AP Physics

Modern Physics

1. Students should be able to describe the Rutherford scattering experiment and to explain how it provides evidence for the existence of the atomic nucleus.

2. Students should know the properties of photons and understand the photoelectric effect so they can:
   a. Relate the energy of a photon in joules or electron-volts to its wavelength in meters or angstroms, or to its frequency.
   b. Relate the linear momentum of a photon to its energy or wavelength, and apply linear momentum conservation to simple processes involving the emission, absorption, or reflection of photons.
   c. Calculate the number of photons per second emitted by a monochromatic source of specific wavelength and power.
   d. Describe a typical photoelectric effect experiment, and explain what experimental observations provide evidence for the photon nature of light. Describe qualitatively how the number of photoelectrons and their maximum kinetic energy depend on the wavelength and intensity of the light striking the surface, and account for this dependence in terms of a photon model of light.
   e. When given the maximum kinetic energy of photoelectrons ejected by photons of one energy or wavelength, determine the maximum kinetic energy of photoelectrons for a different photon energy or wavelength.
   f. Sketch or identify a graph of stopping potential versus frequency for a photoelectric-effect experiment, determine from such a graph the threshold frequency and work function, and calculate an approximate value of h/ e.

3. Students should understand the concept of energy levels for atoms so they can:
   a. Calculate the energy or wavelength of the photon emitted or absorbed in a transition between specified levels, or the energy or wavelength required to ionize an atom.
   b. Explain qualitatively the origin of emission or absorption spectra of gases.
   c. Given the wavelengths or energies of photons emitted or absorbed in a two-step transition between levels, calculate the wavelength or energy for a single-step transition between the same levels.
   d. Write an expression for the energy levels of hydrogen in terms of the ground-state energy, draw a diagram to depict these levels, and explain how this diagram accounts for the various "series" in the hydrogen spectrum.
   e. State the assumptions and conclusions of the Bohr model for the hydrogen atom.

4. Students should understand the concept of DeBroglie wavelength so they can:
   a. Calculate the wavelength of a particle as a function of its momentum.
   b. Describe the Davisson-Germer experiment, and explain how it provides evidence for the wave nature of electrons.

5. Students should understand the nature and production of x-rays so they can calculate the shortest wavelength of x-rays that may be produced by electrons accelerated through a specified voltage.

6. Students should understand Compton scattering so they can:
   a. Describe Compton's experiment, and state what results were observed and what sort of analysis may explain these results.
   b. Account qualitatively for the increase of photon wavelength that is observed, and explain the significance of the Compton wavelength.

7. Students should understand the significance of half-life in radioactive decay so they can:
   a. Recognize that half-life is independent of the number of nuclei present or of external conditions.
   b. Sketch or identify a graph to indicate what fraction of a radioactive sample remains as a function of time, and indicate the half-life on such a graph.
   c. Determine, for an isotope of specified half-life, what fraction of the nuclei has decayed after a given time has elapsed.
8. Students should understand the significance of the mass number and charge of nuclei so they can:
   a. Interpret symbols for nuclei that indicate these quantities.
   b. Use conservation of mass number and charge to complete nuclear reactions.
   c. Determine the mass number and charge of a nucleus after it has undergone specified decay processes.
   d. Describe the process of $\alpha$, $\beta$, and $\gamma$ decay and write a reaction to describe each.
   e. Students should understand the role of the neutrino in $\beta$ decay so they can explain why its existence had to be postulated in order to reconcile experimental data with fundamental conservation laws.

9. Students should know the nature of the nuclear force so they can compare its strength and range with those of the electromagnetic force.

10. Students should understand nuclear fission so they can:
   a. Describe a typical neutron-induced fission, and explain why a chain reaction is possible.
   b. Relate the energy released in fission to the decrease in rest mass.

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1. Calculate the energy in electron volts of a photon in (a) the radio frequency range, 90 MHz, (b) the infrared range, $10^{13}$ Hz, and (c) the ultraviolet range, $10^{18}$ Hz.

2. A quantum of electromagnetic radiation has an energy of 2 keV. What is its wavelength?

3. A metal has a work function of $2 \times 10^{-19}$ J. If yellow light of wavelength 600 nm falls on the surface of the metal, find (a) the maximum kinetic energy of the ejected electrons and (b) the cutoff wavelength for the metal.

4. What wavelength light would have to fall on sodium (work function 2.3 eV) if it is to emit electrons with a maximum speed of $10^6$ m/s?

5. What is the shortest x-ray wavelength that can be produced with an accelerating voltage of 10 kV?

6. The spacing between certain planes in a crystal is known to be 0.3 nm. Find the smallest angle at which interference will occur for x-rays of wavelength 0.07 nm.

