كلية العلوم

القسم : **الفيزياء**

السنة : **الثانية**

المادة : تخصصية٢

المحاضرة : ٤+٥+٦ /نظري/

{{ A to Z مكتبة }}

Atomic physics is the field of physics that studies atoms as an isolated system of electrons and an atomic nucleus. Atomic physics typically refers to the study of atomic structure and the interaction between atoms.[1] It is primarily concerned with the way in which electrons are arranged around the nucleus and the processes by which these arrangements change. This comprises ions, neutral atoms and, unless otherwise stated, it can be assumed that the term *atom* includes ions.

The term *atomic physics* can be associated with nuclear power and nuclear weapons, due to the synonymous use of *atomic* and *nuclear* in standard English. Physicists distinguish between atomic physics—which deals with the atom as a system consisting of a nucleus and electrons—and nuclear physics, which studies nuclear reactions and special properties of atomic nuclei.

As with many scientific fields, strict delineation can be highly contrived and atomic physics is often considered in the wider context of atomic, molecular, and optical physics. Physics research groups are usually so classified.

Isolated atoms

Atomic physics primarily considers atoms in isolation. Atomic models will consist of a single nucleus that may be surrounded by one or more bound electrons. It is not concerned with the formation of molecules (although much of the physics is identical), nor does it examine atoms in a solid state as condensed matter. It is concerned with processes such as ionization and excitation by photons or collisions with atomic particles.

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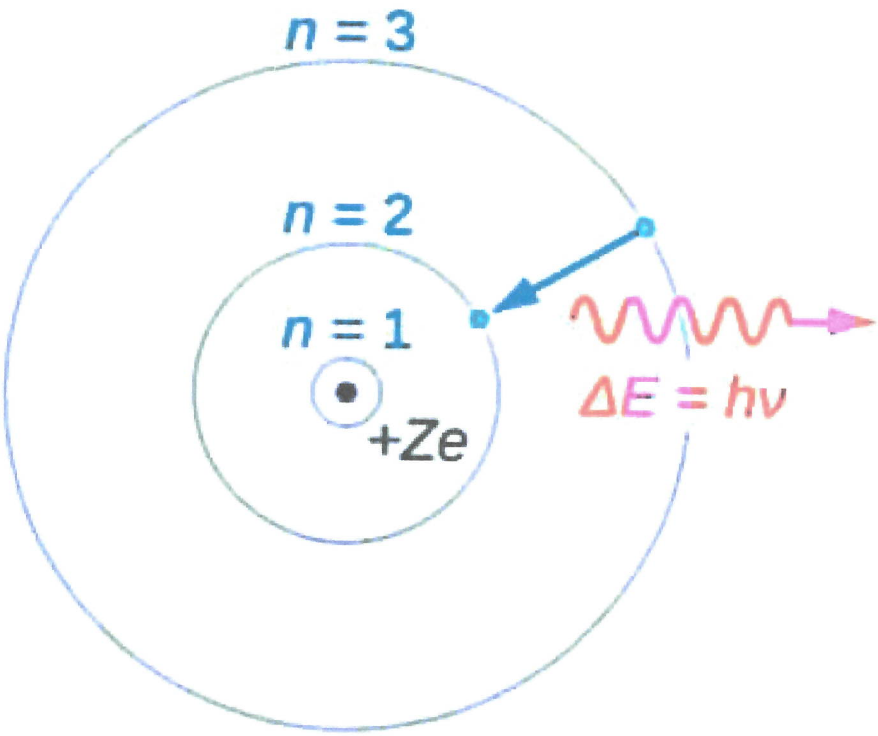
While modelling atoms in isolation may not seem realistic, if one considers atoms in a gas or plasma then the time-scales for atom-atom interactions are huge in comparison to the atomic processes that are generally considered. This means that the individual atoms can be treated as if each were in isolation, as the vast majority of the time they are. By this consideration, atomic physics provides the underlying theory in plasma physics and atmospheric physics, even though both deal with very large numbers of atoms.

Electronic configuration

Electrons form notional shells around the nucleus. These are normally in a ground state but can be excited by the absorption of energy from light (photons), magnetic fields, or but can be excited by the absorption of energy from light (photons), magnetic fields, or interaction with a colliding particle (typically ions or other electrons).



In the Bohr model, the transition of an electron with n=3 to the shell n=2 is shown, where a photon is emitted. An electron from shell (n=2) must have been removed beforehand by ionization

Electrons that populate a shell are said to be in a bound state. The energy necessary to remove an electron from its shell (taking it to infinity) is called the binding energy. Any remove an electron from its shell (taking it to infinity) is called the binding energy. Any quantity of energy absorbed by the electron in excess of this amount is converted to kinetic energy according to the conservation of energy. The atom is said to have undergone the process of ionization.

