Chapter 32: Medical Applications of Nuclear Physics

# 32.1 Medical Imaging and Diagnostics

|  |  |
| --- | --- |
| 1. | *A neutron generator uses an  source, such as radium, to bombard beryllium, inducing the reaction . Such neutron sources are called RaBe sources, or PuBe sources if they use plutonium to get the s. Calculate the energy output of the reaction in MeV.* |
| Solution |  |
| 2. | *Neutrons from a source (perhaps the one discussed in the preceding problem) bombard natural molybdenum, which is 24 percent . What is the energy output of the reaction ? The mass of  is given in Appendix A: Atomic Masses, and that of  is 98.907711 u.* |
| Solution |  |
| 3. | *The purpose of producing  (usually by neutron activation of natural molybdenum, as in the preceding problem) is to produce. Using the rules, verify that the  decay of  produces. (Most  nuclei produced in this decay are left in a metastable excited state denoted .)* |
| Solution |  |
| 4. | *(a) Two annihilation  rays in a PET scan originate at the same point and travel to detectors on either side of the patient. If the point of origin is 9.00 cm closer to one of the detectors, what is the difference in arrival times of the photons? (This could be used to give position information, but the time difference is small enough to make it difficult.) (b) How accurately would you need to be able to measure arrival time differences to get a position resolution of 1.00 mm?* |
| Solution | (a)  (b) |
| 5. | *Table 32.1 indicates that 7.50 mCi of  is used in a brain scan. What is the mass of technetium?* |
| Solution |  |
| 6. | *The activities of  and  used in thyroid scans are given in Table 32.1 to be 50 and , respectively. Find and compare the masses of  and  in such scans, given their respective half-lives are 8.04 d and 13.2 h. The masses are so small that the radioiodine is usually mixed with stable iodine as a carrier to ensure normal chemistry and distribution in the body.* |
| Solution |  |
| 7. | *(a) Neutron activation of sodium, which is 100 percent , produces , which is used in some heart scans, as seen in Table 32.1. The equation for the reaction is . Find its energy output, given the mass of  is 23.990962 u. (b) What mass of  produces the needed 5.0-mCi activity, given its half-life is 15.0 h?* |
| Solution | (a)  (b) |

# 32.2 Biological Effects of Ionizing Radiation

|  |  |
| --- | --- |
| 8. | *What is the dose in mSv for: (a) a 0.1 Gy x-ray? (b) 2.5 mGy of neutron exposure to the eye? (c)  exposure?* |
| Solution | (a)  (b)  (c) |
| 9. | *Find the radiation dose in Gy for: (a) A 10-mSv fluoroscopic x-ray series. (b) 50 mSv of skin exposure by an  emitter. (c) 160 mSv of  and  rays from the  in your body.* |
| Solution | (a)  (b)  (c) |
| 10. | *How many Gy of exposure is needed to give a cancerous tumor a dose of 40 Sv if it is exposed to  activity?* |
| Solution | , from Table 32.2, so exposure is |
| 11. | *What is the dose in Sv in a cancer treatment that exposes the patient to 200 Gy of  rays?* |
| Solution | therefore, the dose is . |
| 12. | *One half the  rays from  are absorbed by a 0.170-mm-thick lead shielding. Half of the  rays that pass through the first layer of lead are absorbed in a second layer of equal thickness. What thickness of lead will absorb all but one in 1000 of these  rays?* |
| Solution |  |
| 13. | *A plumber at a nuclear power plant receives a whole-body dose of 30 mSv in 15 minutes while repairing a crucial valve. Find the radiation-induced yearly risk of death from cancer and the chance of genetic defect from this maximum allowable exposure.* |
| Solution | For cancer:  The risk each year of dying from induced cancer is 30 in a million.  For genetic defect:  The chance each year of an induced genetic defect is 10 in a million. |
| 14. | *In the 1980s, the term picowave was used to describe food irradiation in order to overcome public resistance by playing on the well-known safety of microwave radiation. Find the energy in MeV of a photon having a wavelength of a picometer.* |
| Solution |  |
| 15. | *Find the mass of  that has an activity of .* |
| Solution |  |