7. X-rays of wavelength 0.20 nm are scattered from a block of carbon. If the scattered radiation is detected at 90° to the incident beam, find the Compton shift.

8. X-rays of wavelength 0.071 nm undergo Compton scattering from free electrons in carbon. What is the wavelength of the photons, which are scattered at 90° relative to the incident direction?

9. Calculate the de Broglie wavelength of a 2000-kg car moving at 65 mi/h.

10. Calculate the de Broglie wavelength of a proton that is accelerated through a potential difference of 10 MV.

11. The position of an electron is known to a precision of $10^{-8}$ cm. What is the minimum uncertainty in the measurement of the electron's velocity?

12. The energy of an electron in a particular atom is approximately 2 eV. How long would it take to measure this energy to a precision of 1%?

13. The current in a photocell is cut off by a retarding potential of 0.92 V for radiation of wavelength 250 nm. Find the work function for the material.

14. The material in a photocell has a work function of 2 eV. When a retarding potential is applied, the cutoff wavelength is found to be 350 nm. What is the value of the retarding potential?

15. How many photons are emitted per second by a 100-W sodium lamp if the wavelength of sodium light is 589.3 nm?
\[ \lambda = 3.37 \times 10^{-10} \text{ m} \]

The energy emitted per second by the lamp = (power) = (100 J/s)/1(s) = 100 J/s

\[ V = \lambda \times 10^6 \]

Energy per philosopher: \[ E = \frac{10^6 \times 10^6}{100} \]

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PROBLEMS

1. Determine the wavelength of the following radiation of hydrogen: (a) the third-longest wavelength of the Paschen series; (b) the longest wavelength of the Balmer series; (c) the shortest wavelength (series limit) of the Paschen series; (d) the next-to-longest wavelength of the Lyman series.

2. (a) What value of $n$ is associated with the Lyman series line in hydrogen whose wavelength is 94.96 nm? (b) Could this wavelength be associated with the Paschen or Brackett series?

3. Find the potential energy and kinetic energy of an electron in the ground state of the hydrogen atom.

4. A photon is emitted from a hydrogen atom, which undergoes a transition from the $n = 3$ state to the $n = 2$ state. Calculate (a) the energy, (b) the wavelength, and (c) the frequency of the emitted photon.

5. A laser emits a 0.5-W beam of light at a wavelength of 640 nm. How many photons does the laser emit per second?

6. Calculate the radius of the first, second, and third Bohr orbits of hydrogen.

7. What wavelength radiation would ionize hydrogen when the atom is in its ground state?

8. Calculate the angular momentum of the electron in the $n = 3$ state of hydrogen.


10. What is the radius of the first Bohr orbit in (a) He$^+$ and (b) Be$^+$?

11. List the possible sets of quantum numbers for electrons in the 3$d$ subshell.
1. \[
\frac{1}{\lambda} = R \left( \frac{1}{m^2} - \frac{1}{n^2} \right)
\]

m = 1 = Lyman series
m = 2 = Balmer series
m = 3 = Paschen series

(a) When \( n = 6 \), \( \frac{1}{\lambda} = (1.0974 \times 10^7 \text{ m}^{-1}) \left( \frac{1}{9} - \frac{1}{36} \right) \), and from this,
\[\lambda = 1.094 \times 10^{-6} \text{ m} = 1094 \text{ nm}\]
(b) When \( n = 3 \), \( \frac{1}{\lambda} = (1.0974 \times 10^7 \text{ m}^{-1}) \left( \frac{1}{4} - \frac{1}{9} \right) \), and from this,
\[\lambda = 656.1 \text{ nm}\]
(c) When \( n = \infty \), \( \frac{1}{\lambda} = (1.0974 \times 10^7 \text{ m}^{-1}) \left( \frac{1}{9} - \frac{1}{\infty} \right) \), and from this,
\[\lambda = 820.1 \text{ nm}\]
(d) When \( n = 3 \), \( \frac{1}{\lambda} = (1.0974 \times 10^7 \text{ m}^{-1}) \left( \frac{1}{1} - \frac{1}{9} \right) \), and from this,
\[\lambda = 102.5 \text{ nm}\]

2. \[
\frac{1}{\lambda} = R \left( 1 - \frac{1}{n^2} \right)
\]
for Lyman series

Thus, if \( \lambda = 94.96 \text{ nm} \), we have
\[
\frac{1}{94.96 \times 10^{-9} \text{ m}} = (1.0974 \times 10^7 \text{ m}^{-1}) \left( 1 - \frac{1}{n^2} \right)
\]
and \( n = 5 \)

(b) This spectral line could not be associated with the Paschen or Brackett series because it is shorter than the series limit of either of these series.

