Topic 6D: Long Answer

Skills 57 and 58

Base your answers to questions **416** through **418** on the information below.

Auroras over the polar regions of Earth are caused by collisions between charged particles from the Sun and atoms in Earth's atmosphere. The charged particles give energy to the atoms, exciting them from their lowest available energy level, the ground state, to higher energy levels, excited states. Most atoms return to their ground state within 10. nanoseconds.

In the higher regions of Earth's atmosphere, where there are fewer interatom collisions, a few of the atoms remain in excited states for longer times. For example, oxygen atoms remain in an excited state for up to 1.0 seconds. These atoms account for the greenish and red glows of the auroras. As these oxygen atoms return to their ground state, they emit green photons ($f = 5.38 \times 10^{14}$ Hz) and red photons($f = 4.76 \times 10^{14}$Hz). These emissions last long enough to produce the changing aurora phenomenon.

416. Explain what is meant by an atom being in its ground state.

Ground state is energy level 1

417. Calculate the energy of a photons, in joules, that accounts for the red glow of the aurora. [Show all work, including the equation and substitution with units.]

$f = 4.76 \times 10^{14}$ Hz

$E = hf = (6.63 \times 10^{-34}$ Js$)(4.76 \times 10^{14}$ Hz$) = 3.16 \times 10^{-19}$ J

418. What is the order of magnitude of the time, in seconds, that most atoms spend in an excited state?

10 ns = 10×10^{-9} s = 1×10^{-8} s   Order of magnitude is -8

Base your answers to questions **419** through **421** on the information below.

A photon with a wavelength of 2.29×10^{-7} meter strikes a mercury atom in the ground state.

419. Based on your answer to the question above, state if this photon can be absorbed by the mercury atom. Explain your answer.

③

Yes, An electron in the ground state of mercury has -10.38 eV. By absorbing 5.43eV it will end up with -4.95eV which is energy "level d"

Topic 6D: Long Answer

420. Determine the energy, in electronvolts, of this photon.

5.43 **eV**

② $8.68\times10^{-19}\,J \times \frac{1\,eV}{1.6\times10^{-19}\,J} = 5.429\,eV$

421. Calculate the energy, in joules, of this photon. [Show all work, including the equation and substitution with units.]

① $E=\frac{hc}{\lambda}=\frac{(6.63\times10^{-34}\,Js)(3\times10^{8}\,m/s)}{(2.29\times10^{-7}\,m)}=8.68\times10^{-19}\,J$

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422. The energy required to separate the 3 protons and 4 neutrons in the nucleus of a lithium atom is 39.3 megaelectronvolts. Determine the mass equivalent of this energy, in universal mass units.

.0422 **u**

$39.3\,\cancel{MeV} \times \frac{1\,u}{9.31\times10^{2}\,\cancel{MeV}}$

423. Base your answer to the following question on the information below.

> In a mercury atom, as an electron moves from energy level *i* to energy level *a*, a single photon is emitted.

Determine the energy, in electron volts, of this emitted photon.

$n=i=-1.56\,eV$
$n=a=-10.38\,eV$
$\Delta E = 8.82\,eV$

424. If a proton were to combine with an antiproton, they would annihilate each other and become energy. Calculate the amount of energy that would be released by this annihilation. [Show all work, including the equation and substitution with units.]

$m_p = 1.67\times10^{-27}\,kg$
$m_{\bar{p}} = 1.67\times10^{-27}\,kg$

$E=mc^2$
$=2(1.67\times10^{-27}\,kg)(3\times10^{8}\,m/s)^2$
$=3\times10^{-10}\,J$

Topic 6D: Long Answer

Base your answers to questions **425** and **426** on the information and data table below.

In the first nuclear reaction using a particle accelerator, accelerated protons bombarded lithium atoms, producing alpha particles and energy. The energy resulted from the conversion of mass into energy. The reaction can be written as shown below.

$${}^{1}_{1}\mathrm{H} + {}^{7}_{3}\mathrm{Li} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He} + \text{energy}$$

Data Table

Particle	Symbol	Mass (u)
proton	${}^{1}_{1}\mathrm{H}$	1.007 83
lithium atom	${}^{7}_{3}\mathrm{Li}$	7.016 00
alpha particle	${}^{4}_{2}\mathrm{He}$	4.002 60

425. Determine the energy in megaelectronvolts produced in the reaction of a proton with a lithium atom.

$$.01863u \times \frac{9.31\times10^{2}\,\mathrm{MeV}}{1u} = 17.34\ \mathrm{MeV}$$

②

426. Determine the difference between the total mass of the reactants (the proton and lithium atom), and the total mass of the products (the two alpha particles), in universal mass units.

massreactants − mass of products

$(1.0783u + 7.016u) - 2(4.0026u)$

①

massdefect = .01863u

427. A tau lepton decays into an electron, an electron antineutrino, and a tau neutrino, as represented in the reaction below.

$\tau \rightarrow e + \overline{\nu}_e + \nu_\tau$

On the equation below, show how this reaction obeys the Law of Conservation of Charge by indicating the amount of charge on each particle.

