13.S: Atomic Structure (Summary)

Key Terms

angular momentum orbital quantum number (*l*)	quantum number associated with the orbital angular momentum of an electron in a hydrogen atom
angular momentum projection quantum number (*m*)	quantum number associated with the *z*-component of the orbital angular momentum of an electron in a hydrogen atom
atomic orbital	region in space that encloses a certain percentage (usually 90%) of the electron probability
Bohr magneton	magnetic moment of an electron, equal to $9.3 \times 10^{-24} J/T$ or $5.8 \times 10^{-5} eV/T$
braking radiation	radiation produced by targeting metal with a high-energy electron beam (or radiation produced by the acceleration of any charged particle in a material)
chemical group	group of elements in the same column of the periodic table that possess similar chemical properties
coherent light	light that consists of photons of the same frequency and phase
covalent bond	chemical bond formed by the sharing of electrons between two atoms
electron configuration	representation of the state of electrons in an atom, such as $1s^2 2s^1$ for lithium
fine structure	detailed structure of atomic spectra produced by spin-orbit coupling
fluorescence	radiation produced by the excitation and subsequent, gradual de-excitation of an electron in an atom
hyperfine structure	detailed structure of atomic spectra produced by spin-orbit coupling
ionic bond	chemical bond formed by the electric attraction between two oppositely charged ions
laser	coherent light produced by a cascade of electron de-excitations
magnetic orbital quantum number	another term for the angular momentum projection quantum number
magnetogram	pictoral representation, or map, of the magnetic activity at the Sun’s surface
metastable state	state in which an electron “lingers” in an excited state
monochromatic	light that consists of photons with the same frequency
Moseley plot	plot of the atomic number versus the square root of X-ray frequency
Moseley’s law	relationship between the atomic number and X-ray photon frequency for X-ray production
orbital magnetic dipole moment	measure of the strength of the magnetic field produced by the orbital angular momentum of the electron

Pauli's exclusion principle	no two electrons in an atom can have the same values for all four quantum numbers (n, l, m, ms)
population inversion	condition in which a majority of atoms contain electrons in a metastable state
principal quantum number (*n*)	quantum number associated with the total energy of an electron in a hydrogen atom
radial probability density function	function use to determine the probability of a electron to be found in a spatial interval in *r*
selection rules	rules that determine whether atomic transitions are allowed or forbidden (rare)
spin projection quantum number (m_s)	quantum number associated with the *z*-component of the spin angular momentum of an electron
spin quantum number (*s*)	quantum number associated with the spin angular momentum of an electron
spin-flip transitions	atomic transitions between states of an electron-proton system in which the magnetic moments are aligned and not aligned
spin-orbit coupling	interaction between the electron magnetic moment and the magnetic field produced by the orbital angular momentum of the electron
stimulated emission	when a photon of energy triggers an electron in a metastable state to drop in energy emitting an additional photon
transition metal	element that is located in the gap between the first two columns and the last six columns of the table of elements that contains electrons that fill the *d* subshell
valence electron	electron in the outer shell of an atom that participates in chemical bonding
Zeeman effect	splitting of energy levels by an external magnetic field

Key Equation

Orbital angular momentum	$L=\sqrt{l(l+1)}\hbar$
z-component of orbital angular momentum	$L_z=m\hbar$
Radial probability density function	$P(r)dr=\mid\psi_{n00}\mid^2 4\pi r^2 dr$
Spin angular momentum	$S=\sqrt{s(s+1)}\hbar$
z-component of spin angular momentum	$S_z=m_s\hbar$
Electron spin magnetic moment	$\vec{\mu}_s=(\frac{e}{m_e})\vec{S}$
Electron orbital magnetic dipole moment	$\vec{\mu}=-(\frac{e}{2m_e})\vec{L}$
Potential energy associated with the magnetic interaction between the orbital magnetic dipole moment and an external magnetic field $vecB$	$U(\theta)=-\mu_z B=m\mu_B B$
Maximum number of electrons in a subshell of a hydrogen atom	$N=4l+2$
Selection rule for atomic transitions in a hydrogen-like atom	$\Delta l=\pm 1$

Moseley's law for X-ray production	$(Z-1) = constant\sqrt{f}$

Summary

8.1 The Hydrogen Atom

- A hydrogen atom can be described in terms of its wave function, probability density, total energy, and orbital angular momentum.
- The state of an electron in a hydrogen atom is specified by its quantum numbers (n, l, m).
- In contrast to the Bohr model of the atom, the Schrödinger model makes predictions based on probability statements.
- The quantum numbers of a hydrogen atom can be used to calculate important information about the atom.

8.2 Orbital Magnetic Dipole Moment of the Electron

- A hydrogen atom has magnetic properties because the motion of the electron acts as a current loop.
- The energy levels of a hydrogen atom associated with orbital angular momentum are split by an external magnetic field because the orbital angular magnetic moment interacts with the field.
- The quantum numbers of an electron in a hydrogen atom can be used to calculate the magnitude and direction of the orbital magnetic dipole moment of the atom.

8.3 Electron Spin

- The state of an electron in a hydrogen atom can be expressed in terms of five quantum numbers.
- The spin angular momentum quantum of an electron is = +½. The spin angular momentum projection quantum number is \(\displaystyle m_s =+½\) or −½ (spin up or spin down).
- The fine and hyperfine structures of the hydrogen spectrum are explained by magnetic interactions within the atom.

8.4 The Exclusion Principle and the Periodic Table

- Pauli's exclusion principle states that no two electrons in an atom can have all the same quantum numbers.
- The structure of the periodic table of elements can be explained in terms of the total energy, orbital angular momentum, and spin of electrons in an atom.
- The state of an atom can be expressed by its electron configuration, which describes the shells and subshells that are filled in the atom.

8.5 Atomic Spectra and X-rays

- Radiation is absorbed and emitted by atomic energy-level transitions.
- Quantum numbers can be used to estimate the energy, frequency, and wavelength of photons produced by atomic transitions.
- Atomic fluorescence occurs when an electron in an atom is excited several steps above the ground state by the absorption of a high-energy ultraviolet (UV) photon.
- X-ray photons are produced when a vacancy in an inner shell of an atom is filled by an electron from the outer shell of the atom.
- The frequency of X-ray radiation is related to the atomic number Z of an atom.

8.6 Lasers

- Laser light is coherent (monochromatic and "phase linked") light.
- Laser light is produced by population inversion and subsequent de-excitation of electrons in a material (solid, liquid, or gas).
- CD and Blu-Ray players uses lasers to read digital information stored on discs.