3. \[
E = KE + PE = \frac{1}{2} mv^2 - \frac{ke^2}{r}
\]
but \[
\frac{1}{2} mv^2 = \frac{1}{2} \frac{ke^2}{r}
\]
and

Thus, \( E = -\frac{1}{2} \frac{ke^2}{r} = \frac{PE}{2} \), so \( PE = 2E = 2(-13.6 \text{ eV}) = -27.2 \text{ eV} \)

4. (a) The energy of the photon is found as
\[
E = E_f - E_i = -13.6 \text{ eV} - (-13.6 \text{ eV}) = 13.6 \text{ eV}
\]

(b) \( E = \frac{hc}{\lambda} \) and \( \lambda = \frac{1243 \text{ nm eV}}{1.89 \text{ eV}} = 658 \text{ nm} \)

(c) \( f = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m/s}}{658 \text{ nm}} = 4.56 \times 10^{14} \text{ Hz} \)

5. The energy emitted in 1 s is \( E = (\text{power})t = (0.5 \text{ J/s})(1 \text{ s}) = 0.5 \text{ J} \) and
the energy per photon is \( E' = \frac{hc}{\lambda} = \frac{1243 \text{ nm eV}}{640 \text{ nm}} = 1.94 \text{ eV} = 3.11 \times 10^{-19} \text{ J} \)

Thus, the number of photons per second is \( \frac{E}{E'} = \frac{5 \times 10^{-1} \text{ J}}{3.11 \times 10^{-19} \text{ J/photons}} = 1.61 \times 10^{18} \text{ photons} \)

6. \( r_n = n^2 r_0 = n^2(0.0529 \text{ nm}) \)
   For \( n = 1 \), \( r_1 = r_0 = 0.0529 \text{ nm} \)
   For \( n = 2 \), \( r_2 = 4r_0 = 4(0.0529 \text{ nm}) = 0.212 \text{ nm} \)
   For \( n = 3 \), \( r_3 = 9r_0 = 9(0.0529 \text{ nm}) = 0.476 \text{ nm} \)

7. \( E = \frac{13.6}{n^2} \) becomes for \( n = 1 \) 13.6 eV

8. \( L = nh = 3(1.05 \times 10^{-34} \text{ J s}) = 3.15 \times 10^{-34} \text{ J s} \)

9. The shortest wavelength corresponds to the highest energy emitted. For th
   Lyman series, the energy of the photon is given by
\[
E = 13.6 \text{ eV} \left( 1 - \frac{1}{n^2} \right) \text{ and } E \text{ is a max when } n = \text{ infinity}. \text{ Thus,}
\]
\[
E_{\text{max}} = 13.6 \text{ eV}
\]
and \( \lambda_{\text{min}} = \frac{hc}{E_{\text{max}}} = \frac{1243 \text{ nm eV}}{13.6 \text{ eV}} = 91.4 \text{ nm} \)

10. \( r_n = \frac{n^2 r_0}{Z} \) we have \( r_n = \frac{0.529 \times 10^{-10} \text{ m}}{Z} \)

(a) for \( \text{He}^+ r_n = \frac{0.529 \times 10^{-10} \text{ m}}{2} = 0.265 \times 10^{-10} \text{ m} = 0.265 \text{ Å} \)

(b) for \( \text{Be}^{3+} r_n = \frac{0.529 \times 10^{-10} \text{ m}}{4} = 0.132 \times 10^{-10} \text{ m} = 0.132 \text{ Å} \)

11. In the 3d subshell, \( n = 3 \) and \( l = 2 \). We have
   \[
   n \quad l \quad m_l \quad m_s \quad \begin{array}{c|c|c|c|c}
   3 & 2 & +2 & +1/2 & 3 & 2 & -1 & +1/2 \\
   3 & 2 & +2 & -1/2 & 3 & 2 & -1 & -1/2 \\
   3 & 2 & +1 & +1/2 & 3 & 2 & -2 & +1/2 \\
   3 & 2 & +1 & -1/2 & 3 & 2 & -2 & -1/2 \\
   \end{array}
   \]
PROBLEMS

1. Find the nucleus that has a radius approximately equal to one-half the radius of uranium, $^{238}\text{U}$.

2. Use energy methods to find the distance of closest approach of a 0.5-MeV proton to a gold nucleus at rest.

3. Calculate the total binding energy for $^{40}\text{Ca}$.

4. Calculate the binding energy per nucleon for $^{197}\text{Au}$.

5. Determine the difference of the binding energy of $^3\text{H}$ and $^3\text{He}$.

6. The half-life of a radioactive sample is 30 min. If you start with a sample containing $3 \times 10^{16}$ nuclei, how many of these nuclei remain after 10 min?