If the electron absorbs a quantity of energy less than the binding energy, it will be transferred to an excited state. After a certain time, the electron in an excited state will "jump" (undergo a transition) to a lower state. In a neutral atom, the system will emit a photon of the difference in energy, since energy is conserved.

If an inner electron has absorbed more than the binding energy (so that the atom ionizes), then a more outer electron may undergo a transition to fill the inner orbital. In this case, a visible photon or a characteristic X-ray is emitted, or a phenomenon known as the emitted, or a phenomenon known as the Auger effect may take place, where the released energy is transferred to another bound electron, causing it to go into the continuum. The Auger effect allows one to multiply ionize an atom with a single photon.

There are rather strict selection rules as to the electronic configurations that can be reached by excitation by light — however, there are no such rules for excitation by collision processes.

Bohr Model of the Atom

The Bohr model, proposed by **Niels Bohr in 1913**, is a revolutionary theory describing the structure of the hydrogen atom. It introduced the idea of quantized orbits for electrons, combining classical and quantum physics.

Key Postulates of the Bohr Model

Key Postulates of the Bohr Model

1. Electrons Move in Circular Orbits:

- Electrons revolve around the nucleus in fixed, circular paths called **orbits or energy levels**.

- These orbits are **stable** and do not radiate energy.

2. Quantization of Angular Momentum:

- The angular momentum of an electron is quantized and given by:

$$L = m_e v r = n\hbar, \quad n = 1, 2, 3, \ldots$$

where:

- m_e : Mass of the electron.

- v : Velocity of the electron.

- r : Radius of the orbit.

- $\hbar$: Reduced Planck's constant ($\hbar = \frac{h}{2\pi}$).

• n : Principal quantum number, representing the orbit.

3. Energy Levels:

• Each orbit has a specific energy. The total energy of an electron in the nth orbit is:

$$E_n = -\frac{13.6}{n^2}\ \mathrm{eV},$$

where $13.6\ \mathrm{eV}$ is the ground-state energy of the hydrogen atom.

4. Emission or Absorption of Energy:

• Electrons can transition between orbits by **absorbing** or **emitting** energy equal to the difference between the energy levels:

$$\Delta E = E_f - E_i = h\nu,$$

where:

• h : Planck's constant.

• ν : Frequency of emitted/absorbed

- ν : Frequency of emitted/absorbed radiation.

- E_f, E_i : Final and initial energy levels.

History and developments

Main article: Atomic theory

One of the earliest steps towards atomic physics was the recognition that matter was composed of *atoms*. It forms a part of the texts written in 6th century BC to 2nd century BC, such as those of Democritus or *Vaiśeṣika Sūtra* written by Kaṇāda.[2][3] This theory was later developed in the modern sense of the basic unit of a chemical element by the British chemist and physicist John Dalton in the 18th century.[4] At this stage, it was not clear what atoms were, although they could be described and classified by their properties (in bulk). The atoms were, although they could be described and classified by their properties (in bulk). The invention of the periodic system of elements by Dmitri Mendeleev was another great step forward.

The true beginning of atomic physics is marked by the discovery of spectral lines and attempts to describe the phenomenon, most notably by Joseph von Fraunhofer.[5] The study of these lines led to the Bohr atom model and to the birth of quantum mechanics. In seeking to explain atomic spectra, an entirely new mathematical model of matter was revealed. As far as atoms and their electron shells were concerned, not only did this yield a better overall description, i.e. the atomic orbital model, but it also provided a new theoretical basis for chemistry (quantum chemistry) and spectroscopy.[6]

Since the Second World War, both theoretical and experimental fields have advanced at a

Since the Second World War, both theoretical and experimental fields have advanced at a rapid pace. This can be attributed to progress in computing technology, which has allowed larger and more sophisticated models of atomic structure and associated collision processes.[7][8] Similar technological advances in accelerators, detectors, magnetic field generation and lasers have greatly assisted experimental work.

Beyond the well-known phenomena which can be describe with regular quantum mechanics chaotic processes[9] can occur which need different descriptions.

Significant atomic physicists

Pre quantum mechanics

- John Dalton

Hydrogen atom

Article Talk

This article is about the physics of the hydrogen atom. For a chemical description, see hydrogen. For monatomic hydrogen, see Hydrogen § Atomic hydrogen.

