1 Ordlista i atomfysik

- **Alkali atoms** Atoms with one valence electron, the first group in the periodic table.
- **Anomalous Zeeman effect** Happens when the netto spin from the electrons is not zero. While the Zeeman effect in some atoms (e.g., hydrogen) showed the expected equally-spaced triplet, in other atoms the magnetic field split the lines into four, six, or even more lines and some triplets showed wider spacings than expected. These deviations were labeled the "anomalous Zeeman effect" and were very puzzling to early researchers.
- **Anti-symmetric wavefunction**

$$\Psi(\bar{r_1}, \bar{r_2}) = -\Psi(\bar{r_2}, \bar{r_1}) \tag{1}$$

  Particles whose wave functions which are anti-symmetric under particle interchange have half-integral intrinsic spin, and are termed fermions.
- **Atomic clock** The principle of operation of an atomic clock is not based on nuclear physics, but rather on atomic physics; it uses the microwave signal that electrons in atoms emit when they change energy levels. It can use the resonance frequenzy of atoms such as cesium 133. By exciting an atom to its excited state you get the frequency when it falls back to its ground state.
- **Atomic mass unit**

$$1 \text{ u} = 1.99 \cdot 10^{-26} \text{ kg} \tag{2}$$

- **Balmer series**

  The Balmer series is characterized by the electron transitioning to $n = 2$, where n refers to the radial quantum number or principal quantum number of the electron, from a higher n. $\alpha : 3 \to 2$, $\beta : 4 \to 2$
- **Bequerel** Becquerel, Bq, is the SI-unit for radioactive decay. 1 Bq means one decay per second.
- **Bohr magneton** In atomic physics, the Bohr magneton (symbol μ_B) is a physical constant and the natural unit for expressing the magnetic moment of an electron caused by either its orbital or spin angular momentum.

  The Bohr magneton is defined in SI units by

$$\mu_\text{B} = \frac{e\hbar}{2m_\text{e}} \tag{3}$$

  and in Gaussian CGS units by

$$\mu_\text{B} = \frac{e\hbar}{2m_\text{e}c} \tag{4}$$

- **Bohr radius** The Bohr radius (a_0 or r_{Bohr}) is a physical constant, approximately equal to the most probable distance between the proton and electron in a hydrogen atom in its ground state. It is named after Niels Bohr, due to its role in the Bohr model of an atom. It's value is $5.29177 \cdot 10^{-11}$ m.

$$a_0 = \frac{4\pi\varepsilon_0\hbar^2}{m_\text{e}e^2} = \frac{\hbar}{m_\text{e}\, c\, \alpha} \tag{5}$$

- **Boson** A boson is a particle with integer spin (photon, gluon, higgs boson ets). Many bosons can occupy the same quantum state, which can lead to a Bose-Einstein condensate.

- **Central field approximation** In atomic physics, the central field approximation for many-electron atoms takes the combined electric fields of the nucleus and all the electrons acting on any of the electrons to be radial and to be the same for all the electrons in the atom. That is, every electron sees an identical potential $U(r)$ that is only a function of its distance from the nucleus.

- **Clebsch-Gordon koefficients** In physics, the Clebsch–Gordan (CG) coefficients are numbers that arise in angular momentum coupling in quantum mechanics. They appear as the expansion coefficients of total angular momentum eigenstates in an uncoupled tensor product basis.

- **Coulomb force** Force between two charged particles, scalar form:

$$F = \frac{1}{4\pi\epsilon_0} \frac{|q_1 q_2|}{r^2} \tag{6}$$

- **Coupling** In physics, two systems are coupled if they are interacting with each other.

- **Darwin term** One term in the non-relativistic expansion of the Dirac equation is given by:

$$H_{\text{Darwinian}} = \frac{\hbar^2}{8m_e^2 c^2} 4\pi \left(\frac{Ze^2}{4\pi\varepsilon_0} \right) \delta^3 (\vec{r}) \tag{7}$$

or

$$H_{\text{Darwinian}} = \frac{2n}{m_e c^2} \quad , E_n^2 \tag{8}$$

Thus, the Darwin term affects only the s-orbit. For example it gives the 2s-orbit the same energy as the 2p-orbit by raising the 2s-state by $9.057 \cdot 10^{-5}$ eV.