# 32.3 Therapeutic Uses of Ionizing Radiation

|  |  |
| --- | --- |
| 16. | *A beam of 168-MeV nitrogen nuclei is used for cancer therapy. If this beam is directed onto a 0.200-kg tumor and gives it a 2.00-Sv dose, how many nitrogen nuclei were stopped? (Use an RBE of 20 for heavy ions.)* |
| Solution |  |
| 17. | *(a) If the average molecular mass of compounds in food is 50.0 g, how many molecules are there in 1.00 kg of food? (b) How many ion pairs are created in 1.00 kg of food, if it is exposed to 1000 Sv and it takes 32.0 eV to create an ion pair? (c) Find the ratio of ion pairs to molecules. (d) If these ion pairs recombine into a distribution of 2000 new compounds, how many parts per billion is each?* |
| Solution | (a)  (b)  (c)  (d) |
| 18. | *Calculate the dose in Sv to the chest of a patient given an x-ray under the following conditions. The x-ray beam intensity is , the area of the chest exposed is , 35.0% of the x-rays are absorbed in 20.0 kg of tissue, and the exposure time is 0.250 s.* |
| Solution | First calculate the energy absorbed. |
| 19. | *(a) A cancer patient is exposed to  rays from a 5000-Ci  transillumination unit for 32.0 s. The  rays are collimated in such a manner that only 1.00% of them strike the patient. Of those, 20.0% are absorbed in a tumor having a mass of 1.50 kg. What is the dose in rem to the tumor, if the average  energy per decay is 1.25 MeV? None of the s from the decay reach the patient. (b) Is the dose consistent with stated therapeutic doses?* |
| Solution | (a)  (b) This is consistent with stated therapeutic doses for cancer patients. |
| 20. | *What is the mass of  in a cancer therapy transillumination unit containing 5.00 kCi of ?* |
| Solution |  |
| 21. | *Large amounts of  are produced in copper exposed to accelerator beams. While machining contaminated copper, a physicist ingests . Each  decay emits an average -ray energy of 0.550 MeV, 40.0% of which is absorbed in the scientist’s 75.0-kg body. What dose in mSv is caused by this in one day?* |
| Solution | First, we need to determine the number of decays per day:  decays/day  Next, we can calculate the energy because each decay emits an average of 0.550 MeV of energy:    Then, dividing by the mass of tissue gives the dose:  Dose in rad/d  Finally, from Table 32.2, we see that the RBE is 1 for  radiation, so:    This dose is approximately , which is larger than background radiation sources, but smaller than doses given for cancer treatments. |
| 22. | *Naturally occurring  is listed as responsible for 16 mrem/y of background radiation. Calculate the mass of  that must be inside the 55-kg body of a woman to produce this dose. Each  decay emits a 1.32-MeV , and 50% of the energy is absorbed inside the body.* |
| Solution | . The energy deposited (per year) is |
| 23. | *(a) Background radiation due to  averages only 0.01 mSv/y, but it can range upward depending on where a person lives. Find the mass of  in the 80.0-kg body of a man who receives a dose of 2.50-mSv/y from it, noting that each  decay emits a 4.80-MeV  particle. You may neglect dose due to daughters and assume a constant amount, evenly distributed due to balanced ingestion and bodily elimination. (b) Is it surprising that such a small mass could cause a measurable radiation dose? Explain.* |
| Solution | (a) . The energy deposited (per year) is      (b) No. The energy per decay is large, the half-life is relatively small, and it is an alpha emitter. |
| 24. | *The annual radiation dose from  in our bodies is 0.01 mSv/y. Each  decay emits a  averaging 0.0750 MeV. Taking the fraction of  to be  of normal  and assuming the body is 13% carbon, estimate the fraction of the decay energy absorbed. (The rest escapes, exposing those close to you.)* |
| Solution |  |
| 25. | *If everyone in Australia received an extra 0.05 mSv per year of radiation, what would be the increase in the number of cancer deaths per year? (Assume that time had elapsed for the effects to become apparent.) Assume that there are  deaths per Sv of radiation per year. What percent of the actual number of cancer deaths recorded is this?* |
| Solution | (a) The population of Australia is roughly 23 million.    (b) |

