Name _____

Hour _____

Hydrogen Energy Levels

Note: A partial energy level diagram for hydrogen is shown at right. It will be useful for many of the problems in this unit.

-.54 eV ———————————— $n = 5$

-.85 eV ———————————— $n = 4$

Question A:
   A spectroscope is an instrument that separates incident white light into individual wavelengths. Explain how a diffraction grating is used in a spectroscope to accomplish this function.

-1.51 eV ———————————— $n = 3$

-3.40 eV ———————————— $n = 2$

Question B:
   Are the Balmer lines in the hydrogen spectrum more closely spaced at the long wavelength or short wavelength end of the series? Use the Balmer equation to explain your answer.

-13.6 eV ———————————— $n = 1$

Question C:
   Use the Rydberg constant to calculate the wavelengths of the first four lines in the . . .
   a) Balmer series of the hydrogen spectrum.
   b) Lyman series of the hydrogen spectrum.
   c) Paschen series of the hydrogen spectrum.

Question D:
   Use the Rydberg constant to calculate the wavelength of the . . .
   a) fifth line in the Balmer series of the hydrogen spectrum.
   b) sixth line in the Balmer series of the hydrogen spectrum.
   c) Why are these lines not usually observed in the Balmer series for hydrogen?

Question E:
   Hydrogen has a ground state energy level of –13.6 eV, so the equation $\dfrac{-13.6}{n^2}$ can be used to calculate its successive energy levels.
   a) Calculate the energy levels for hydrogen at . . . $n = 2$ . . . $n = 3$ . . . $n = 4$ . . . $n = 5$ . . . $n = 6$.
   b) Use the results from Part *a* to construct an energy level diagram for hydrogen, including the ground state and first 5 excited states.
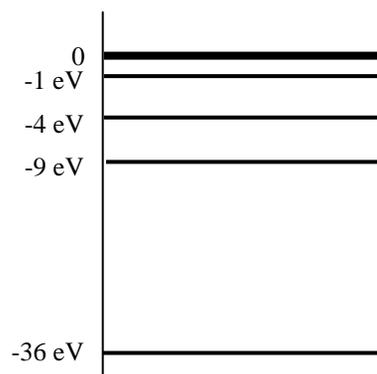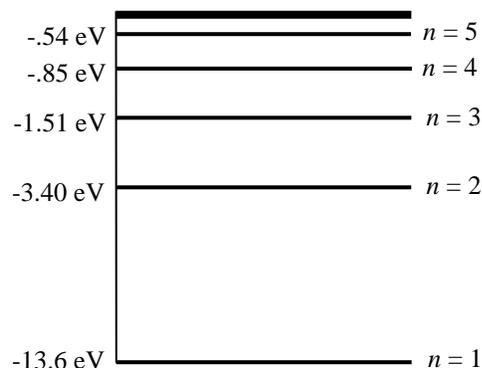
Question H:
   A hydrogen atom emits a photon of wavelength 102.6 nm. From what excited energy level to what lower energy level did the electron transition?

Question I:
   The energy level diagram at right shows the ground state and first three excited states for a hypothetical atom. Suppose an electron in this atom is excited to the state of $n = 4$.
   a) How much energy was required to excite the atom if the electron was originally in the ground state?
   b) Calculate the longest possible wavelength that a photon could possess when emitted by this atom as the electron moves from $n = 4$ to a lower state.
   c) Calculate the shortest possible wavelength that a photon could possess when emitted by this atom as the electron moves from $n = 4$ to a lower state.

0 ————————————

-1 eV ————————————

-4 eV ————————————

-9 eV ————————————

-36 eV ————————————

Question J:
In the situations below, consider the Balmer, Lyman, and Paschen series of emission lines for the hydrogen atom.
a) Use energy levels to calculate the longest wavelength in the Balmer series.
b) Use energy levels to calculate the longest wavelength in the Lyman series.
c) Use energy levels to calculate the longest wavelength in the Paschen series.
d) Compare the answers above to the answers calculated in Question C. How do the answers obtained by the two methods compare?

Question K:
The sun is a yellow star and emits most of its radiation in the yellow portion of the spectrum, with its peak at a frequency of 5.20 x 10^{14} Hz. Calculate the energy emitted in one photon of this visible yellow light.

