of any daughter nuclides.* |
| Solution |  |
| 54. | *A tree falls in a forest. How many years must pass before the  activity in 1.00 g of the tree’s carbon drops to 1.00 decay per hour?* |
| Solution |  |
| 55. | *What fraction of the  that was on Earth when it formed  years ago is left today?* |
| Solution |  |
| 56. | *A 5000-Ci  source used for cancer therapy is considered too weak to be useful when its activity falls to 3500 Ci. How long after its manufacture does this happen?* |
| Solution |  |
| 57. | *Natural uranium is 0.7200%  and 99.27% . What were the percentages of  and  in natural uranium when Earth formed  years ago?* |
| Solution | Assume we have a 10,000-particle sample and take it backwards in time.  and . |
| 58. | *The  particles emitted in the decay of  (tritium) interact with matter to create light in a glow-in-the-dark exit sign. At the time of manufacture, such a sign contains 15.0 Ci of . (a) What is the mass of the tritium? (b) What is its activity 5.00 y after manufacture?* |
| Solution | (a) . The half-life of tritium is 12.33 y, and the atomic mass is , so  or    (b) |
| 59. | *World War II aircraft had instruments with glowing radium-painted dials (see Figure 31.2). The activity of one such instrument was  Bq when new. (a) What mass of  was present? (b) After some years, the phosphors on the dials deteriorated chemically, but the radium did not escape. What is the activity of this instrument 57.0 years after it was made?* |
| Solution | (a) . The half-life of radium is and the atomic mass is , so  or    (b) |
| 60. | *(a) The  source used in a physics laboratory is labeled as having an activity of  on the date it was prepared. A student measures the radioactivity of this source with a Geiger counter and observes 1500 counts per minute. She notices that the source was prepared 120 days before her lab. What fraction of the decays is she observing with her apparatus? (b) Identify some of the reasons that only a fraction of the s emitted are observed by the detector.* |
| Solution | (a)  (b) Only part of the emitted radiation goes in the direction of the detector. Only a fraction of that causes a response in the detector. Some of the emitted radiation (mostly *α* particles) is observed within the source. Some is absorbed within the source, some is absorbed by the detector, and some does not penetrate the detector. |
| 61. | *Armor-piercing shells with depleted uranium cores are fired by aircraft at tanks. (The high density of the uranium makes them effective.) The uranium is called depleted because it has had its  removed for reactor use and is nearly pure . Depleted uranium has been erroneously called non-radioactive. To demonstrate that this is wrong: (a) Calculate the activity of 60.0 g of pure . (b) Calculate the activity of 60.0 g of natural uranium, neglecting the  and all daughter nuclides.* |
| Solution | (a)  (b) |
| 62. | *The ceramic glaze on a red-orange Fiestaware plate is  and contains 50.0 grams of , but very little . (a) What is the activity of the plate? (b) Calculate the total energy that will be released by the  decay. (c) If energy is worth 12.0 cents per , what is the monetary value of the energy emitted? (These plates went out of production some 30 years ago, but are still available as collectibles.)* |
| Solution | (a)  (b) From Appendix B, the energy released per decay is 4.27 MeV, so    (c) The monetary value of the energy is |
| 63. | *Large amounts of depleted uranium () are available as a by-product of uranium processing for reactor fuel and weapons. Uranium is very dense and makes good counter weights for aircraft. Suppose you have a 4000-kg block of . (a) Find its activity. (b) How many calories per day are generated by thermalization of the decay energy? (c) Do you think you could detect this as heat? Explain.* |
| Solution | (a)  (b)  (c) This will not be noticeable. |
| 64. | *The* Galileo *space probe was launched on its long journey past several planets in 1989, with an ultimate goal of Jupiter. Its power source is 11.0 kg of , a by-product of nuclear weapons plutonium production. Electrical energy is generated thermoelectrically from the heat produced when the 5.59-MeV  particles emitted in each decay crash to a halt inside the plutonium and its shielding. The half-life of  is 87.7 years. (a) What was the original activity of the  in becquerel? (b) What power was emitted in kilowatts? (c) What power was emitted 12.0 y after launch? You may neglect any extra energy from daughter nuclides and any losses from escaping  rays.* |
| Solution | (a)  (b)  (c) |
| 66. | ***Unreasonable Results*** *A nuclear physicist finds  of  in a piece of uranium ore and assumes it is primordial since its half-life is . (a) Calculate the amount of  that would had to have been on Earth when it formed  ago for  to be left today. (b) What is unreasonable about this result? (c) What assumption is responsible?* |
| Solution | (a)  (b) This mass is impossibly large; it is greater than the mass of the entire Milky Way galaxy.  (c) The assumption that the  was primordial is unreasonable because its half-life is too short compared to the age of the earth. |
| 67. | ***Unreasonable Results*** *(a) Repeat Exercise 31.57 but include the 0.0055% natural abundance of  with its  half-life. (b) What is unreasonable about this result? (c) What assumption is responsible? (d) Where does the  come from if it is not primordial?* |
| Solution | (a) Calculate the ratio of the original abundance to its present value.    (b) This is an absurdly large ratio, since it implies more  than the known mass of the universe.  (c) The unreasonable assumption is that  existed primordially and was not created as a daughter nucleus from an alpha process.  (d) See Figure 31.27.  is in the decay chain of . |
| 68. | ***Unreasonable Results*** *The manufacturer of a smoke alarm decides that the smallest current of  radiation he can detect is . (a) Find the activity in curies of an  emitter that produces a  current of  particles. (b) What is unreasonable about this result? (c) What assumption is responsible?* |
| Solution | (a)  (b) This is much too hot a source.  (c) The  current is unreasonably large. The –radiation is detected by another, more sensitive, method. |