- **de-Broigle wavelength** The de Broglie wavelength is the wavelength, λ, associated with a massive particle and is related to its momentum, p, through the Planck constant, h:

$$\lambda = \frac{h}{p} \tag{9}$$

- **Degeneration** In quantum mechanics, an energy level is said to be degenerate if it corresponds to two or more different measurable states of a quantum system. Conversely, two or more different states of a quantum mechanical system are said to be degenerate if they give the same value of energy upon measurement. The number of different states corresponding to a particular energy level is known as the degree of degeneracy of the level. It is represented mathematically by the Hamiltonian for the system having more than one linearly independent eigenstate with the same eigenvalue.

- **Dirac equation** Relativistic version of the Schrödinger equations, produces spin, antimatter and relativistic effects etc.

- **Doppler broadening** In atomic physics, Doppler broadening is the broadening of spectral lines due to the Doppler effect caused by a distribution of velocities of atoms or molecules. Different velocities of the emitting particles result in different Doppler shifts, the cumulative effect of which is the line broadening.

- **Earnshaws theorem** Earnshaw's Theorem states that a collection of point charges cannot be maintained in a stable stationary equilibrium configuration solely by the electrostatic interaction of the charges.

- **Ehrenfests theorem**
$$\frac{d}{dt}\langle A\rangle = \frac{1}{i\hbar}\langle[A,H]\rangle + \left\langle\frac{\partial A}{\partial t}\right\rangle\ , \tag{10}$$

- **Einstein coefficientes** Einstein coefficients are mathematical quantities which are a measure of the probability of absorption or emission of light by an atom or molecule. The Einstein A coefficient is related to the rate of spontaneous emission of light and the Einstein B coefficients are related to the absorption and stimulated emission of light.

- **Elektric dipole transition** Electric dipole transition is the dominant effect of an interaction of an electron in an atom with the electromagnetic field. Between certain electron states the electric dipole transition rate may be zero due to one or more selection rules, particularly the angular momentum selection rule. In such a case, the transition is termed electric dipole forbidden, and the transitions between such levels must be approximated by higher-order transitions.

- **Elektron configuration** In atomic physics and quantum chemistry, the electron configuration is the distribution of electrons of an atom or molecule (or other physical structure) in atomic or molecular orbitals. For example, the electron configuration of the neon atom is $1s^2\ 2s^2\ 2p^6$.

- **Entanglement** Quantum entanglement is a physical phenomenon that occurs when pairs or groups of particles are generated or interact in ways such that the quantum state of each particle cannot be described independently — instead, a quantum state may be given for the system as a whole.

- **Fabry-Perot ètalon** The heart of the Fabry–Pérot interferometer is a pair of partially reflective glass optical flats spaced micrometers to centimeters apart, with the reflective surfaces facing each other. (Alternatively, a Fabry–Pérot etalon uses a single plate with two parallel reflecting surfaces.) The flats in an interferometer are often made in a wedge shape to prevent the rear surfaces from producing interference fringes; the rear surfaces often also have an anti-reflective coating.

- **Fermi's golden rule** One of the prominent failures of the Bohr model for atomic spectra was that it couldn't predict that one spectral line would be brighter than another. From the quantum theory came an explanation in terms of wavefunctions, and for situations where the transition probability is constant in time, it is usually expressed in a relationship called Fermi's golden rule.

- **Fine strukture** In atomic physics, the fine structure describes the splitting of the spectral lines of atoms due to electron spin and relativistic corrections to the non-relativistic Schrödinger equation.