# 32.5 Fusion

|  |  |
| --- | --- |
| 26. | *Verify that the total number of nucleons, total charge, and electron family number are conserved for each of the fusion reactions in the proton-proton cycle in , , and . (List the value of each of the conserved quantities before and after each of the reactions.)* |
| Solution | (i)  (ii)  (iii) |
| 27. | *Calculate the energy output in each of the fusion reactions in the proton-proton cycle, and verify the values given in the above summary.* |
| Solution | (i)  (ii)  In (ii) and (iii) you can use atomic masses throughout since the two missing electrons on each side of the equation will offset each other.  (iii) |
| 28. | *Show that the total energy released in the proton-proton cycle is 26.7 MeV, considering the overall effect in , , and  and being certain to include the annihilation energy.* |
| Solution | Check: |
| 29. | *Verify by listing the number of nucleons, total charge, and electron family number before and after the cycle that these quantities are conserved in the overall proton-proton cycle in .* |
| Solution |  |
| 30. | *The energy produced by the fusion of a 1.00-kg mixture of deuterium and tritium was found in Example Calculating Energy and Power from Fusion. Approximately how many kilograms would be required to supply the annual energy use in the United States?* |
| Solution | From Table 7.6, we know  and from Example 32.2, we know that a 1.00 kg mixture of deuterium and tritium releases  of energy, so: |
| 31. | *Tritium is naturally rare, but can be produced by the reaction . How much energy in MeV is released in this neutron capture?* |
| Solution |  |
| 32. | *Two fusion reactions mentioned in the text are  and . Both reactions release energy, but the second also creates more fuel. Confirm that the energies produced in the reactions are 20.58 and 2.22 MeV, respectively. Comment on which product nuclide is most tightly bound,  or .* |
| Solution | is more tightly bound, since this reaction gives off more energy per nucleon. This energy shows up in the binding energy of the products:  for  is 0.875 MeV and  for  is 6.81 MeV. |
| 33. | *(a) Calculate the number of grams of deuterium in an 80,000-L swimming pool, given deuterium is 0.0150% (by number) of natural hydrogen. (b) Find the energy released in joules if this deuterium is fused via the reaction . (c) Could the neutrons be used to create more energy? (d) Discuss the amount of this type of energy in a swimming pool as compared to that in, say, a gallon of gasoline, also taking into consideration that water is far more abundant.* |
| Solution | (a)  (b)  (c) Yes, for example,  (d) From Table 7.1, a gallon of gasoline generates of energy, so the energy in the deuterium is approximately 6 orders of magnitude larger than that of a gallon of gasoline. Therefore, this energy, if it could be harvested could solve a lot of energy problems, considering how much water there is in the world. |
| 34. | *How many kilograms of water are needed to obtain the 198.8 mol of deuterium, assuming that deuterium is 0.01500% (by number) of natural hydrogen?* |
| Solution |  |
| 35. | *The power output of the Sun is . (a) If 90% of this is supplied by the proton-proton cycle, how many protons are consumed per second? (b) How many neutrinos per second should there be per square meter at the Earth from this process? This huge number is indicative of how rarely a neutrino interacts, since large detectors observe very few per day.* |
| Solution | (a)  (b) |
| 36. | *Another set of reactions that result in the fusing of hydrogen into helium in the Sun and especially in hotter stars is called the carbon cycle. It is , , , , ,* . *Write down the overall effect of the carbon cycle (as was done for the proton-proton cycle in). Note the number of protons () required and assume that the positrons () annihilate electrons to form more  rays.* |
| Solution |  |
| 37. | *(a) Find the total energy released in MeV in each carbon cycle (elaborated in the above problem) including the annihilation energy. (b) How does this compare with the proton-proton cycle output?* |
| Solution | (a)  (i)  (ii) To get this to work out you have to note that the masses in the table are for the complete atom while the reaction involves only nuclei—i.e., the atom minus the electrons – and correct for this.    (iii)  (iv)  (v) See comment to part (ii)    (vi)    (b) This is the same  as the proton-proton cycle. |
| 38. | *Verify that the total number of nucleons, total charge, and electron family number are conserved for each of the fusion reactions in the carbon cycle given in the above problem. (List the value of each of the conserved quantities before and after each of the reactions.)* |
| Solution | (i)  (ii)  (iii)  (iv)  (v)  (vi) |
| 39. | *Integrated Concepts The laser system tested for inertial confinement can produce a 100-kJ pulse only 1.00 ns in duration. (a) What is the power output of the laser system during the brief pulse? (b) How many photons are in the pulse, given their wavelength is ? (c) What is the total momentum of all these photons? (d) How does the total photon momentum compare with that of a single 1.00 MeV deuterium nucleus?* |
| Solution | (a)  (b)  (c)  (d) |
| 40. | ***Integrated Concepts*** *Find the amount of energy given to the  nucleus and to the  ray in the reaction , using the conservation of momentum principle and taking the reactants to be initially at rest. This should confirm the contention that most of the energy goes to the  ray.* |
| Solution | Conservation of energy, including rest energy, will give us the energy released in the reaction. This energy is shared between the energy of the gamma ray and the kinetic energy of the .    is small compared to the rest masses of the particles, so we can use non-relativistic equations for the energy and momentum of the :    Solving the quadratic equation and using the binomial expansion gives:    Since the rest mass of  is , the velocity is  .  The energies are thus |
| 41. | *Integrated Concepts (a) What temperature gas would have atoms moving fast enough to bring two  nuclei into contact? Note that, because both are moving, the average kinetic energy only needs to be half the electric potential energy of these doubly charged nuclei when just in contact with one another. (b) Does this high temperature imply practical difficulties for doing this in controlled fusion?* |
| Solution | (a) We’ll consider two nuclei to be just in contact when the distance between their centers is two  radii.      From Chapter 13,    (b) Yes, it is very hard, but by using lasers and high pressures it can be accomplished over a very small region in space. These temperatures cannot be generated in a normal container; you must contain it by using electromagnetic forces or by the use of lasers. |
| 42. | *Integrated Concepts (a) Estimate the years that the deuterium fuel in the oceans could supply the energy needs of the world. Assume world energy consumption to be ten times that of the United States which is  J/y and that the deuterium in the oceans could be converted to energy with an efficiency of 32%. You must estimate or look up the amount of water in the oceans and take the deuterium content to be 0.015% of natural hydrogen to find the mass of deuterium available. Note that approximate energy yield of deuterium is  J/kg. (b) Comment on how much time this is by any human measure. (It is not an unreasonable result, only an impressive one.)* |
| Solution | (a) How much water is in the ocean? Estimate by assuming the earth is 70% covered with water, which is on average 4000 m deep (according to some references). The volume of a shell 4000 m thick is the volume of a sphere the radius of the earth  less the volume of a sphere of radius , so        (b) This is approximately half the lifetime of the earth and approximately 100 times longer than man has been in existence, and approximately 200,000 times the length of recorded history. |