# 31.6 Binding Energy

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| 69. | *is a loosely bound isotope of hydrogen. Called deuterium or heavy hydrogen, it is stable but relatively rare—it is 0.015% of natural hydrogen. Note that deuterium has , which should tend to make it more tightly bound, but both are odd numbers. Calculate, the binding energy per nucleon, for  and compare it with the approximate value obtained from the graph in Figure 31.27.* |
| Solution |  |
| 70. | *is among the most tightly bound of all nuclides. It is more than 90% of natural iron. Note that  has even numbers of both protons and neutrons. Calculate, the binding energy per nucleon, for  and compare it with the approximate value obtained from the graph in Figure 31.27.* |
| Solution |  |
| 71. | *is the heaviest stable nuclide, and its  is low compared with medium-mass nuclides. Calculate , the binding energy per nucleon, for  and compare it with the approximate value obtained from the graph in Figure 31.27.* |
| Solution | This binding energy per nucleon is approximately the value given in the graph. |
| 72. | *(a) Calculate for , the rarer of the two most common uranium isotopes. (b) Calculate for . (Most of uranium is .) Note that  has even numbers of both protons and neutrons. Is the  of  significantly different from that of  ?* |
| Solution | (a)  (b)  This is a significant difference given that these are isotopes. |
| 73. | *(a) Calculate for . Stable and relatively tightly bound, this nuclide is most of natural carbon. (b) Calculate for . Is the difference in  between  and  significant? One is stable and common, and the other is unstable and rare.* |
| Solution | (a)  (b)  This is not significantly different from the value for  , but it is sufficiently lower to allow decay into another nuclide that is more tightly bound. |
| 74. | *The fact that  is greatest for  near 60 implies that the range of the nuclear force is about the diameter of such nuclides. (a) Calculate the diameter of an  nucleus. (b) Compare  for  and . The first is one of the most tightly bound nuclides, while the second is larger and less tightly bound.* |
| Solution | (a)  (b) |
| 75. | *The purpose of this problem is to show in three ways that the binding energy of the electron in a hydrogen atom is negligible compared with the masses of the proton and electron. (a) Calculate the mass equivalent in u of the 13.6-eV binding energy of an electron in a hydrogen atom, and compare this with the mass of the hydrogen atom obtained from Appendix A. (b) Subtract the mass of the proton given in Table 31.2 from the mass of the hydrogen atom given in Appendix A. You will find the difference is equal to the electron’s mass to three digits, implying the binding energy is small in comparison. (c) Take the ratio of the binding energy of the electron (13.6 eV) to the energy equivalent of the electron’s mass (0.511 MeV). (d) Discuss how your answers confirm the stated purpose of this problem.* |
| Solution | (a) , compared to 1.00782 u for .  (b)  (c)  (d) In part (a), since the mass equivalent of the BE of the electron is 8 orders of magnitude smaller than the mass of the hydrogen atom, the BE of the electron is negligible compared to the masses of the proton and electron. In part (b), since the mass difference between the proton and the hydrogen atom equals the mass of the electron, there is negligible BE of the electron. And finally, in part (c), since the BE is 5 orders of magnitude smaller than the energy equivalent of the electron’s mass, it is clearly negligible compared to the mass of the electron. |
| 76. | ***Unreasonable Results*** *A particle physicist discovers a neutral particle with a mass of 2.02733 u that he assumes is two neutrons bound together. (a) Find the binding energy. (b) What is unreasonable about this result? (c) What assumptions are unreasonable or inconsistent?* |
| Solution | (a)  (b) The binding energy cannot be negative; the nucleons would not stay together.  (c) The particle cannot be made from two neutrons. |

