4.4 Ifølge Bohrs 2. postulat *kan* et atom blive exciteret ved at absorbere en foton. I et gasudladningsrør med hydrogen bliver atomerne exciteret ved en anden mekanisme. På grund af den store spændingsforskel mellem rørets to ender bliver der trukket elektroner ud fra minuspolen ned gennem røret til pluspolen. Disse elektroner bliver accelereret af det elektriske felt, og hvis de rammer et hydrogenatom, kan det modtage tilstrækkelig energi til at springe fra grundtilstanden til en exciteret tilstand, eller det kan blive ioniseret. Hvis atomet springer til en exciteret tilstand, vil det på et eller andet tidspunkt falde tilbage til grundtilstanden, hvorved det udsender en foton – eller evt. flere fotoner.

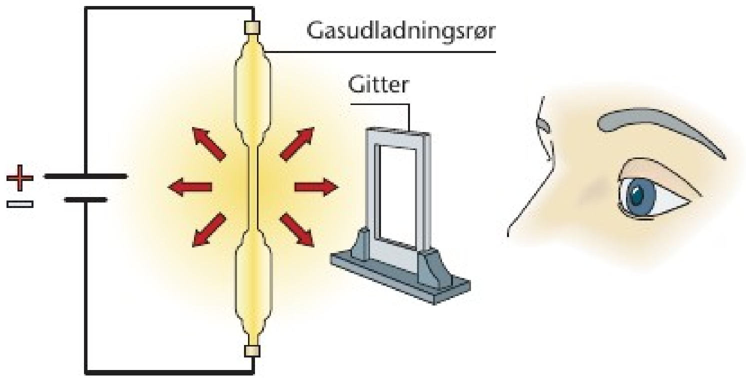
a. Beregn den energi, der skal tilføres et hydrogenatom i grundtilstanden i gassen, for at det efterfølgende kan udsende en foton fra enhver af de 3 første linier i Balmerserien. Angiv energien i eV.
b. Hvor stor en spændingsforskel skal elektronerne i gasudladningsrøret gennemløbe for at excitere hydrogenatomerne, så de udsender de første 3 linier i Balmerserien?
c. Prøv at finde nogle grunde til at røret først lyser ved meget større spændingsforskelle mellem +polen og –polen.

4.5 Forestil dig et hydrogenatom, som er exciteret.

a. Tegn et energiniveaudiagram for hydrogenatomer og forklar, at det kan udsende to fotoner ved at falde tilbage fra den stationære tilstand nr. 3 til grundtilstanden. Indtegn de to energiovergange i diagrammet.
b. Forestil dig, at atomet er exciteret til tilstand nr. 4 og henfalder til grundtilstanden. Indtegn i energiniveaudiagrammet alle de måder, hvorpå det kan lade sig gøre. Forklar for hver mulighed, hvor mange fotoner der bliver udsendt.

Lidt hjælp

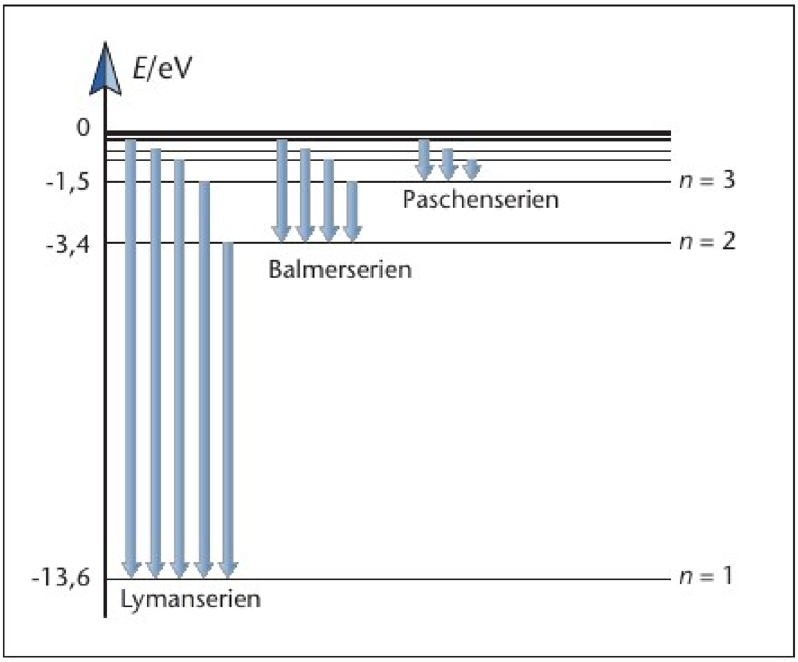
Figur 4.1
Gasudladningsrøret er tilsluttet en højspændingskilde. Hvis du ser på lyset fra gasudladningsrøret gennem et optisk gitter, ser du et liniespektrum.