- **Fine strukture constant** In physics, the fine-structure constant, also known as Sommerfeld's constant, commonly denoted α, is a fundamental physical constant characterizing the strength of the electromagnetic interaction between elementary charged particles.
$$\alpha = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{\hbar c} = \frac{\mu_0}{4\pi}\frac{e^2 c}{\hbar} = \frac{k_\mathrm{e} e^2}{\hbar c} = \frac{c\mu_0}{2R_\mathrm{K}} \tag{11}$$

- **Fotoelektrisc effect** The photoelectric effect is the observation that many metals emit electrons when light shines upon them. Electrons emitted in this manner can be called photoelectrons.

- **g-faktor, Landé** In physics, the Landé g-factor is a particular example of a g-factor, namely for an electron with both spin and orbital angular momenta.
$$g_J \approx \frac{3}{2} + \frac{S(S+1) - L(L+1)}{2J(J+1)}. \tag{12}$$

- **HeNe-laser** A helium–neon laser or HeNe laser, is a type of gas laser whose gain medium consists of a mixture of helium and neon(10:1) inside of a small bore capillary tube, usually excited by a DC electrical discharge. The best-known and most widely used HeNe laser operates at a wavelength of 632.8 nm in the red part of the visible spectrum.

- **Hund's rules** In atomic physics, Hund's rules refers to a set of rules that German physicist Friedrich Hund formulated around 1927, which are used to determine the term symbol that corresponds to the ground state of a multi-electron atom.
  1.For a given electron configuration, the term with maximum multiplicity has the lowest energy. The multiplicity is equal to $2S + 1$, where S is the total spin angular momentum for all electrons. Therefore, the term with lowest energy is also the term with maximum S.
  2. For a given multiplicity, the term with the largest value of the total orbital angular momentum quantum number L has the lowest energy.
  3. For a given term, in an atom with outermost subshell half-filled or less, the level with the lowest value of the total angular momentum quantum number J (for the operator $\boldsymbol{J} = \boldsymbol{L} + \boldsymbol{S}$) lies lowest in energy. If the outermost shell is more than half-filled, the level with the highest value of J is lowest in energy.

- **Hyperfine strukture** In atomic physics, hyperfine structure is the different effects leading to small shifts and splittings in the energy levels of atoms, molecules and ions. Hyperfine structure, with energy shifts typically orders of magnitude smaller than those of fine structure, results from the interactions of the nucleus (or nuclei, in molecules) with internally generated electric and magnetic fields.

- **Identic particles** Identical particles, also called indistinguishable or indiscernible particles, are particles that cannot be distinguished from one another, even in principle. Species of identical particles include, but are not limited to elementary particles such as electrons, composite subatomic particles such as atomic nuclei, as well as atoms and molecules.

- **inhomogenious broadening** Inhomogeneous broadening is an increase in the linewidth of an atomic transition caused by effects which cause different radiating or absorbing atoms (or ions) to interact with different wavelength components. This means that the absorption and emission cross sections have different spectral shapes for different atoms. The fluorescence spectrum from such a material can then exhibit peaks which are broader than those of single atoms, since it shows an average over many differently emitting atoms. In similar ways, absorption spectra can be broadened.

- **isotope shift** If atomic spectra also have hyperfine structure the shift refers to the center of gravity of the spectra. There are two effects which contribute to this shift:
  1. The mass difference. This difference induces a change in the reduced electronic mass. This purely kinematical effect, studied theoretically by Hughes and Eckart[1] is important for light elements.
  2. The volume difference. This difference induces a change in the electric charge distribution of the nucleus. This effect is important in heavy elements and its first theory was formulated by Pauli and Peierls.[2][3][4]

- **jj-coupling (Angular momentum coupling)** In quantum mechanics, the procedure of constructing eigenstates of total angular momentum out of eigenstates of separate angular momenta is called angular momentum coupling. For instance, the orbit and spin of a single particle can interact through spin–orbit interaction, in which case the complete physical picture must include spin-orbit coupling. Or two charged particles, each with a well-defined angular momentum, may interact by Coulomb forces, in which case coupling of the two one-particle angular momenta to a total angular momentum is a useful step in the solution of the two-particle Schrödinger equation. In both cases the separate angular momenta are no longer constants of motion, but the sum of the two angular momenta usually still is.