7. How many radioactive atoms are present in a sample that has an activity of 0.2 $\mu$Ci and a half-life of 8.1 days?

8. Find the energy released in the alpha decay of $^{235}\text{U}$.

9. Is it energetically possible for a $^7\text{Be}$ nucleus to spontaneously decay into two alpha particles? Explain.

10. A sample of organic material is found to contain 18 g of carbon. The investigators believe the bones to be 20,000 years old based on samples of pottery taken from the site. If so, what is the expected activity of the sample?

11. Is it energetically possible for a $^{12}\text{C}$ nucleus to spontaneously decay into three alpha particles? Explain.

12. The radioactive isotope $^{185}\text{Au}$ has a half-life of 64.8 h. A sample containing this isotope has an initial activity of 40 $\mu$Ci. Calculate the number of nuclei that will decay in the time interval between $t_1 = 10$ h and $t_2 = 12$ h.
Thus, the number which are decayed between 10 h and 1 h 1 = 10 h

Similarity, the number present at 1 h can be found to be

\[ N_1 = 9 \times 10^{-4} \times 10^{-1} \, \text{nuclei} \]

Now use \( N_0 \) to find the number present at 1 h

\[ N_0 = \frac{1.78 \times 10^{-4} \times 10^{-1}}{8.30 \times 10^{-4} \, \text{decays/minute}} = 0.21 \]

The decay constant is \( \lambda = \frac{0.693}{0.09} = 7.7 \times 10^{-5} \, \text{h}^{-1} \)

The decay number of the sample is

\[ 1 \times 10^{-8} \times 1.78 \times 10^{-4} \times 10^{-1} = 1 \times 10^{-11} \, \text{nuclei} \]

Since the value is less than zero, the decay cannot occur spontaneously.

From which, \( R = \frac{0.78 \text{ decays/minute}}{10^{-4} \text{ nuclei}} \)

The decay constant is \( \lambda = \frac{0.693}{0.09} = 7.7 \times 10^{-5} \, \text{h}^{-1} \)

The original activity of the sample is

\[ 1 \times 10^{-8} \times 1.78 \times 10^{-4} \times 10^{-1} = 1 \times 10^{-11} \, \text{nuclei} \]

Since \( k = 1.6 \times 10^{-4} \, \text{h}^{-1} \)

First, assume the decay will occur and compute the energy balance:

\[ \Delta H = \Delta H^0 + \left( \Delta H^\text{f,ex} \right) \]

From which, \( \Delta H = 1.6 \times 10^{-4} \, \text{h}^{-1} \)

8

From which, \( \lambda = \frac{0.693}{0.09} = 7.7 \times 10^{-5} \, \text{h}^{-1} \)

The rate of change of the reaction is \( \frac{dN}{dt} = 0.5 \, \text{MeV} \)

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Nuclear Fission and Fusion

1. Complete the table for a chain reaction in which two neutrons from each step individually cause a new reaction.

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<th>2</th>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tbody>
<tr>
<td>NO. OF REACTIONS</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Complete the table for a chain reaction where three neutrons from each reaction cause a new reaction.

<table>
<thead>
<tr>
<th>EVENT</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO. OF REACTIONS</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Complete these beta reactions, which occur in a breeder reactor.

\[
\begin{align*}
\text{\textsubscript{239}} \text{\textsubscript{92}} \text{U} & \rightarrow _____ + ^0 \text{e}^- \\
\text{\textsubscript{239}} \text{\textsubscript{93}} \text{Np} & \rightarrow _____ + ^0 \text{e}^- 
\end{align*}
\]

4. Complete the following fission reactions.

\[
\begin{align*}
\text{\textsubscript{0}} \text{n} + \text{\textsubscript{235}} \text{\textsubscript{92}} \text{U} & \rightarrow \text{\textsubscript{143}} \text{\textsubscript{54}} \text{Xe} + \text{\textsubscript{90}} \text{\textsubscript{38}} \text{Sr} + _____ (\text{\textsubscript{0}} \text{n}) \\
\text{\textsubscript{0}} \text{n} + \text{\textsubscript{235}} \text{\textsubscript{92}} \text{U} & \rightarrow \text{\textsubscript{152}} \text{\textsubscript{60}} \text{Nd} + _____ + 4 (\text{\textsubscript{0}} \text{n}) \\
\text{\textsubscript{0}} \text{n} + \text{\textsubscript{239}} \text{\textsubscript{94}} \text{Pu} & \rightarrow _____ + \text{\textsubscript{97}} \text{\textsubscript{40}} \text{Zr} + 2 (\text{\textsubscript{0}} \text{n})
\end{align*}
\]

5. Complete the following fusion reactions.

\[
\begin{align*}
\text{\textsubscript{1}} \text{H} + \text{\textsubscript{1}} \text{H} & \rightarrow \text{\textsubscript{3}} \text{He} + _____ \\
\text{\textsubscript{1}} \text{H} + \text{\textsubscript{3}} \text{H} & \rightarrow \text{\textsubscript{4}} \text{He} + _____
\end{align*}
\]
Nuclear Reactions

Complete these nuclear reactions.