# 31.7 Tunneling

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| 77. | *Derive an approximate relationship between the energy of  decay and half-life using the data in Table 31.3. It may be useful to graph the log of  against  to find some straight-line relationship.* |
| Solution | Regression analysis |
| 78. | ***Integrated Concepts*** *A 2.00-T magnetic field is applied perpendicular to the path of charged particles in a bubble chamber. What is the radius of curvature of the path of a 10 MeV proton in this field? Neglect any slowing along its path.* |
| Solution | Since the energy of the proton (10.0MeV) is substantially less than the rest mass energy of the proton (938MeV), we know the velocity is non-relativistic and that . Therefore, |
| 79. | *(a) Write the decay equation for the  decay of . (b) What energy is released in this decay? The mass of the daughter nuclide is 231.036298 u. (c) Assuming the residual nucleus is formed in its ground state, how much energy goes to the  particle?* |
| Solution | (a)  (b)  (c) The energy released is much smaller than the rest energy of the decay products, so it is safe to use non-relativistic formulas for conservation of energy and momentum. The available energy goes into kinetic energy of the two particles and, of course, momentum is conserved. The original momentum is zero (decaying particle is at rest), so the magnitudes of the momenta for each decay particles will be equal.  Thus: and |
| 80. | ***Unreasonable Results*** *The relatively scarce naturally occurring calcium isotope  has a half-life of about . (a) A small sample of this isotope is labeled as having an activity of 1.0 Ci. What is the mass of the  in the sample? (b) What is unreasonable about this result? (c) What assumption is responsible?* |
| Solution | (a)  (b) The mass is much too large for such a small sample.  (c) The activity is much too high to be reasonable. |
| 81. | ***Unreasonable Results*** *A physicist scatters  rays from a substance and sees evidence of a nucleus*  *in radius. (a) Find the atomic mass of such a nucleus. (b) What is unreasonable about this result? (c) What is unreasonable about the assumption?* |
| Solution | (a)  (b) The greatest known values of  are around 260. This is unreasonably large.  (c) The assumed radius is much too large to be reasonable. |
| 82. | ***Unreasonable Results*** *A frazzled theoretical physicist reckons that all conservation laws are obeyed in the decay of a proton into a neutron, positron, and neutrino (as in  decay of a nucleus) and sends a paper to a journal to announce the reaction as a possible end of the universe due to the spontaneous decay of protons. (a) What energy is released in this decay? (b) What is unreasonable about this result? (c) What assumption is responsible?* |
| Solution | (a)  (b) Negative energy implies energy input is necessary and the reaction cannot be spontaneous.  (c) Although all conversation laws are obeyed, energy must be supplied, so the assumption of spontaneous decay is incorrect. |