- **Ionization energy** The ionization energy (IE) is qualitatively defined as the amount of energy required to remove the most loosely bound electron of an isolated gaseous atom to form a cation. It is quantitatively expressed in symbols as:

$$X + \text{energy} \rightarrow X^{+} + e^{-} \tag{13}$$

- **LASER L**ight **A**mplification by **S**timulated **Em**ission of **R**adiation.

- **Laser spektroscopy** Absorption spectroscopy usually implies having a tunable frequency source and producing a plot of absorption as a function of frequency. This was not feasible with lasers until the advent of the dye lasers which can be tuned over a nearly continuous range of frequencies.

- **Lifetime** The classical radiative lifetime of and electron in an excited state is given by.

$$\frac{1}{\tau} = \frac{e^2\omega^2}{6\pi\epsilon_0 m_e c^3} \tag{14}$$

The classical value of the lifetime gives the fastest time in which the atom could decay on a given transition and is often close to the observed lifetimes for strong transitions.

- **Lorentz force** In physics, particularly electromagnetism, the Lorentz force is the combination of electric and magnetic force on a point charge due to electromagnetic fields. If a particle of charge q moves with velocity v in the presence of an electric field E and a magnetic field B, then it will experience a force

$$\mathbf{F} = q\left[\mathbf{E} + (\mathbf{v} \times \mathbf{B})\right] \tag{15}$$

- **LS-terms** examples: ${}^3P_{1/2}$ etc

- **LS-coupling** In light atoms (generally $Z \leq 30$[3]), electron spins si interact among themselves so they combine to form a total spin angular momentum S. The same happens with orbital angular momenta ℓ_i, forming a total orbital angular momentum L. The interaction between the quantum numbers L and S is called Russell–Saunders coupling or LS coupling. Then S and L couple together and form a total angular momentum J:

$$\mathbf{J} = \mathbf{L} + \mathbf{S}, \tag{16}$$

where L and S are the totals:

$$\mathbf{L} = \sum_i \boldsymbol{\ell}_i,\ \mathbf{S} = \sum_i \mathbf{s}_i. \tag{17}$$

This is an approximation which is good as long as any external magnetic fields are weak.

- **Lyman series** In physics and chemistry, the Lyman series is a hydrogen spectral series of transitions and resulting ultraviolet emission lines of the hydrogen atom as an electron goes from $n \leq 2$ to $n = 1$ (where n is the principal quantum number) the lowest energy level of the electron. The transitions are named sequentially by Greek letters: from $n = 2$ to $n = 1$ is called Lyman-alpha, 3 to 1 is Lyman-beta, 4 to 1 is Lyman-gamma, etc.

- **Magnetic dipole moment** En magnetisk dipol är ett fysikaliskt objekt som har ett magnetiskt dipolmoment. Eftersom det inte finns några kända magnetisk monopol (magnetfält är solenoidala enligt Maxwells ekvationer), är magnetisk dipol en annan term för magnet.

  Många elementarpartiklar med spinn har ett magnetiskt dipolmoment, bland annat elektroner och myoner. Protonens och neutronens magnetiska moment är mycket mindre, men många atomkärnors magnetiska dipolmoment kan studeras med kärnmagnetisk resonans.

$$\bar{\mu}E = -\boldsymbol{\mu} \cdot \mathbf{B} = \mu B \cos\phi, \tag{18}$$

- **MASER** A maser, an acronym for **M**icrowave **A**mplification by "**S**timulated **E**mission of **R**adiation", is a device that produces coherent electromagnetic waves through amplification by stimulated emission.