أحادي الذرة

A **hydrogen atom** is an atom of the chemical element hydrogen. The electrically neutral (محايد) hydrogen atom contains a single positively charged proton in the nucleus, and a single negatively charged electron bound to the nucleus by the Coulomb (كولون) force. **Atomic hydrogen** constitutes (يشكل) about 75% of the baryonic mass (الكتلة الباريونية) of the universe.[1]

Hydrogen atom,

1

In everyday life on Earth, isolated hydrogen atoms (called "atomic hydrogen") are extremely rare. Instead, a hydrogen atom tends to combine with other atoms in compounds, or with another hydrogen atom to form ordinary (diatomic) hydrogen gas, H_2. "Atomic hydrogen" and "hydrogen atom" in ordinary English use have overlapping, yet distinct, meanings. For example, a water molecule contains two hydrogen atoms, but does not contain atomic hydrogen (which would refer to isolated hydrogen atoms).

Atomic spectroscopy shows that there is a discrete infinite set of states in which a hydrogen (or any) atom can exist, contrary to the predictions of classical physics. Attempts to develop a theoretical understanding of the states of the hydrogen atom have been important to the history of quantum mechanics, since all other atoms can be roughly understood by knowing in detail about states of the hydrogen atom have been important to the history of quantum mechanics, since all other atoms can be roughly understood by knowing in detail about this simplest atomic structure.

Isotopes

Main article: Isotopes of hydrogen

The most abundant isotope, protium (^1H), or light hydrogen, contains no neutrons and is simply a proton and an electron. Protium is stable and makes up 99.985% of naturally occurring hydrogen atoms.[2]

Deuterium (^2H) contains one neutron and one proton in its nucleus. Deuterium is stable, makes up 0.0156% of naturally occurring hydrogen,[2] and is used in industrial processes like nuclear reactors and Nuclear Magnetic Resonance.

Tritium (^3H) contains two neutrons and one

Tritium (^3H) contains two neutrons and one proton in its nucleus and is not stable, decaying with a half-life of 12.32 years. Because of its short half-life, tritium does not exist in nature except in trace amounts.

Heavier isotopes of hydrogen are only created artificially in particle accelerators and have half-lives on the order of 10^{-22} seconds. They are unbound resonances located beyond the neutron drip line; this results in prompt emission of a neutron.

The formulas below are valid for all three isotopes of hydrogen, but slightly different values of the Rydberg constant (correction formula given below) must be used for each hydrogen isotope.

Hydrogen ion

Hydrogen ion

Main articles: hydrogen cation and hydrogen anion

Lone neutral hydrogen atoms are rare under normal conditions. However, neutral hydrogen is common when it is covalently bound to another atom, and hydrogen atoms can also exist in cationic and anionic forms.

If a neutral hydrogen atom loses its electron, it becomes a cation. The resulting ion, which consists solely of a proton for the usual isotope, is written as "H^+" and sometimes called *hydron*. Free protons are common in the interstellar medium, and solar wind. In the context of aqueous solutions of classical Brønsted–Lowry acids, such as hydrochloric acid, it is actually hydronium, H_3O^+, that is meant. Instead of a literal ionized single hydrogen atom being formed, the acid transfers the hydrogen to H_2O, forming H_3O^+.

If instead a hydrogen atom gains a second electron, it becomes an anion. The hydrogen anion is written as "H^-" and called *hydride*.

Theoretical analysis

The hydrogen atom has special significance in quantum mechanics and quantum field theory as a simple two-body problem physical system which has yielded many simple analytical solutions in closed-form.

Failed classical description

Experiments by Ernest Rutherford in 1909 showed the structure of the atom to be a dense, positive nucleus with a tenuous negative charge cloud around it. This immediately raised questions about how such a system could be stable. Classical electromagnetism had shown that any accelerating charge radiates energy, as shown by the Larmor formula. If the electron is assumed to orbit in a perfect circle and radiates energy continuously, the electron would rapidly spiral into the nucleus with a fall time of:[3]

$$t_{\text{fall}} \approx \frac{a_0^3}{4r_0^2 c} \approx 1.6 \times 10^{-11}\ \text{s},$$

where a_0 is the Bohr radius and r_0 is the classical electron radius. If this were true, all atoms would instantly collapse. However, atoms seem to be stable. Furthermore, the spiral inward would release a smear of electromagnetic frequencies as the orbit got smaller. Instead, atoms were observed to emit only discrete frequencies of radiation. The resolution would lie in the development of quantum mechanics.

Bohr–Sommerfeld Model