Topic 12.1 – Interaction of matter with radiation – AHL

NAME: _____

Show formulas, substitutions, answers (in spaces provided) and units!

The following questions are about the photoelectric effect.

1. In the graph to the right label the cutoff voltage, and explain how it is determined. 1. __In graph__.
   _____

2. In the mathematical formulation of the photoelectric effect, $hf = \phi + E_{K,max}$ describe what each part of the equation represents, in terms of work and energy.
   _____

3. Describe and explain an experiment to test the Einstein model of the photoelectric effect. Include a sketch of the apparatus. _____
   _____
   _____
   _____

A photosensitive metal has a work function of 2.35 eV.

4. Find the minimum frequency of light needed to free an electron from its surface.
   4. _____

5. Find the maximum kinetic energy of an electron freed by a photon having a frequency of 9.85×10^{15} Hz. 5. _____

The following question is an application of the de Broglie hypothesis.

6. State the de Broglie hypothesis, and cite experimental evidence supporting it.
   _____

7. An electron is accelerated from rest through a potential difference of 215 V. What is its expected de Broglie wavelength? 7. _____

The following questions are about the Bohr model of the hydrogen atom.

8. Using Coulomb's law for a proton and an electron and the fact that this force is centripetal in nature, show that $mv^2 = ke^2/r$ for an electron with orbital radius r.

9. Using the result from 8 and the definition of mechanical energy $E = E_K + E_P$, show that the total mechanical energy of a hydrogen atom is given by $E = -(1/2)ke^2/r$. Hint: $E_P = -ke^2/r$.

10. Write the relationship between angular momentum L and momentum $p = mv$ for an electron orbiting a hydrogen nucleus at a radius of r. 10. _____

11. Write the assumption Bohr made for angular momentum in formulaic form. 11. _____

12. Using 8 and your results from 10 and 11 show that $r_n = n^2h^2 / (4\pi^2ke^2m)$.

13. Using 9 and 12 show that for the hydrogen atom $E_n = -13.6 / n^2$ eV.

The following question is about the "electron in a box."

14. Show that the allowed kinetic energies of an electron that resonates in a box of length L is given by $E_K = n^2h^2/(8mL^2)$. Include a sketch of at least three resonances.

The following questions are about tunneling.

15. Explain radioactive decay in terms of the wave function ψ. Use an alpha particle in a nucleus as an example. _____
_____

16. List three factors which affect tunneling. How do they affect it? 16. _____
_____

The following questions are about the Heisenberg uncertainty principle and violation of conservation of energy.

17. Explain how the HUP allows conservation of energy to be violated. _____
_____

18. An electron and a positron are created from the void. Calculate how long they can exist. What will happen when they recombine? 18. _____
_____

19. Use the HUP to show that an electron cannot exist within an atomic nucleus. Assume the diameter of the nucleus is 2×10^{-15} m.

An electron and a jet fighter are observed to have equal speeds of 325 m/s, accurate to within ±0.0100%.

20. What is the minimum uncertainty in the position of the electron? 20. _____

21. What is the minimum uncertainty in the position of the jet if its mass is 750. kg?
21. _____

An electron in an excited state has a lifetime of 1.25×10^{-8} seconds before it deexcites.

22. What is the minimum uncertainty in the energy of the photon emitted on de-excitation?
22. _____

23. What is the magnitude in the broadening of the frequency of the spectral line?
23. _____