- **Mass effects** Due to mass shifts in different isotopes, they have different spectral lines.

$$\Delta\bar{v}_{Mass} \approx \frac{m_e}{M_p}\frac{\delta A}{A'A''}\bar{v}_{\infty} \tag{19}$$

- **Metastability** Metastability denotes the phenomenon when a system spends an extended time in a configuration other than the system's state of least energy. During a metastable state of finite lifetime all state-describing parameters reach and hold stationary values. While in isolation:

  the state of least energy is the only one the system will inhabit for a definite amount of time, until more external energy is added to the system (unique "absolutely stable" state);
  the system will spontaneously leave any other state (of higher energy) to eventually return (after a sequence of transitions) to the least energetic state.

- **Nuclear magnetic moment** The nuclear magnetic moment is the magnetic moment of an atomic nucleus and arises from the spin of the protons and neutrons. It is mainly a magnetic dipole moment; the quadrupole moment does cause some small shifts in the hyperfine structure as well. All nuclei that have nonzero spin also possess a nonzero magnetic moment and vice versa, although the connection between the two quantities is not straightforward or easy to calculate.

- **Nuclear radius** We can estimate the radius of a nucleus by firing an alpha particle directly at the nucleus. The alpha particle will lose kinetic energy as it approaches the nucleus and gain potential energy due to the electric field because of the electrostatic repulsion between the positively charged nucleus and the positively charged alpha particle.

$$R = r_0 A^{1/3} \tag{20}$$

- **Nuclear spin** It is common practice to represent the total angular momentum of a nucleus by the symbol I and to call it "nuclear spin". For electrons in atoms we make a clear distinction between electron spin and electron orbital angular momentum, and then combine them to give the total angular momentum. But nuclei often act as if they are a single entity with intrinsic angular momentum I. Associated with each nuclear spin is a nuclear magnetic moment which produces magnetic interactions with its environment.

$$\begin{cases} A \text{ odd} & \Leftrightarrow \quad \text{half-integer spin} \\ A \text{ even} & \Leftrightarrow \quad \text{integer spin} \end{cases} \tag{21}$$

- **Optisc pumping** Optical pumping is a process in which light is used to raise (or "pump") electrons from a lower energy level in an atom or molecule to a higher one. It is commonly used in laser construction, to pump the active laser medium so as to achieve population inversion.

- **Parity** In quantum mechanics, a parity transformation (also called parity inversion) is the flip in the sign of one spatial coordinate. In three dimensions, it is also often described by the simultaneous flip in the sign of all three spatial coordinates (a point reflection):

$$\mathbf{P}: \begin{pmatrix} x \\ y \\ z \end{pmatrix} \mapsto \begin{pmatrix} -x \\ -y \\ -z \end{pmatrix}. \tag{22}$$

- **Paschen-Back effect** The Paschen-Back effect is the splitting of atomic energy levels in the presence of a strong magnetic field. This occurs when an external magnetic field is sufficiently large to disrupt the coupling between orbital ($\vec{L}$) and spin ($\vec{S}$) angular momenta. This effect is the strong-field limit of the Zeeman effect. When s = 0, the two effects are equivalent.

- **Pauli exclusion principle** The Pauli exclusion principle is the quantum mechanical principle that states that two identical fermions (particles with half-integer spin) cannot occupy the same quantum state simultaneously.

- **Plack's law** Planck's law describes the electromagnetic radiation emitted by a black body in thermal equilibrium at a definite temperature.

$$B_\nu(\nu, T) = \frac{2h\nu^3}{c^2} \frac{1}{e^{\frac{h\nu}{k_\mathrm{B}T}} - 1} \tag{23}$$

- **Population inversion** In science, specifically statistical mechanics, a population inversion occurs while a system (such as a group of atoms or molecules) exists in a state with more members in an excited state than in lower energy states. It is called an "inversion" because in many familiar and commonly encountered physical systems, this is not possible. The concept is of fundamental importance in laser science because the production of a population inversion is a necessary step in the workings of a standard laser.

$$\frac{N_2}{N_1} = \frac{g_2}{g_1} \exp \frac{-(E_2 - E_1)}{kT}, \tag{24}$$

- **Principal quantum number** In quantum mechanics, the principal quantum number (symbolized n) is one of four quantum numbers which are assigned to each electron in an atom to describe that electron's state.

