PH2400 Exam III Spring 2001

Some Constants:

\[ \begin{align*} 
\pi &= 3.14159 \\
\hbar &= 6.626 \times 10^{-34} \text{ J}\cdot\text{s} \\
\hbar c &= 1240 \text{ eV}\cdot\text{nm} \\
c &= 3.00 \times 10^8 \text{ m/s} \\
R_H &= 1.0974 \times 10^7 \text{ m}^{-1} = 13.606 \text{ eV}/\hbar c \\
1 \text{ eV} &= 1.6022 \times 10^{-19} \text{ J} \\
1 \text{ amu} &= 931.48432 \text{ MeV}/c^2 = 1.66054 \times 10^{-27} \text{ kg} 
\end{align*} \]

Write your solutions on these pages, and turn in the entire exam along with your equation sheet. If you need extra paper, just ask.

*For problems 11 to 15: to receive full credit for correct answers, you must show your work!*

Report numerical answers to three (3) significant figures.

Score Summary (to be filled in by instructor)

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Totals ______ + ________ + ________ = ________
Multiple Choice:
(Circle your choice(s))

1. A transition between vibrational states for a typical diatomic molecule corresponds to a vibrational energy change closest to
   a. 13.6 eV   b. $0.511 \times 10^6$ eV   c. 0.3 eV   d. 0.005 eV   e. 0

2. The ground state electronic configuration of a certain neutral atom is given as $1s^22s^22p^63s^23p^3$. The atomic number, Z, for this atom is
   a. 0   b. 1   c. 3   d. 11   e. 15   f. 32

3. At $t = 0$, a scientist measures the activity of 1.00 g of a radioactive isotope to be 4.00 Ci. After 1 hour, the scientist measures the activity from the same sample to be 1.00 Ci. What is the half-life of this isotope?
   a. 1.50 Ci   b. 2.00 hours   c. 30.0 min   d. 1.39 hours   e. 0.719 hours

4. A typical fermi energy for a solid would be about
   a. 938 MeV   b. 13.6 eV   c. 3 eV   d. 0.1 eV   f. $1/40$ eV

5. Some properties of the neutron are that it has a spin $= \frac{1}{2}$ (same as proton), mass $\approx$ mass of proton, size $\approx$ size of proton, no net charge, and a magnetic moment roughly the same magnitude (within a factor of 2) of that of the proton (though of opposite sign). Which of the following is a logical conclusion about the neutron based on this information?
   a. the neutron can be accelerated by a uniform electric field.
   b. the neutron has some internal structure - it is not a uniform distribution of matter.
   c. the number of neutrons in a nucleus should be roughly the same as the number of protons.
   d. the neutron can be accelerated by a non-uniform electric field.
   e. the neutron can be accelerated by a uniform magnetic field.
**Short Answer**

Provide a short answer (1 or 2 sentences, equations, and/or appropriately labeled diagram) for each.

6. Consider the electronic states of an atom. How many states are there with \( n = 3 \)?

7. Consider the nuclear reaction \( ^{215}_{84} Po \rightarrow X + \alpha \). What are \( Z \) and \( A \) for the nucleus \( X \)?

8. \(^{115}\text{In} (Z = 49)\) decays via beta decay to \(^{115}\text{Sn} (Z = 50)\) with a half-life of \(6 \times 10^{14}\ \text{yr}\). Does the beta particle emitted have a positive or negative charge? Explain.
9. Why does the electrical resistance of a semiconductor decrease with an increase in temperature?

10. The electron of a hydrogen atom makes a transition from the $n=4, l=2$ subshell to the $n=2$ shell. What is the value of $l$ for the final state?
Problems
(SHOW YOUR WORK, you will not get credit unless I can see how you got your answer.)

11. A magnesium (Mg) atom with one electron removed is a Mg\(^+\) ion. It has 11 electrons. In the ground state of this ion, how many of these electrons are in a state with orbital quantum number, \(l = 0\)?

12. A blue LED emits light with an typical wavelength of 470 nm. Based on this data, what is the band gap for the semiconductor used?

13. \(^{22}\)Na undergoes beta decay with a \(\frac{1}{2}\) life of 2.62 years. What is the maximum energy the beta particle can have? You may find the data below to be of use.

Masses (in amu)

\[
\begin{array}{ll}
\text{Mass} & \text{Value} \\
^{20}\text{F} & 19.999982 \\
^{20}\text{Ne} & 19.992435 \\
^{22}\text{Ne} & 21.991383 \\
^{22}\text{Na} & 21.994434 \\
^{23}\text{Mg} & 22.994124 \\
\end{array}
\]
14. Radioactive carbon-14 ($^{14}$C) is used for “carbon dating.” The $^{14}$C is naturally created in the atmosphere by cosmic rays and is incorporated into living plants and animals just like other isotopes of carbon. Once the plant or animal dies, no further $^{14}$C is supplied. If the fraction of the carbon which is $^{14}$C in a living plant is $F$, and the fraction of the carbon which is $^{14}$C in a sample of a plant from an archeological dig is $F/10$, how long ago did the plant die? The half-life for $^{14}$C decay is 5730 years.

15. Consider an electron in a magnetic field of $B = 8.50$ Teslas = 8.50 T. The energy levels are given by $E = \mu_z B$. The possible values for $z$-component of the electron’s spin magnetic moment are determined by $\mu_z = \frac{e\hbar}{m_e} S_z = (11.58 \times 10^{-5} \text{ eV} / \text{T}) S_z$. What is(are) the wavelength(s) of photons which will be absorbed?