# 32.6 Fission

|  |  |
| --- | --- |
| 43. | *(a) Calculate the energy released in the neutron-induced fission (similar to the spontaneous fission in Example 32.3)* *, given  and . (b) This result is about 6 MeV greater than the result for spontaneous fission. Why? (c) Confirm that the total number of nucleons and total charge are conserved in this reaction.* |
| Solution | (a)  (b) The mass of is given in Example 32.3. Because the gain of an external neutron yields about 6 MeV, this extra is about the average  for heavy nuclei.  (c) |
| 44. | *(a) Calculate the energy released in the neutron-induced fission reaction , given  and .(b) Confirm that the total number of nucleons and total charge are conserved in this reaction.* |
| Solution | (a)  (b) |
| 45. | *(a) Calculate the energy released in the neutron-induced fission reaction* , *given  and . (b) Confirm that the total number of nucleons and total charge are conserved in this reaction.* |
| Solution | (a)  (b)  Therefore, both the total number of nucleons and the total charge are conserved. |
| 46. | *Confirm that each of the reactions listed for plutonium breeding just following Example 32.4 conserves the total number of nucleons, the total charge, and electron family number.* |
| Solution | (i)  (ii)  (iii) |
| 47. | *Breeding plutonium produces energy even before any plutonium is fissioned. (The primary purpose of the four nuclear reactors at Chernobyl was breeding plutonium for weapons. Electrical power was a by-product used by the civilian population.) Calculate the energy produced in each of the reactions listed for plutonium breeding just following Example 32.4. The pertinent masses are , , and .* |
| Solution | (i)  (ii)  (iii) |
| 48. | *The naturally occurring radioactive isotope  does not make good fission fuel, because it has an even number of neutrons; however, it can be bred into a suitable fuel (much as  is bred into ). (a) What are and for ? (b) Write the reaction equation for neutron captured by  and identify the nuclide  produced in . (c) The product nucleus  decays, as does its daughter. Write the decay equations for each, and identify the final nucleus. (d) Confirm that the final nucleus has an odd number of neutrons, making it a better fission fuel. (e) Look up the half-life of the final nucleus to see if it lives long enough to be a useful fuel.* |
| Solution | (a)  (b)  (c)  (d) , which is odd.  (e) , which makes it a useful fuel. |
| 49. | *The electrical power output of a large nuclear reactor facility is 900 MW. It has a 35.0% efficiency in converting nuclear power to electrical. (a) What is the thermal nuclear power output in megawatts? (b) How many  nuclei fission each second, assuming the average fission produces 200 MeV? (c) What mass of  is fissioned in one year of full-power operation?* |
| Solution | (a)  (b)  (c) |
| 50. | *A large power reactor that has been in operation for some months is turned off, but residual activity in the core still produces 150 MW of power. If the average energy per decay of the fission products is 1.00 MeV, what is the core activity in curies?* |
| Solution |  |