- **Quantum defect** The quantum defect of a Rydberg atom refers to a correction applied to the equations governing Rydberg atom behavior to take into account the fact that the inner electrons do not entirely screen their associated charge in the nucleus.[2] It is used particularly for the alkalis that contain a single electron in their outer shell.

- **Quantum number** Quantum numbers describe values of conserved quantities in the dynamics of a quantum system. In the case of quantum numbers of electrons, they can be defined as "the sets of numerical values which give acceptable solutions to the Schrödinger wave equation for the hydrogen atom".

- **Lamb shift** In physics, the Lamb shift, named after Willis Lamb (1913–2008), is a small difference in energy between two energy levels 2S1/2 and 2P1/2 (in term symbol notation) of the hydrogen atom in quantum electrodynamics (QED). According to the Dirac equation, the 2S1/2 and 2P1/2 orbitals should have the same energy. However, the interaction between the electron and the vacuum (which is not accounted for by the Dirac equation) causes a tiny energy shift which is different for states 2S1/2 and 2P1/2.

- **Raman scattering** Raman scattering or the Raman effect is the inelastic scattering of a photon. When photons are scattered from an atom or molecule, most photons are elastically scattered (Rayleigh scattering), such that the scattered photons have the same energy (frequency and wavelength) as the incident photons. A small fraction of the scattered photons (approximately 1 in 10 million) are scattered by an excitation, with the scattered photons having a frequency different from, and usually lower than, that of the incident photons.[4] In a gas, Raman scattering can occur with a change in energy of a molecule due to a transition to another (usually higher) energy level.

- **Reduced mass** In physics, the reduced mass is the "effective" inertial mass appearing in the two-body problem of Newtonian mechanics. It is a quantity which allows the two-body problem to be solved as if it were a one-body problem. Given two bodies, one with mass m1 and the other with mass m2, the equivalent one-body problem, with the position of one body with respect to the other as the unknown, is that of a single body of mass [1][2]

$$\mu = \frac{1}{\dfrac{1}{m_1} + \dfrac{1}{m_2}} = \frac{m_1 m_2}{m_1 + m_2}, \tag{25}$$

- **Relativistic effect** We things go fast, weird relativistic effects occur.

- **Rydberg atoms** A Rydberg atom is an excited atom with one or more electrons that have a very high principal quantum number. These atoms have a number of peculiar properties including an exaggerated response to electric and magnetic fields, long decay periods and electron wavefunctions that approximate, under some conditions, classical orbits of electrons about the nuclei.[3] The core electrons shield the outer electron from the electric field of the nucleus such that, from a distance, the electric potential looks identical to that experienced by the electron in a hydrogen atom.

- **Rydberg's formula** The Rydberg formula is used in atomic physics to describe the wavelengths of spectral lines of many chemical elements.

$$\frac{1}{\lambda} = R_\infty \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) = \frac{m_{\mathrm{e}} e^4}{8\varepsilon_0^2 h^3 c} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \tag{26}$$

- **Rydberg's constant** The Rydberg constant represents the limiting value of the highest wavenumber (the inverse wavelength) of any photon that can be emitted from the hydrogen atom, or, alternatively, the wavenumber of the lowest-energy photon capable of ionizing the hydrogen atom from its ground state. The spectrum of hydrogen can be expressed simply in terms of the Rydberg constant, using the Rydberg formula.

$$R_\infty = \frac{m_{\mathrm{e}} e^4}{8{\varepsilon_0}^2 h^3 c} = 1.097\ 373\ 156\ 8539(55) \times 10^7\ \mathrm{m}^{-1}, [2] \tag{27}$$

$$R_M = \frac{R_\infty}{(1 + m_e/M)}, \tag{28}$$

- **Angular momentum** Klassiskt: Relaterar till momentet av de yttre krafter som verkar på kroppen, $\bar{L} = \bar{r} \times \bar{p}$.
  Kvantmekaniskt: Inom kvantmekaniken är rörelsemängdsmomentet kvantiserad, det vill säga det kan inte variera kontinuerligt, utan endast mellan specifika tillåtna värden. Rörelsemängdsmomentet för en subatomisk partikel, beroende på dess rörelse genom rummet, är alltid en heltalsmultipel av $\hbar$, definierad som Plancks konstant dividerad med 2π.