# Test Prep For AP® Courses

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| 1. | *A nucleus is observed to emit a  ray with a frequency of . What must happen to the nucleus as a consequence?*   1. The nucleus must gain 0.26 MeV. 2. The nucleus must also emit an α particle of energy 0.26 MeV in the opposite direction. 3. The nucleus must lose 0.26 MeV. 4. The nucleus must also emit a β particle of energy 0.26 MeV in the opposite direction. |
| Solution | (c) |
| 2. | *A uranium nucleus emits an α particle. Assuming charge is conserved, the resulting nucleus must be*   1. thorium 2. plutonium 3. radium 4. curium |
| Solution | (a) |
| 3. | *A typical carbon nucleus contains 6 neutrons and 6 protons. The 6 protons are all positively charged and in very close proximity, with separations on the order of 10-15 meters, which should result in an enormous repulsive force. What prevents the nucleus from dismantling itself due to the repulsion of the electric force?*   1. The attractive nature of the strong nuclear force overpowers the electric force. 2. The weak nuclear force barely offsets the electric force. 3. Magnetic forces generated by the orbiting electrons create a stable minimum in which the nuclear charged particles reside. 4. The attractive electric force of the surrounding electrons is equal in all directions and cancels out, leaving no net electric force. |
| Solution | (a) |
| 4. | *A nucleus in an excited state undergoes decay, losing 1.33 MeV when emitting a  ray. In order to conserve energy in the reaction, what frequency must the  ray have?* |
| Solution | The amount of energy in the photon must equal the amount of energy lost by the nucleus, and we will change the energy into standard units in order to easily determine the frequency: |
| 5. | *is commonly used in smoke detectors because its α decay process provides a useful tool for detecting the presence of smoke particles. When  undergoes α decay, what is the resulting nucleus? If  were to undergo β decay, what would be the resulting nucleus? Explain each answer.* |
| Solution | When  undergoes α decay, it loses 2 neutrons and 2 protons. The resulting nucleus is therefore .  For β decay, the nucleus releases a negative charge. In order for charge to be conserved overall, the nucleus must gain a positive charge, increasing its atomic number by 1, resulting in |
| 6. | *A  nucleus undergoes a decay process, and the resulting nucleus is . What is the value of the charge released by the original nucleus?*   1. +1 2. 0 3. -1 4. -2 |
| Solution | (c) |
| 7. | *Explain why the overall charge of the nucleus is increased by +1 during the β decay process.* |
| Solution | During this process, the nucleus emits a particle with -1 charge. In order for the overall charge of the system to remain constant, the charge of the nucleus must therefore increase by +1. |
| 8. | *Identify the missing particle based upon conservation principles:* |
| Solution | (b) |
| 9. | *Are the following reactions possible? For each, explain why or why not.* |
| Solution | 1. No. Nucleon number is conserved (238 = 234 + 4), but the atomic number or charge is NOT conserved (92 ≠ 88+2). 2. Yes. Nucleon number is conserved (223 = 209 + 14), and atomic number is conserved (88 = 82 + 6). 3. Yes. Nucleon number is conserved (14 = 14), and charge is conserved if the electron’s charge is properly counted (6 = 7 + (-1)). 4. No. Nucleon number is not conserved (24 ≠ 23). The positron released counts as a charge to conserve charge, but it doesn’t count as a nucleon. |
| 10. | *A radioactive sample has N atoms initially. After 3 half-lives have elapsed, how many atoms remain?*   1. N/3 2. N/6 3. N/8 4. N/27 |
| Solution | (c) |
| 11. | *When  decays, the product is . The half-life of this decay process is 1.78 ms. If the initial sample contains 3.4 x 1017 parent nuclei, how many are remaining after 35 ms have elapsed? What kind of decay process is this (alpha, beta or gamma)?* |
| Solution | This must be alpha decay since 4 nucleons (2 positive charges) are lost from the parent nucleus. The number remaining is found from:    nuclei |
| 12. | *Binding Energy is a measure of how much work must be done against nuclear forces in order to disassemble a nucleus into its constituent parts. For example, the amount of energy in order to disassemble  into 2 protons and 2 neutrons requires 28.3 MeV of work to be done on the nuclear particles. Describe the force that makes it so difficult to pull a nucleus apart. Would it be accurate to say that the electric force plays a role in the forces within a nucleus? Explain why or why not.* |
| Solution | The strong force is the attractive nuclear force that holds the nucleus together. The electric force between the protons is repulsive and present in the nucleus, but it has a much smaller magnitude than the strong force. So the sum of the net forces present holds the nucleus tightly together. |

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