1. \( _{92}^{238}U \rightarrow _{90}^{234}Th + \_\_\_\_ + \_\_\_\_ \)

2. \( _{90}^{234}Th \rightarrow _{91}^{234}Pa + \_\_\_\_\_ \)

3. \( _{91}^{234}Pa \rightarrow \_\_\_\_ + _{2}^{4}He \)

4. \( _{86}^{220}Rn \rightarrow \_\_\_\_ + _{2}^{4}He \)

5. \( _{84}^{216}Po \rightarrow \_\_\_\_ + _{1}^{0}e \)

6. \( _{84}^{216}Po \rightarrow \_\_\_\_ + _{2}^{4}He \)

7. \( _{83}^{210}Bi \rightarrow \_\_\_\_ + _{1}^{0}e \)

8. \( _{0}^{1}n + _{5}^{10}B \rightarrow \_\_\_\_ + _{2}^{4}He \)

THORIUM LATE, I OVERTHLEPT!

NUCLEAR PHYSICS --- IT'S THE SAME TO ME WITH THE FIRST TWO LETTERS INTERCHANGED!
Quantum Review

1. Which type of radiation has the greatest energy per photon (AA83)
   - a. gamma
   - b. infrared
   - c. microwave
   - d. ultraviolet
   - e. visible

2. An electron volt is a measure of (AP88)
   - a. energy
   - b. electric field
   - c. electric potential due to one electron
   - d. force per unit electro charge
   - e. electric charge

3. Compared to a 5.0 electron-volt photon, a 10 electron-volt photon has greater (AA88)
   - a. frequency
   - b. rest mass
   - c. speed
   - d. wavelength
   - e. none of the above

4. In the graph above, what does the intercept of each line with the horizontal axis represent (AA85, MP2)
   - a. energy of the light which corresponds to a given frequency
   - b. threshold frequency of light for the emission of photoelectrons
   - c. relative energy of the light incident upon each metal
   - d. total kinetic energy of all the electrons emitted by each metal
   - e. frequency of electron emission

5. In a photoelectric effect experiment a metal has a work function of 3.8 eV. An opposing voltage of 8 volts is found to reduce the current to zero. This indicated that the (AA83)
   - a. released electrons had an average of 8 eV of energy
   - b. released electrons had 11.8 eV of energy
   - c. photons striking the metal had 4.2 eV of energy
   - d. photons striking the metal had 3.8 eV of energy
   - e. photons striking the metal has at most 11.8 eV of energy
6. Which phenomenon can best be explained by assuming an electron has wave characteristics (AA85)
   a. Frank-Hertz effect
   b. interference patterns
   c. photoelectric effect
   d. radioactivity
   e. static electricity

7. Einstein's photoelectric theory explains that for a given metallic surface, the maximum kinetic energy of the ejected electrons depends upon the (AA85)
   a. angle of incidence of the incident light
   b. duration of exposure of the metal surface
   c. frequency of the incident light
   d. intensity of the incident light
   e. the number of ejected electrons per second

8. In photoelectric emission, the number of electrons ejected per second (ppb28.3)
   a. is proportional to the intensity of the light.
   b. is proportional to the wavelength of the light.
   c. is proportional to the frequency of the light.
   d. is proportional to the work function of the material.
   e. is given by none of the above.

9. A photon and an electron have the same wavelength. It follows that (ppb29.1)
   a. the momentum of the photon is less than that of the electron.
   b. the photon and the electron have the same momentum.
   c. the momentum of the photon is greater than that of the electron.
   d. the photon and the electron have the same energy.
   e. the photon and the electron have the same speed.

Consider the following statements:
I. An atom has two energy levels whose energy difference matches the energy of a photon.
II. The lower of these two levels is occupied by an electron.
III. The higher of these two levels is occupied by an electron.

10. Which of the above must be true for the atom to absorb the photon in a one-photon process? (AA83, MPA)
    a. both I and II
    b. both II and III
    c. only I
    d. only II
    e. only III

11. The bright-line spectrum produced by isolated and excited atoms of an element contains wavelengths that are (AA83)
    a. characteristic of the particular element
    b. the same for all elements
    c. evenly distributed throughout the visible spectrum
    d. dependent upon the intensity of the source
    e. described by none of the above
12. An 8 eV photon strikes the atom. Which of the following events could occur? The diagram shows the energy levels of the atom. (aoaie17,w52):
   a. The photon is absorbed and an electron with 8 eV is ejected.
   b. The photon is absorbed and an electron with 2 eV is ejected.
   c. The atom is raised to 1 eV and an electron with 7 eV is ejected.
   d. The photon is absorbed and an electron with 6 eV is ejected.
   e. The atom is ionized and the photon recoils with 2 eV of energy.