$E_{ladet\ partikel} = q \cdot U$

hvor q er ladningen for partiklen og U er spændingsforskellen mellem elektroderne.

Figur 4.4
Energiniveaudiagram for hydrogen-atomet. Til udregning af de stationære tilstandes energier har vi benyttet, at h · c · R = 13,6 eV.



38.25. A triply ionized beryllium ion, Be^{3+} (a beryllium atom with three electrons removed), behaves very much like a hydrogen atom except that the nuclear charge is four times as great. (a) What is the ground-level energy of Be^{3+}? How does this compare to the ground-level energy of the hydrogen atom? (b) What is the ionization energy of Be^{3+}? How does this compare to the ionization energy of the hydrogen atom? (c) For the hydrogen atom the wavelength of the photon emitted in the $n = 2$ to $n = 1$ transition is 122 nm (see Example 38.6). What is the wavelength of the photon emitted when a Be^{3+} ion undergoes this transition? (d) For a given value of n, how does the radius of an orbit in Be^{3+} compare to that for hydrogen?

Baggrundsteori

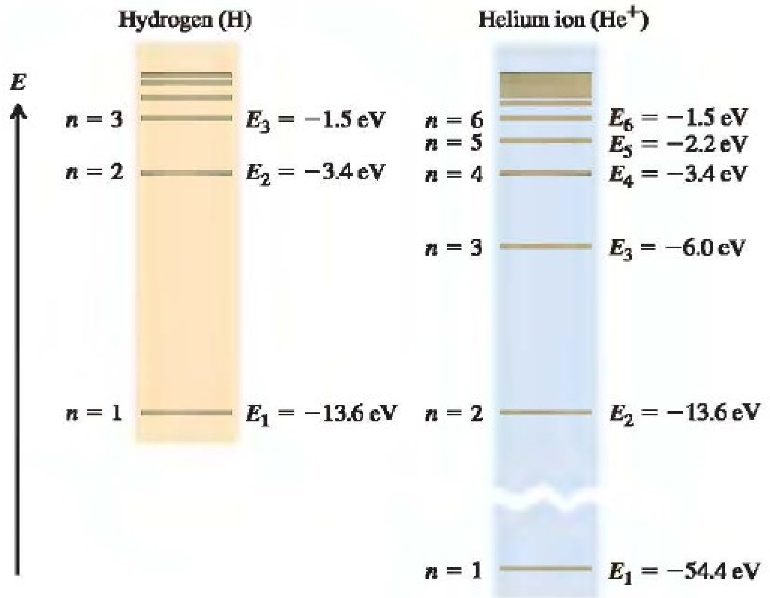
Hydrogenlike Atoms

We can extend the Bohr model to other one-electron atoms, such as singly ionized helium (He^+), doubly ionized lithium (Li^{2+}), and so on. Such atoms are called *hydrogenlike* atoms. In such atoms, the nuclear charge is not e but Ze, where Z is the *atomic number*, equal to the number of protons in the nucleus. The effect in the previous analysis is to replace e^2 everywhere by Ze^2. In particular, the orbit radii r_n given by Eq. (38.12) become smaller by a factor of Z, and the energy levels E_n given by Eq. (38.18) are multiplied by Z^2. We invite you to verify these statements. The reduced-mass correction in these cases is even less than 0.1% because the nuclei are more massive than the single proton of ordinary hydrogen. Figure 38.22 compares the energy levels for H and for He^+, which has $Z = 2$.

Atoms of the *alkali* metals have one electron outside a core consisting of the nucleus and the inner electrons, with net core charge $+e$. These atoms are approximately hydrogenlike, especially in excited levels. Even trapped electrons and electron vacancies in semiconducting solids act somewhat like hydrogen atoms.

Although the Bohr model predicted the energy levels of the hydrogen atom correctly, it raised as many questions as it answered. It combined elements of

38.22 Energy levels of H and He^+. The energy expression, Eq. (38.18), is multiplied by $Z^2 = 4$ for He^+, so the energy of an He^+ ion with a given n is almost exactly four times that of an H atom with the same n. (There are small differences of the order of 0.05% because the reduced masses are slightly different.)



classical physics with new postulates that were inconsistent with classical ideas. The model provided no insight into what happens during a transition from one orbit to another; the angular speeds of the electron motion were not in general the angular frequencies of the emitted radiation, a result that is contrary to classical electrodynamics. Attempts to extend the model to atoms with two or more electrons were not successful. An electron moving in one of Bohr's circular orbits forms a current loop and should produce a magnetic moment. However, a hydrogen atom in its ground level has no magnetic moment due to orbital motion. In Chapters 39 and 40 we will find that an even more radical departure from classical concepts was needed before the understanding of atomic structure could progress further.