Skill 58: Mass-energy equivalence

The source of all energy in the universe is the conversion of mass into energy.

The Law of Conservation of Mass and the Law of Conservation of Energy can be combined to the Law of Conservation of Mass-Energy. Mass and energy are the same thing.

Energy and mass are the same thing. Neither can be created or destroyed.

Mass can be converted to energy. Energy can be converted to mass.

The equation **$E=mc^2$** is used to relate a quantity of mass to the amount of energy it contains when mass is given in kg.

If mass is given in Universal mass units use the conversion from the reference table.

1 universal mass unit (u)		9.31×10^2 MeV
Rest mass of the electron	m_e	9.11×10^{-31} kg
Rest mass of the proton	m_p	1.67×10^{-27} kg
Rest mass of the neutron	m_n	1.67×10^{-27} kg

397. A 60 kilogram mass is converted completely into energy.

a. Calculate the amount of energy released in joules.

$E = mc^2 = (60 kg)(3\times10^8 m/s)^2 = 5.4\times10^{18} J$

b. Convert this energy from joules into electron-volts.

$5.4\times10^{18} J \times \frac{1 eV}{1.6\times10^{-19} J} = 3.37\times10^{37} eV$

398. a) Determine the amount of energy (in MeV) released when 2 universal mass units are converted to energy.

$2 u \times \frac{9.31\times10^2 MeV}{1 u} = 1862 MeV$ or $1.862\times10^3 MeV$

b) Convert this energy to joules

$1.862\times10^3 MeV = 1.862\times10^3\times10^6 eV = 1.862\times10^9 eV \times \frac{1.6\times10^{-19} J}{1 eV} = 2.98\times10^{-10} J$

399. If a deuterium nucleus has a mass of 1.53×10^{-3} universal mass units (u) less than its components, how much energy does its mass represent?

Mass defect = $1.53\times10^{-3}\,u \times \frac{9.31\times10^{2}\,MeV}{1\,u} = 1.42\,MeV$

400. The energy produced by the complete conversion of 2×10^{-5}kg of mass into energy is

a) 1.8 TJ b) 6 GJ c) 1.8 MJ d) 6.0 kJ

$E = mc^2$

$= (2\times10^{-5}\,kg)(3\times10^{8}\,m/s)^2 = 1.8\times10^{12}\,J$ 1.8 TJ

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401. What is the minimum total energy released when an electron and its antiparticle (positron) annihilate each other?

A) 1.64×10^{-13} J B) 8.20×10^{-14} J
C) 5.47×10^{-22} J D) 2.73×10^{-22} J

402. What total mass must be converted into energy to produce a gamma photon with an energy of 1.03×10^{-13} joule?

A) 1.14×10^{-30} kg
B) 3.43×10^{-22} kg
C) 3.09×10^{-5} kg
D) 8.75×10^{29} kg

403. The total conversion of 1.00 kilogram of the Sun's mass into energy yields

A) 9.31×10^{2} MeV B) 8.38×10^{19} MeV
C) 3.00×10^{8} J D) 9.00×10^{16} J

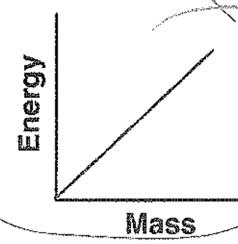
404. The energy produced by the complete conversion of 2.0×10^{-5} kilogram of mass into energy is

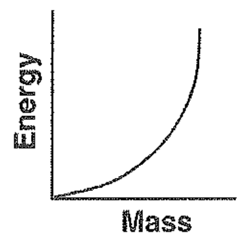
A) 1.8 TJ B) 6.0 GJ
C) 1.8 MJ D) 6.0 kJ

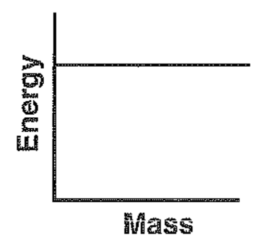
405. A tritium nucleus is formed by combining two neutrons and a proton. the mass of this nucleus is 9.106×10^{-3} universal mass unit less than the combined mass of the particles from which it is formed. Approximately how much energy is released when this nucleus us formed.

