Department of Astronomy & Astrophysics, University of Toronto

RADIATION PROCESSES – AST1440F

Review Questions for Section 7

1. We know that, on the atomic scale, energy and angular momentum are quantized. Explain how phase space itself is quantized and how this limits the density of Fermions.
2. What is the approximate orbital velocity of the electron in the ground state of hydrogen? Will the velocity be higher or lower for excited states of hydrogen? How does the electron velocity depend on Z, the nuclear charge? Can Z be high enough for relativistic effects to be important?
3. The lowest orbital angular momentum state of a bound electron ($\ell = 0$) is nonzero but the angular momentum of the atom as a whole is zero. Explain how this is possible.
4. Why is solving Schröedinger's equation an eigenvalue problem and how is this related to the quantization of the atomic world?
5. Why do higher Coulomb states (higher n) have higher statistical weights? What is $g(n)$?
6. A multi-electron atom is a very complex physical system with Coulomb interactions between all the particles. What other (more subtle) interactions are involved? In particular, how does the orbital angular momentum (or the spin angular momentum) of one electron interact with that of another electron or with the nucleus or with an external magnetic field?
7. How does the Normal Zeeman effect differ from the Anomalous Zeeman effect and why?
8. How does the Zeeman effect differ from the Paschen-Back effect?
9. If an atom emits a *single* photon, how can the atom readjust its equilibrium to conserve energy and angular momentum? Can $\Delta\ell$ be zero? Is this likely?
10. Explain how "forbidden" radiation can satisfy $\Delta\ell = 0$.
11. How does forbidden radiation differ from permitted radiation?
12. What does it mean when we say that a particular atomic state is "metastable"?
13. How can a given electron configuration – (n, ℓ) specified for each electron – correspond to more than one energy state?
14. Why are more states possible if the valence electrons are *non-equivalent*?
15. Why are the term types (states) determined solely by the valence electrons?
16. For increasingly heavier atoms, are the angular momentum states filled in order: $\ell = 0, 1, 2, 3, \ldots$ and so on? What do you think is the physical explanation for this?
17. Why are the terms for 7 equivalent d-electrons the same as for 3 d-electrons?
18. What *two* empirical rules can be used to order the states of an atom in energy? Why do they apply only to ground electron configurations in general?

19. How does Russell-Saunders coupling differ from (j,j)-coupling and for which atoms do each apply?
20. Why are the energy states of hydrogen for a particular n *degenerate* (i.e., independent of ℓ)? Why is this not true for any other atom including hydrogenic atoms like Li with a single electron outside closed shells?
21. In the semi-classical theory of atomic absorption, which aspects are classical and which are quantum mechanical? What is the rationale or justification behind the theory? That is, why should it give the correct probability of absorption per photon?
22. In computing the so-called matrix elements, it is common to use the "dipole approximation" for the perturbing potential of an EM-wave. What exactly is being assumed here and why does it result in a fairly good approximation? What is the origin of the "dipole" designation.
23. What is the origin of the term "oscillator strength"?
24. What is the Thomas-Kuhn Summation rule for helium? Why can we be sure that f_{on} is always less than unity for any bound state of hydrogen? Again, for hydrogen, how does f_{on} depend on n for large n?
25. The dipole approximation provides an estimate of *permitted* transition probabilities. How, in principle, would we compute *forbidden* transition probabilities?
26. How, in principle, do we modify the argument for *bound-bound* transition probabilities to one for *bound-free* transition probabilities?
27. How does the monochromatic bound-free absorption coefficient depend on frequency ν? How does this compare with the ν-dependence of the *free-free* absorption coefficient?
28. Sketch the bound-free absorption coefficient as a function of frequency allowing for several absorption "edges". Does $a_{n\nu}$ go to zero or infinity as $\nu \to 0$? To answer this, consider $a_{n\nu}$ at each absorption edge as $n \to \infty$ and consider the energy required to raise the electron to the continuum.
29. How in principle do we calculate the recombination coefficient knowing the photoionization rate?
30. How does $\sigma_n^{(r)}(\nu)$ depend on n, ν, and T_e? What is the limit as $\nu \to 0,\ \chi_n \to 0,\ n \to \infty$?
31. How does the frequency-integrated recombination coefficient depend on n and T_e?
32. In which regimes of ν and T_e does bremsstrahlung dominate recombination?