13. Excited atoms in a gas discharge tube return to their ground state by emitting
   a. electrons
   b. neutrons
   c. photons
   d. protons
   e. quarks

14. The radiation emitted from a gaseous sample of these atoms in an excited state will show spectral lines. Which one of the spectral energies will not be represented by a line in the spectrum? (aoaie16,w51)
   a. 0.5 eV
   b. 1.0 eV
   c. 1.5 eV
   d. 2.0 eV
   e. 2.5 eV

15. All of the following are properties of x-rays EXCEPT
   a. they penetrate light materials
   b. they ionize gases
   c. they are deflected by magnetic fields
   d. they discharge electrified bodies
   e. they are diffracted by crystals
16. Which of the following graphs best represents the de Broglie wavelength of a particle as a function of the linear momentum $p$ of the particle? (AP88, MP1)

(A) ![Graph A]

(B) ![Graph B]

(C) ![Graph C]

(D) ![Graph D]

17. It is possible to explain the fact that electrons occupy discrete energy states in atoms by applying the

a. Doppler effect
b. fact that the speed of light is finite
c. ideal gas law
d. theory of relativity
e. wave nature of matter

18. A photon collides with a free electron at rest. The electron recoils and the scattered photon moves away in a new direction. Compared with the incoming photon, the scattered photon has its (AP74)

a. speed reduced
d. energy increased
b. linear momentum unaffected

c. frequency increased
e. wavelength increased

19. In the Rutherford experiment, alpha particles were directed at gold foil. The observation that a few alpha particles were deflected through large angles led Rutherford to conclude that (AA88)

a. gold atoms have a net positive electrical charge
d. there are small, massive, charged particles in the gold foil
b. gold atoms are less massive than alpha particles
c. the electrons of gold atoms move in specific orbits
e. the mass of an alpha particle is greater than the mass of a proton

Answers for 20.

20. Which postulates are from the Bohr atomic theory?

a. I and II only
d. II and IV only
b. I and III only
e. III and IV only
c. II and III only
21. The atom will be ionized if bombarded by electrons of kinetic energy:
   a. 9.8 ev
   b. 10.8 ev
   c. 12.8 ev
   d. 13.8 ev

22. The atom will not absorb a photon whose energy is:
   a. 10.2 ev
   b. 10.8 ev
   c. 12.1 ev
   d. 12.75 ev

23. In the following transitions, the photon of greatest frequency will be emitted when the atom passes from energy level:
   a. $n = 5$ to $n = 3$
   b. $n = 4$ to $n = 3$
   c. $n = 3$ to $n = 2$
   d. $n = 2$ to $n = 1$
A photon in one of the spectral lines in the Balmer series has an energy of $3.0 \times 10^{-19}$ joule. The frequency of this photon is:

a. $2.2 \times 10^{14}$ Hz  
b. $3.5 \times 10^{14}$ Hz  
c. $4.5 \times 10^{14}$ Hz  
d. $6.6 \times 10^{14}$ Hz

When the energy level of the hydrogen atom changes from $n = 4$ to $n = 2$, a photon is emitted with an energy of:

a. $8.5 \times 10^{-20}$ J  
b. $2.6 \times 10^{-19}$ J  
c. $4.1 \times 10^{-19}$ J  
d. $3.4 \times 10^{-19}$ J

The Lyman series of spectral lines in the hydrogen spectrum similar to the Balmer series. It results from those energy changes in the hydrogen atom in which the atom goes from higher energy levels to that for which $n = 1$. In which part of the spectrum do these lines belong?

a. infrared  
b. radio  
c. ultraviolet  
d. visible

Hydrogen atoms in the ground state are bombarded by electrons having a maximum kinetic energy of 12.2 ev. The highest energy level to which these electrons can raise the hydrogen atom which they strike is that for which $n =$:

a. 1  
b. 2  
c. 3  
d. 4

A photon of 15.0 ev is absorbed by a hydrogen atom and ionizes it by ejecting its electron. The kinetic energy of the ejected electron is:

a. 1.4 ev  
b. 13.6 ev  
c. 15 ev  
d. 28.6 ev

The atoms of a quantity of hydrogen gas drop from the state for which $n = 3$ to that for which $n = 1$ in one or more jumps. The maximum number of spectral lines of different frequencies that will be produced by these energy changes is:

a. 1  
b. 2  
c. 3  
d. 4

If the hydrogen atom changes from the energy level for which $n = 2$ that for which $n = 1$, it emits a:

a. 3.4 ev photon  
b. 10.2 ev photon  
c. 13.6 ev photon  
d. 17 ev photon
1. In a nuclear reaction, alpha decay refers to (AA88)
   - a. any process that has a half-life
   - b. disintegration of an alpha particle
   - c. a decrease in an alpha particle's energy
   - d. emission of a helium nucleus from a nucleus
   - e. radiation damage to material inside a nuclear reactor