# 32.7 Nuclear Weapons

|  |  |
| --- | --- |
| 51. | *Find the mass converted into energy by a 12.0-kT bomb.* |
| Solution |  |
| 52. | *What mass is converted into energy by a 1.00-MT bomb?* |
| Solution |  |
| 53. | *Fusion bombs use neutrons from their fission trigger to create tritium fuel in the reaction . What is the energy released by this reaction in MeV?* |
| Solution |  |
| 54. | *It is estimated that the total explosive yield of all the nuclear bombs in existence currently is about 4,000 MT. (a) Convert this amount of energy to kilowatt-hours, noting that . (b) What would the monetary value of this energy be if it could be converted to electricity costing 10 cents per kW·h?* |
| Solution | (a)  (b) |
| 55. | *A radiation-enhanced nuclear weapon (or neutron bomb) can have a smaller total yield and still produce more prompt radiation than a conventional nuclear bomb. This allows the use of neutron bombs to kill nearby advancing enemy forces with radiation without blowing up your own forces with the blast. For a 0.500-kT radiation-enhanced weapon and a 1.00-kT conventional nuclear bomb: (a) Compare the blast yields. (b) Compare the prompt radiation yields.* |
| Solution | (a)  The conventional bomb has 2.5 times the blast yield of the enhanced bomb.  (b)  The enhanced bomb has 3 times the prompt radiation yield. |
| 56. | *(a) How many  nuclei must fission to produce a 20.0-kT yield, assuming 200 MeV per fission? (b) What is the mass of this much ?* |
| Solution | (a)  (b) |
| 57. | *Assume one-fourth of the yield of a typical 320-kT strategic bomb comes from fission reactions averaging 200 MeV and the remainder from fusion reactions averaging 20 MeV. (a) Calculate the number of fissions and the approximate mass of uranium and plutonium fissioned, taking the average atomic mass to be 238. (b) Find the number of fusions and calculate the approximate mass of fusion fuel, assuming an average total atomic mass of the two nuclei in each reaction to be 5. (c) Considering the masses found, does it seem reasonable that some missiles could carry 10 warheads? Discuss, noting that the nuclear fuel is only a part of the mass of a warhead.* |
| Solution | (a) Given that for fission reactions, the energy produced is 200 MeV per fission, we can convert the of 320 kT yield into the number of fissions:    Then,  (b) Similarly, given that for fusion reactions, the energy produced is 20 MeV per fusion, we convert the of 320 kT yield into the number of fusions:    Then:    (c) The nuclear fuel totals only 6 kg, so it is quite reasonable that some missiles carry 10 overheads. The mass of the fuel would only be 60 kg and therefore the mass of the 10 warheads, weighing about 10 times the nuclear fuel, would be only 1500 lbs. If the fuel for the missiles weighs 5 times the total weight of the warheads, the missile would weigh about 9000 lbs or 4.5 tons. This is not an unreasonable weight for a missile. |
| 58. | *This problem gives some idea of the magnitude of the energy yield of a small tactical bomb. Assume that half the energy of a 1.00-kT nuclear depth charge set off under an aircraft carrier goes into lifting it out of the water—that is, into gravitational potential energy. How high is the carrier lifted if its mass is 90,000 tons?* |
| Solution |  |
| 59. | *It is estimated that weapons tests in the atmosphere have deposited approximately 9 MCi of  on the surface of the earth. Find the mass of this amount of .* |
| Solution |  |
| 60. | *A 1.00-MT bomb exploded a few kilometers above the ground deposits 25.0% of its energy into radiant heat. (a) Find the calories per  at a distance of 10.0 km by assuming a uniform distribution over a spherical surface of that radius. (b) If this heat falls on a person’s body, what temperature increase does it cause in the affected tissue, assuming it is absorbed in a layer 1.00-cm deep?* |
| Solution | (a)  (b)  Note: See Tables 14.1 and 11.1 and assume the density of flesh is approximately that of water. |
| 61. | *Integrated Concepts One scheme to put nuclear weapons to nonmilitary use is to explode them underground in a geologically stable region and extract the geothermal energy for electricity production. There was a total yield of about 4,000 MT in the combined arsenals in 2006. If 1.00 MT per day could be converted to electricity with an efficiency of 10.0%: (a) What would the average electrical power output be? (b) How many years would the arsenal last at this rate?* |
| Solution | (a)  (b) |