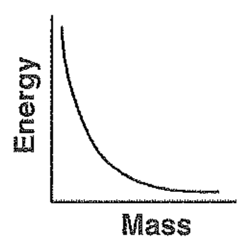
A) 8.48×10^{-2} MeV B) 2.73 MeV
C) 8.48 MeV D) 273 MeV

406. Which graph best represents the relationship between energy and mass when matter is converted into energy?

A)


B)


C)


D)


407. The energy equivalent of the rest mass of an electron is approximately

A) 5.1×10^{5} J B) 8.2×10^{-14} J
C) 2.7×10^{-22} J D) 8.5×10^{-28} J

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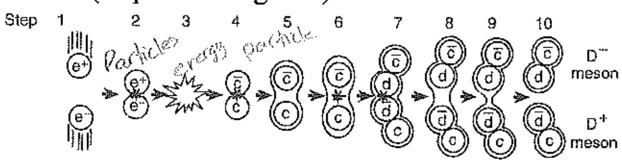
408. The diagram below represents the sequence of events (steps 1 through 10) resulting in the production of a D– meson and a D+ meson. An electron and a positron (antielectron) collide (step 1), annihilate each other (step 2), and become energy (step 3). This energy produces an anticharm quark and a charm quark (step 4), which then split apart (steps 5 through 7). As they split, a down quark and an antidown quark are formed, leading to the final production of a D– meson and a D+ meson (steps 8 through 10).



Adapted from: Electon/Positron Annihilation http://www.particleadventure.org/frameless/eedd.html 7/23/2007

Which statement best describes the changes that occur in this sequence of events?

A) Energy is converted into matter and then matter is converted into energy.
B) Matter is converted into energy and then energy is converted into matter.
C) Isolated quarks are being formed from baryons.
D) Hadrons are being converted into leptons.

409. The energy equivalent of 5.0×10^{-3} kilogram is

A) 8.0×10^{5} J B) 1.5×10^{6} J
C) 4.5×10^{14} J D) 3.0×10^{19} J

$E = mc^2 = (5\times10^{-3} kg)(3\times10^8 m/s)^2$

410. If a deuterium nucleus has a mass of 1.53×10^{-3} universal mass units less than its components, this mass represents an energy of

A) 1.38 MeV B) 1.42 MeV
C) 1.53 MeV D) 3.16 MeV

Mass defect = $1.53\times10^{-3} u \times \frac{9.31\times10^2 MeV}{1u}$

411. What is the energy equivalent of a mass of 0.026 kilogram?

A) 2.34×10^{15} J B) 2.3×10^{15} J
C) 2.34×10^{17} J D) 2.3×10^{17} J

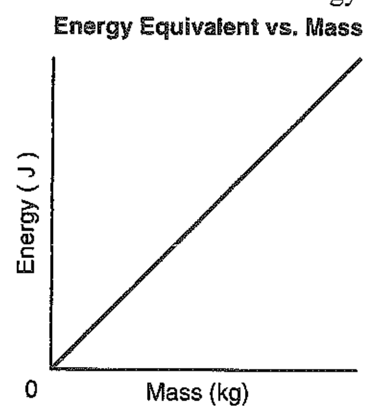
$E = mc^2 = (.026 kg)(3\times10^8 m/s)^2$

412. How much energy would be generated if a 1.0×10^{-3}-kilogram mass were completely converted to energy?

A) 9.3×10^{-1} MeV B) 9.3×10^{2} MeV
C) 9.0×10^{13} J D) 9.0×10^{16} J

$E = mc^2 = (1\times10^{-3} kg)(3\times10^8 m/s)^2 = 9\times10^{13} J$

413. The graph below represents the relationship between mass and its energy equivalent



$m = \frac{y}{x} = \frac{E}{m} = c^2$

The slope of the graph represents

A) the electrostatic constant
B) gravitational field strength
C) the speed of light squared
D) Planck's constant

414. Approximately how much energy would be generated if the mass in a nucleus of a ^2_1H atom were completely converted to energy? [The mass of ^2_1H is 2.0 atomic mass units.]

A) 3.2×10^{-19} J B) 1.5×10^{-10} J
C) 9.3×10^{2} MeV D) 1.9×10^{3} MeV

$2u \times \frac{9.31\times10^2 MeV}{1u} = 1862 MeV$
$1.9\times10^3 MeV$

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415. What is the energy equivalent of a mass of 1 kilogram?

A) 9×10^{16} J B) 9×10^{13} J
C) 9×10^{7} J D) 9×10^{7} J

$E = mc^2 = (1\,kg)(3\times10^8\,m/s)^2$
$= 9\times10^{16}\,J$