Question L:
After applying a sunscreen, Cheri lies in the summer sun on a California beach. She soaks up the electromagnetic waves given off by the sun, including some ultraviolet rays of 310 nm and some ultraviolet rays of 280 nm.
a) Calculate the energy carried by each 310 nm photon.
b) Calculate the energy carried by each 280 nm photon.
c) Which ultraviolet wavelength is more likely to give Cheri a tan? Which wavelength is more likely to give Cheri a sunburn? Explain your answer.

Question M:
A hydrogen atom is in its ground state when an incident photon with a 85 nm wavelength collides with it. All of the photon's energy is transferred to the electron, freeing it from the atom. Ionization energy of hydrogen is 13.6 eV.
a) Calculate the energy of the photon.
b) Calculate the kinetic energy of the emitted electron.

Question N:
An experiment is performed on a sample of atoms known to have a ground state of -5.0 eV. The gas is illuminated with "white light" (400 – 700 nm). A spectrometer capable of analyzing radiation in this range is used to measure the radiation. The sample is observed to absorb light at only 400 nm. After the "white light" is turned off, the sample is observed to emit visible radiation of 400 nm and 600 nm.
a) Determine the values of the energy levels for:
  i. The ground state.
  ii. The energy level to which the system was first excited.
  iii. The other energy level that the experiment suggests may exist.
b) What is the wavelength of any other radiation that might have been emitted in the experiment? Why was it not observed?

AP Physics: Chapter 27
Atomic Physics

Question A:
A monochromatic beam of light strikes a sodium surface (Φ = 2.46 eV), causing electrons to be emitted with a maximum speed of 1.00 x 10^6 m/s. Calculate the wavelength of this incident light.
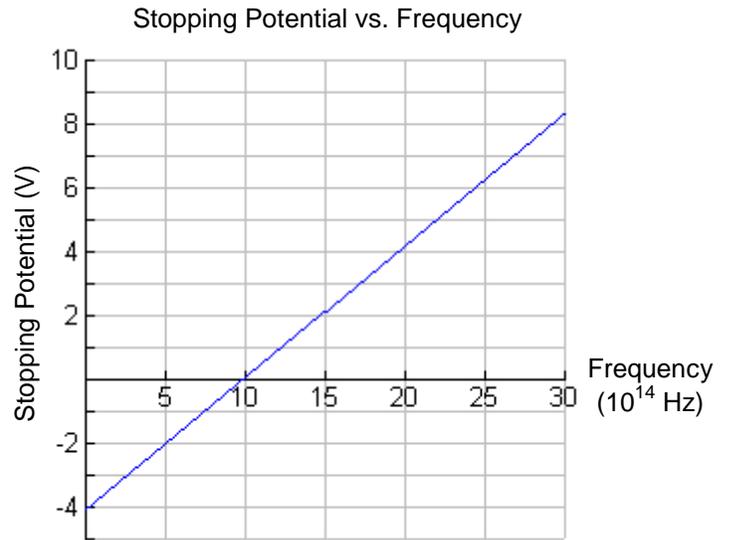
Question B:
When a certain metal is illuminated with light of frequency 3.0 x 10^{15} Hz, a stopping potential of 7.0 V is required to stop the most energetic ejected electrons. Calculate the work function of this metal.

Question C:
A graph of stopping potential versus frequency for an aluminum surface in a photoelectric effect experiment is shown at right.
   a) Calculate the cutoff wavelength for the surface.
   b) Use the graph to calculate an experimental value for the work function of aluminum.
   c) Calculate an experimental value for h/e.

Stopping Potential vs. Frequency

Stopping Potential (V) vs. Frequency (10^{14} Hz)

Question D:
If matter has a wave nature, why is this not observable in our daily experience?