# Test Prep For AP® Courses

|  |  |
| --- | --- |
| 1. | *A patient receives A rad of radiation as part of her treatment and absorbs E J of energy. The RBE of the radiation particles is R. If the RBE is increased to 1.5R, what will be the energy absorbed by the patient?*   1. 1.5*E* J 2. *E* J 3. 0.75*E* J 4. 0.67*E* J |
| Solution | (b) |
| 2. | *If a 90-kg person is exposed to 50 mrem of alpha particles (with RBE of 16), calculate the dosage (in rad) received by the person. What is the amount of energy absorbed by the person?* |
| Solution | 3.125 × 10−3 rad, 2.81 × 10−3 J |
| 3. | [Figure\_Ch32\_S01]  *The figure above shows a graph of the potential energy between two light nuclei as a function of the distance between them. Fusion can occur between the nuclei if the distance is*   1. large so that kinetic energy is low. 2. large so that potential energy is low. 3. small so that nuclear attractive force can overcome Coulomb’s repulsion. 4. small so that nuclear attractive force cannot overcome Coulomb’s repulsion. |
| Solution | (c) |
| 4. | *In a nuclear fusion reaction, 2 g of hydrogen is converted into 1.985 g of helium. What is the energy released?*   1. 4.5 × 103 J 2. 4.5 × 106 J 3. 1.35 × 1012 J 4. 1.35 × 1015 J |
| Solution | (c) |
| 5. | *When deuterium and tritium nuclei fuse to produce helium, what else is produced?*   1. positron 2. proton 3. α-particle 4. neutron |
| Solution | (d) |
| 6. | *Suppose two deuterium nuclei are fused to produce helium.*   1. *Write the equation for the fusion reaction.* 2. *Calculate the difference between the masses of reactants and products.* 3. *Using the result calculated in b), find the energy produced in the fusion reaction.*   *Assume that the mass of deuterium is 2.014102 u, the mass of helium is 4.002603 u and 1 u = 1.66 × 10-27 kg.* |
| Solution | a) ; b) 4.25 × 10−29 kg; c) 3.825 × 10−12 J or 23.875 MeV |
| 7. | *Which of the following statements about nuclear fission is true?*   1. No new elements can be produced in a fission reaction. 2. Energy released in fission reactions is generally less than that from fusion reactions. 3. In a fission reaction, two light nuclei are combined into a heavier one. 4. Fission reactions can be explained on the basis of the conservation of mass-energy. |
| Solution | (d) |
| 8. | *What is the energy obtained when 10 g of mass is converted to energy with an efficiency of 70%?*   1. 3.93 × 1027 MeV 2. 3.93 × 1030 MeV 3. 5.23 × 1027 MeV 4. 5.23 × 1030 MeV |
| Solution | (a) |
| 9. | *In a neutron-induced fission reaction of 239Pu, which of the following is produced along with 96Sr and four neutrons?* |
| Solution | (b) |
| 10. | *When 235U is bombarded with one neutron, the following fission reaction occurs:*  *.*   1. *Find the values for x and y.* 2. *Assuming that the mass of 235U is 235.04 u, the mass of 141Ba is 140.91 u, the mass of 92Kr is 91.93 u, and the mass of n is 1.01 u, a student calculates the energy released in the fission reaction as 2.689 × 10−8, but forgets to write the unit. Find the correct unit and convert the answer to MeV.* |
| Solution | a) , ; b) mJ, 167.865 MeV |

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