-1 e → -1 e + 0 e + 0 e

428. Base your answer to the following question on the statement below.

The spectrum of visible light emitted during transitions in excited hydrogen atoms is composed of blue, green, red, and violet lines.

What characteristic of light determines the amount of energy carried by a photon of that light?

A) amplitude [✓ B) frequency]
C) phase D) velocity

429. The strongest alpha line in the Balmer series of the hydrogen spectrum consists of light having a wavelength of 6.56×10^{-7} meter.

a Calculate the frequency of this light.

b Determine the energy in joules of a photon of this light.

c Determine the energy in electronvolts of a photon of this light.

a) $f = \frac{c}{\lambda} = \frac{3.0\times10^{8}\,\mathrm{m/s}}{6.56\times10^{-7}\,\mathrm{m}} = 4.57\times10^{14}\,\mathrm{Hz}$

b) $E = hf = (6.63\times10^{-34}\,\mathrm{Js})(4.57\times10^{14}\,\mathrm{Hz})$

$= 3.03\times10^{-19}\,\mathrm{J}$

c) $3.03\times10^{-19}\,\mathrm{J} \times \frac{1\,\mathrm{eV}}{1.6\times10^{-19}\,\mathrm{J}} = 1.895\,\mathrm{eV}$

Topic 6D: Long Answer

Base your answers to questions **430** through **432** on the passage below.

For years, theoretical physicists have been refining a mathematical method called lattice quantum chromodynamics to enable them to predict the masses of particles consisting of various combinations of quarks and antiquarks. They recently used the theory to calculate the mass of the rare B_c particle, consisting of a charm quark and a bottom antiquark. The predicted mass of the B_c particle was about six times the mass of a proton.

Shortly after the prediction was made, physicists working at the Fermi National Accelerator Laboratory, Fermilab, were able to measure the mass of the B_c particle experimentally and found it to agree with the theoretical prediction to within a few tenths of a percent. In the experiment, the physicists sent beams of protons and antiprotons moving at 99.999% the speed of light in opposite directions around a ring 1.0 kilometer in radius. The protons and antiprotons were kept in their circular paths by powerful electromagnets. When the protons and antiprotons collided, their energy produced numerous new particles, including the elusive B_c.

These results indicate that lattice quantum chromodynamics is a powerful tool not only for confirming the masses of existing particles, but also for predicting the masses of particles that have yet to be discovered in the laboratory.

430. Explain how it is possible for a colliding proton and antiproton to produce a particle with six times the mass of either.

Energy was converted into mass

431. Identify the class of matter to which the B_c particle belongs.

$c\bar{b}$ → a quark and antiquark is called a meson

432. Determine both the sign and the magnitude of the charge of the B_c particle in elementary charges.

$$\left.\begin{array}{l} c = 2/3 \\ \bar{b} = 1/3 \end{array}\right\} +1e$$

433. More Sci- Than Fi, Physicists Create Antimatter

Physicists working in Europe announced yesterday that they had passed through natures looking glass and had created atoms made of antimatter, or antiatoms, opening up the possibility of experiments in a realm once reserved for science fiction writers. Such experiments, theorists say, could test some of the basic tenets of modern physics and light the way to a deeper understanding of nature.

By corralling [holding together in groups] clouds of antimatter particles in a cylindrical chamber laced with detectors and electric and magnetic fields, the physicists assembled antihydrogen atoms, the looking glass equivalent of hydrogen, the most simple atom in nature. Whereas hydrogen consists of a positively charged proton circled by a negatively charged electron, in antihydrogen the protons counterpart, a positively charged antiproton, is circled by an antielectron, otherwise known as a positron. According to the standard theories of physics, the antimatter universe should look identical to our own. Antihydrogen and hydrogen atoms should have the same properties, emitting the exact same frequencies of light, for example. . . .Antimatter has been part of physics since 1927 when its existence was predicted by the British physicist Paul Dirac. The antielectron, or positron, was discovered in 1932. According to the theory, matter can only be created in particle-antiparticlepairs. It is still a mystery, cosmologists say, why the universe seems to be overwhelmingly composed of normal matter.

Dennis Overbye, More Sci- Than Fi, Physicists Create Antimatter, New York Times, Sept. 19, 2002

Identify *one* characteristic that antimatter particles must possess if clouds of them can be corralled by electric and magnetic fields.

The must have electric charge

Base your answers to questions **434** and **435** on the passage below.

More Sci- Than Fi, Physicists Create Antimatter

Repeat of text from previous page

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wrong

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Dennis Overbye, "More Sci- Than Fi, Physicists
Create Antimatter," New York Times, Sept. 19, 2002

434. How should the emission spectrum of antihydrogen compare to the emission spectrum of hydrogen?

It should be identical

Topic 6D: Long Answer

435. The author of the passage concerning antimatter incorrectly reported the findings of the experiment on antimatter. Which particle mentioned in the article has the charge incorrectly identified?

antiproton is negative