Question E:
Calculate the energy and momentum of an electron of de Broglie wavelength .700 nm.
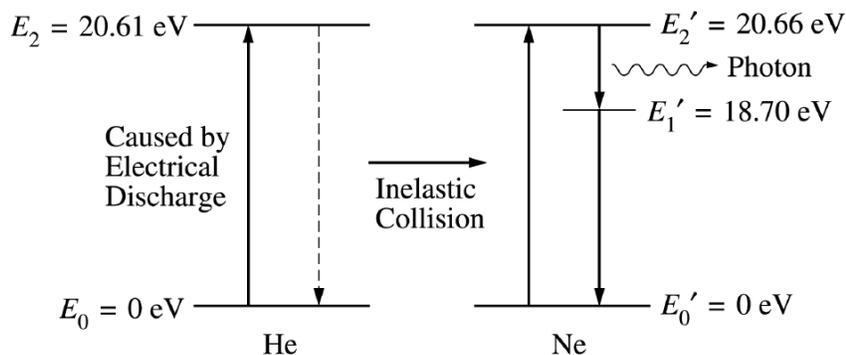
Question F:
A monoenergetic beam of electrons is incident on a single slit of width .500 nm. A diffraction pattern is formed on a screen 20.0 cm from the slit. If the distance from the center of the central maximum to the first minima is 2.10 cm, what is the energy of the incident electrons?

Question G:
Energy level diagrams for atoms that comprise a helium-neon laser are given. As indicated on the left, the helium atom is excited by an electrical discharge and an electron jumps from energy level E_0 to energy level E_2. The helium atom (atomic mass 4) then collides inelastically with a neon atom (atomic mass 20), and the helium atom falls to the ground state, giving the neon atom enough energy to raise an electron from E_0' to E_2'. The laser emits light when an electron in the neon atom falls from energy level E_2' to energy level E_1'.
   a) Calculate the minimum speed the helium atom must have in order to raise the neon electron from E_0' to E_2'.
   b) Calculate the DeBroglie wavelength of the helium atom when it has the speed determined in (a).
   c) The excited neon electron then falls from E_2' to E_1' and emits a photon of laser light. Calculate the wavelength of this light.
   d) This laser light is used to repair a detached retina in a patient's eye. The laser puts out pulses of length 20×10^{-3} s that average 0.50 W output per pulse. How many photons does each pulse contain?

$E_2 = 20.61$ eV

$E_2' = 20.66$ eV

Photon

$E_1' = 18.70$ eV

Caused by Electrical Discharge

Inelastic Collision

$E_0 = 0$ eV

$E_0' = 0$ eV

He

Ne

Question A:
  An isotope with an atomic mass of 59.93 u has an atomic number of 27.
  a) Use Appendix B to identify the element and isotope.
  b) Determine the number of neutrons in one atom of this isotope.
 c) Determine the number of atoms in a sample of 2.34×10^{-4} kg of this isotope.

Question B:
  The symbol $^{90}_{38}$ Sr represents a radioactive isotope of Strontium.

  a) Use Appendix B to determine the mass in kilograms of a single atom of Strontium-90.
  b) How many protons are in one atom of Strontium-90?
  c) How many neutrons are in one atom of Strontium-90?

Question C:
  What fraction of a radioactive sample has decayed after two half-lives have elapsed?
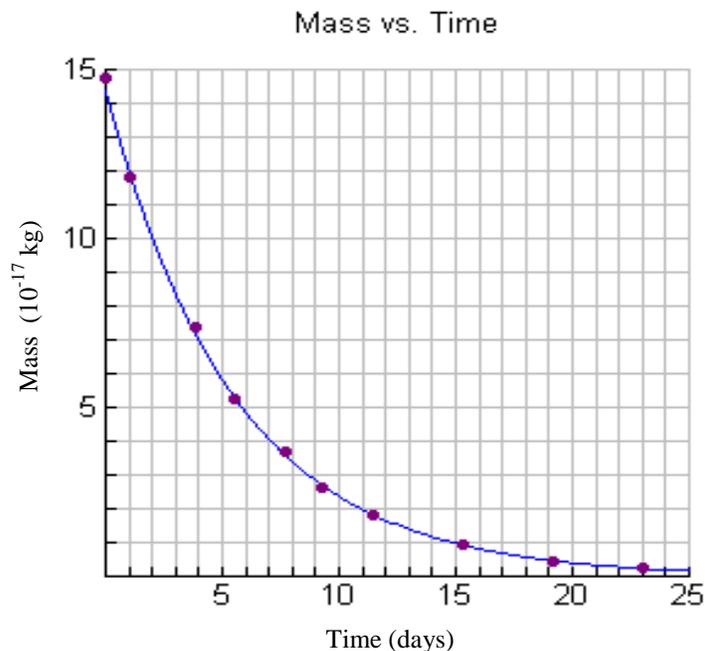
Mass vs. Time

Question D:
  The Mass vs. Time graph above shows the decay of a radioactive sample. The initial activity of the sample is 840 counts/sec.
  a) Use the graph to determine an approximate value for the half-life of the sample.
  b) Identify the isotope shown in the graph using Appendix B in your textbook.
  c) Use the exact half-life of the isotope from Appendix B to calculate the activity of the sample after 11.5 days.