- **Schrödinger's equation** In quantum mechanics, the Schrödinger equation is a partial differential equation that describes how the quantum state of a quantum system changes with time.

$$i\hbar \frac{\partial}{\partial t} \Psi(\mathbf{r}, t) = \hat{H} \Psi(\mathbf{r}, t) \tag{29}$$

- **Scintillation detector** A scintillator is a material that exhibits scintillation — the property of luminescence[1] when excited by ionizing radiation. Luminescent materials, when struck by an incoming particle, absorb its energy and scintillate, (i.e., re-emit the absorbed energy in the form of light).[2] Sometimes, the excited state is metastable, so the relaxation back down from the excited state to lower states is delayed (necessitating anywhere from a few nanoseconds to hours depending on the material): the process then corresponds to either one of two phenomena, depending on the type of transition and hence the wavelength of the emitted optical photon: delayed fluorescence or phosphorescence, also called after-glow.

- **Spectroskopy** Spectroscopy is the study of the interaction between matter and electromagnetic radiation.

- **Spin** In quantum mechanics and particle physics, spin is an intrinsic form of angular momentum carried by elementary particles, composite particles (hadrons), and atomic nuclei. Spin is one of two types of angular momentum in quantum mechanics, the other being orbital angular momentum.

- **Spin-orbit interaction** In quantum physics, the spin–orbit interaction is an interaction of a particle's spin with its motion. The first and best known example of this is that spin–orbit interaction causes shifts in an electron's atomic energy levels due to electromagnetic interaction between the electron's spin and the magnetic field generated by the electron's orbit around the nucleus. This is detectable as a splitting of spectral lines.

- **Stark effect** The Stark effect is the shifting and splitting of spectral lines of atoms and molecules due to presence of an external electric field. The amount of splitting or shifting is called the Stark splitting or Stark shift.

- **Stern-Gerlach's experiment** The Stern–Gerlach experiment showed that the spatial orientation of angular momentum is quantized. It demonstrated that atomic-scale systems have intrinsically quantum properties, and that measurement in quantum mechanics affects the system being measured. In the original experiment, silver atoms were sent through a non-uniform magnetic field, which deflected them before they struck a detector screen. Other kinds of particles can be used. If the particles have a magnetic moment related to their spin angular momentum, the magnetic field gradient deflects them from a straight path. The screen reveals discrete points of accumulation rather than a continuous distribution, owing to the quantum nature of spin. Historically, this experiment was decisive in convincing physicists of the reality of angular momentum quantization in all atomic-scale systems.

- **Two-state system** In quantum mechanics, a two-state system (also known as a two-level system) is a system which can exist in any quantum superposition of two independent (physically distinguishable) quantum states. The Hilbert space describing such a system is two-dimensional. Therefore, a complete basis spanning the space will consist of two independent states.

- **Two-photon spectroscopy** Two-photon spectroscopy uses two counter-propagating laser beams. A simultaneous absorbtion of two photons occur which drives the atomic transition.If the atom absorbs one photon from each of the counter-propagating beams then the Doppler shigts cancel in the rest frame of the atom.

- **Wavefunction** A wave function in quantum mechanics describes the quantum state of an isolated system of one or more particles. There is one wave function containing all the information about the entire system, not a separate wave function for each particle in the system.

- **Zeeman effect** The Zeeman effect, named after the Dutch physicist Pieter Zeeman, is the effect of splitting a spectral line into several components in the presence of a static magnetic field.

$$E_{Zeeman} = g_J \mu_B B M_J \tag{30}$$