2. A particle is emitted when radon - $^{222}_{86}$Rn decays into polonium - $^{218}_{84}$Po. What is the particle (AA88)?
   - a. a proton
   - b. a neutron
   - c. a gamma ray
   - d. a beta particle
   - e. an alpha particle

3. Strontium - $^{90}_{38}$Sr is unstable and decays by emitting a beta particle. What nuclide is formed as a result of this process (AA88)?
   - a. $^{91}_{38}$Sr
   - b. $^{90}_{38}$Sr
   - c. $^{90}_{38}$Sr
   - d. $^{89}_{38}$Y
   - e. $^{89}_{38}$Sr

4. A nucleus of tritium contains 2 neutrons and 1 proton. If the nucleus undergoes beta decay, emitting an electron, the nucleus is transmuted into (AP88)
   - a. the nucleus of an isotope of helium
   - b. the nucleus of an isotope of lithium
   - c. an alpha particle
   - d. a triton
   - e. a deuteron

5. After 2 hours, 1/8 of the initial amount of a radioactive isotope is left. What is the half-life of this isotope (AA85)?
   - a. 15 minutes
   - b. 30 minutes
   - c. 40 minutes
   - d. 60 minutes
   - e. more than 60 minutes

6. What is the mass number of the resulting nucleus after uranium - $^{238}$ has undergone alpha decay (AA85)?
   - a. 234
   - b. 236
   - c. 238
   - d. 239
   - e. 242

7. What is the number of neutrons in the nucleus of an atom of aluminum isotope $^{27}_{13}$Al (AA85)?
   - a. 12
   - b. 13
   - c. 14
   - d. 27
   - e. 40
8. A radioactive sample has a half-life of nine months. What fraction of the original activity will remain after three years (AA83)

   a. 1/2
   b. 1/4
   c. 1/8
   d. 1/16
   e. 1/32

9. The atomic mass number of an element is (AA83)

   a. always equal to or less than its atomic number
   b. always greater than or equal to its atomic number
   c. sometimes greater and sometimes less than its atomic number
   d. equal to its atomic number except in the case of isotopes
   e. always equal to the number of protons in the nucleus

10. Thorium (229/0Th) undergoes alpha decay. What is the daughter nucleus of this process (AA83)

    a. 225/60Th
    b. 225/88Ra
    c. 227/88Ra
    d. 227/66Rn
    e. 225/86Rn

11. A uranium atom at rest spontaneously decays in two fragments. Which of the following statements are always true (AA83)

    a. kinetic energy is constant
    b. the two fragments have equal energy
    c. the speed of the one is equal to the speed of the other fragment
    d. the sum of the momenta of the two fragments is zero
    e. the sum of the kinetic energies of the two fragments is zero

12. Which of the following statements is true of a beta particle (AP88)

    a. its speed in a vacuum is 3 x 10^8 m/s
    b. it has a charge equal and opposite to that of an alpha particle
    c. it is more penetrating than a gamma ray of the same energy
    d. it has a mass of about 1,840 times that of a proton
    e. it can exhibit wave properties

13. The end product of the nuclear reaction

\[ ^{12} \text{He} + ^{94} \text{Be} \rightarrow ^{10} \text{n} + \underline{\text{_____}} \] is (AP74)

    a. 10/6B
    b. 12/6B
    c. 12/6C
    d. 14/6C
    e. 12/7N

14. A radioactive nucleus of uranium (238/2 U) decays with successive emissions of alpha, beta, beta, alpha, and alpha particles. The resulting nucleus has an atomic mass number of (AP74)

    a. 233
    b. 232
    c. 230
    d. 226
    e. 224

15. An isotope of the element manganese has an atomic number of 25 and a mass number of 55. The nucleus of a manganese atom contains

    a. 25 protons and 30 neutrons
    b. 30 protons and 25 neutrons
    c. 25 protons and 55 neutrons
    d. 25 protons and 25 neutrons
    e. 55 protons and 25 neutrons
15. The alpha particle consists of

- a. 1 proton and 1 neutron
- b. 1 proton and 2 neutrons
- c. 2 protons and 2 neutrons
- d. 2 protons and 4 neutrons
- e. 2 protons, 2 neutrons and 2 electrons

17. A particle was emitted from the nucleus of an atom and it was found that the atomic number of the atom increased. The emitted particle was probably

- a. a beta particle
- b. an alpha particle
- c. a proton
- d. a positron
- e. a neutron

18. The annihilation of a proton and an antiproton produces much more energy than the annihilation of an electron and a positron because

- a. protons spin much faster than electrons
- b. a proton is much more massive than an electron
- c. the positron is not the antiparticle of the electron
- d. at the same temperature, protons move much faster than electrons
- e. at the same temperature, electrons move much faster than protons

19. Nuclear fusion occurs when

- a. heavy ions fuse together.
- b. very light nuclei fuse together.
- c. uranium emits a neutron.
- d. uranium splits into two or more fragments.