Question E:
  The half-life of an isotope of phosphorus is approximately 14 days. A sample of this phosphorus isotope originally contains 3.0×10^{16} nuclei.
  a) Use Appendix B in your textbook to calculate the mass of the original sample.
  b) What mass of the sample remains after 14 days?
  c) After how many days will the mass of the remaining sample be approximately 2×10^{-10} kg?

Question F:

Carbon-14, a radioactive isotope with a half-life of 5730 years, can be used to establish the approximate age of some ancient remains. Suppose a 1.00 kilogram sample of carbon has an original activity of 231 counts per second. Calculate the decay rate after . . .
  a) 5730 years.
  b) 11,460 years.

Question G:

Suppose a nucleus such as $^{226}_{88}$Ra is initially at rest and then undergoes alpha decay. Which has more kinetic energy after the decay, the alpha particle or the daughter nucleus?

Question H:

A nucleus of mass 228 u, initially at rest, undergoes alpha decay. If the recoiling daughter nucleus has a momentum of 9.23×10^{-20} kg·m/s, calculate the . . .
  a) velocity of the alpha particle.
  b) kinetic energy of the alpha particle.

Question I:

A $^{212}_{84}$Po nucleus undergoes radioactive decay and emits an alpha particle with a velocity of 2.02×10^7 m/s.
  a) Write an equation representing this decay process.
  b) Calculate the velocity of the recoiling lead nucleus.
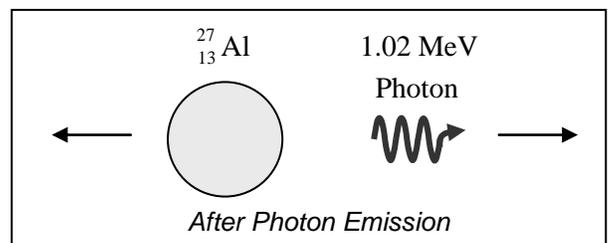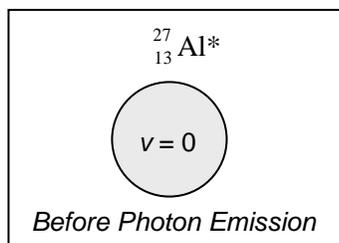 c) Without using data from Appendix B, calculate the energy released in a single alpha decay of $^{212}_{84}$Po

Question J:

When $^{235}_{92}$U absorbs a neutron, one possible fission reaction produces $^{141}_{56}$Ba and $^{92}_{36}$Kr as products. Write an equation representing this reaction. How many neutrons are released?

Question K:

Using the atomic mass values in Appendix B, find the energy released in each fission reaction listed below. In addition, the atomic mass of $^{98}_{40}$Zr is 97.9120 u and the atomic mass of $^{135}_{52}$Te is 134.9087 u.

  a) $^{1}_{0}$n + $^{235}_{92}$U → $^{98}_{40}$Zr + $^{135}_{52}$Te + 3 $^{1}_{0}$n

  b) $^{1}_{0}$n + $^{235}_{92}$U → $^{88}_{38}$Sr + $^{136}_{54}$Xe + 12 $^{1}_{0}$n

Question L:

Before Photon Emission   After Photon Emission

Following a nuclear reaction, a nucleus of aluminum is at rest in an excited state represented by $^{27}_{13}$Al*, as shown above left. The excited nucleus returns to the ground state $^{27}_{13}$Al by emitting a gamma ray photon of energy 1.02 MeV, as shown above right. The aluminum nucleus in the ground state has a mass of 4.48×10^{-26} kg. Assume nonrelativistic equations apply to the motion of the nucleus.
  a) Calculate the wavelength of the emitted photon in meters.
  b) Calculate the momentum of the emitted photon in kg·m/s.
  c) Calculate the speed of the recoiling nucleus in m/s.
  d) Calculate the kinetic energy of the recoiling nucleus in Joules.