20. Nuclear fusion occurs naturally in

- a. the sun.
- b. the upper atmosphere.
- c. uranium mines.
- d. All of the above.

21. The emission of an electron by a nucleus is generally accompanied by a(n)

- a. antineutrino.
- b. neutrino.
- c. neutron.
- d. positron.

22. If the value of nuclear mass per nucleon were graphed versus increasing atomic number for all the elements, the graph would

- a. be a straight line.
- b. show that nuclear mass per nucleon always increases with increasing atomic number.
- c. start high, dip quickly, then slowly increase.

23. A proton of mass m-p and a neutron of mass m-n combine in a fusion process to form a stable deuterium nucleus. The mass of this nucleus is

- a. equal to m-p plus m-n.
- b. greater than m-p plus m-n.
- c. less than m-p plus m-n.
- d. sometimes less than and sometimes equal to m-p plus m-n.
- e. sometimes greater than and sometimes equal to m-n.

24. When a neutron leaves a nucleus, the nucleus of mass m-n and new nucleus compared to original nucleus.

- a. decreases.
- b. increases.
- c. stays the same.
TRUE or FALSE The mass of a free proton is more than the mass of a proton bound inside a nucleus.

TRUE or FALSE The value obtained for average mass per nucleon is the same no matter what nucleus it is measured in.

TRUE or FALSE It is impossible for a hydrogen atom to emit an alpha particle.

The purpose of the cadmium rods in a nuclear reactor is:
- a. to absorb excess heat.
- b. to control the number of neutrons in the reactor.
- c. to prevent a chain reaction.
- d. to serve as radiation shields.

A chain reaction can be maintained through the fission of U-235 because U-235:
- a. is easily penetrated by neutrons.
- b. is very unstable.
- c. releases one or more new neutrons on disintegrating.
- d. splits into products having very high kinetic energy.

The mass of a proton is 1.0073 u and that of a neutron is 1.0087 u. The most probable value for the mass of a deuteron is:
- a. 2.0140 u
- b. 2.0160 u
- c. 2.0180 u
- d. 2.0200 u

Nuclear fission occurs when:
- a. a nucleus divides spontaneously, for no apparent reason.
- b. electrical forces inside a nucleus overcome nuclear forces.
- c. nuclei are split in two by a very small cutting device.
- d. one nucleus bumps into another causing a chain reaction.

Which of the following are NOT emitted in radioactive decay?
- a. Alpha particles
- b. Beta particles
- c. High energy electromagnetic radiation
- d. All of the above are emitted.

The atomic number of an atom or ion refers to its number of:
- a. electrons
- b. neutrons
- c. nucleons
- d. protons

The atomic mass number of an atom refers to its number of:
- a. electrons
- b. neutrons
- c. nucleons
- d. protons

List the name of each of the following types of radiation:
- a. High frequency electromagnetic radiation
- b. Identical to electrons
- c. Like electrons, but with a positive charge
- d. Nuclei of the element helium
- e. Neutral particles with a mass number of one

Consider the following atom $^{226}_{88}$Ra.

- a. How many protons does it contain? __________
- b. How many neutrons does it contain? __________
- c. What is its atomic mass in atomic mass units? __________
Quantum Nuclear

1 A 2 E 3 B 4 A
2 A 3 B 4 A 28 B
3 A 4 A 5 C 29 C
4 B 5 C 6 A 30 A
5 E 6 A 7 C 31 B
6 B 8 D 9 B 32 D
7 C 9 B 33 D 34 C
8 A 10 B 35 "
9 B 11 D 36 88
10 A 12 E 13 C 14 D 37 9 e
11 A 12 E 13 C 14 D 37 9 e
12 B 15 A 16 C 36 88
13 C 16 C 17 A 36 88
14 D 17 A 18 B 13 8
15 C 18 B 22 6
16 C 19 B 20 A 21 A
17 E 19 B 20 A 21 A
18 E 20 A 21 A 22 C
19 D 22 C 23 C 24 A
20 A 23 C 24 A
21 D 25 T 26 F 27 T
22 C 25 T 26 F 27 T
23 D 26 F 27 T 28 B
24 C 27 C 28 A
25 C 28 A 29 C
26 C 29 C 30 B
27 C 30 B 31 B