Tentamen Structuur der Materie

March 31, 2014

Opgave 1

a) $l = 0, 1, 2, n - 1 \rightarrow l = 0, 1, 2, 3, 4$

b) see p.77, $\cos\theta = \frac{m_l}{\sqrt{l(l+1)}}$

c) Use $n = l + \nu + 1$, such that we have $\nu = 4$ and 1 (number of nodes) for the 5s and 5f states, respectively. Draw this with the correct zero crossings, always starting positive, the maximum is always far away from the nucleus (r=0) and it goes to zero exponentially. See p.80

d) $E_n = \frac{-13.6\text{eV}}{n^2}$ p.77

e) States with higher angular momentum are affected most by the repulsive centrifugal force, pushed further from the nucleus and are less tightly bound.

Opgave 2

a) Strong, weak and electromagnetic interaction

b) gluon, W/Z bosons and photon, respectively

c) $< 10^{-22}$ s, $10^{-14} - 10^{-20}$s, $10^{-8} - 10^{-13}$ s respectively.

d) Q= -1

e) Y = -1 (see p.357)

f) $I_3 = -1/2$

g) Baryon number conserved. Lepton number conserved. $\Delta S = 1$, so not allowed

h) Strangeness changing is allowed by the weak interaction.

Opgave 3

a) 22 electrons: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$

b) $3d^2$, so two equivalent electrons with $s1 = s2 = 1/2$ and $l1 = l2 = 2$, this couples to $S = 0, 1$ and $L = 0, 1, 2, 3, 4$. Equivalent electrons so $L + S$=even. ${}^1S_0$, ${}^3P_{0,1,2}$, ${}^1D_2$, ${}^3F_{2,3,4}$, ${}^1G_4$

c) ${}^3F_2$

d) $R = 1.12A^{1/3}$ fm, so A=47, gives R=4 fm

e) $\frac{22e}{4/3\pi R^3} = 0.08e/\text{fm}^3$

f) see p.410: 22 protonen, $1s_{1/2}1p_{3/2}1p_{1/2}1d_{5/2}2s_{1/2}1d_{3/2}1f_{7/2}$
25 neutrons: $1s_{1/2}1p_{3/2}1p_{1/2}1d_{5/2}2s_{1/2}1d_{3/2}1f_{7/2}$

g) $J = 7/2$ from previous question, $P = (-1)^L$ with L=3

Opgave 4

a) $2S + 1 = 3$, so $S = 1$ and $L = 1$, $J = |L - S|, ..., |L + S| = 0, 1, 2$

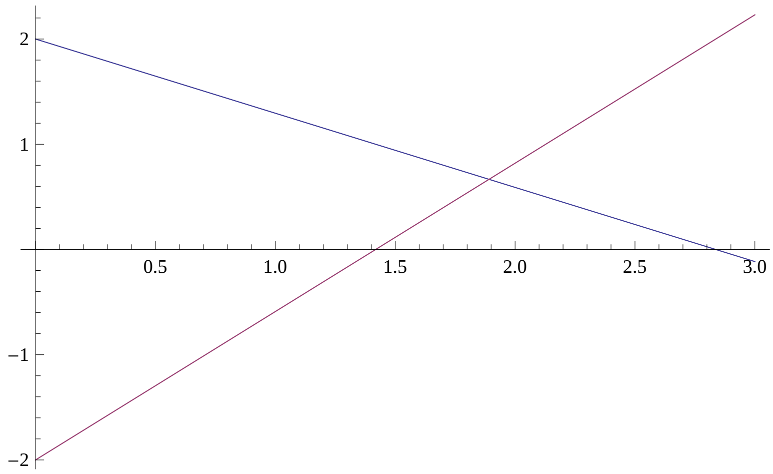
b) see figure 4.18. Use formula for E_{SO}, to find that the energy is $-2B_{SO}, -B_{SO}, B_{SO}$ for $J = 0, 1, 2$ respectively. So the ${}^3P$ term is in between the $J = 2$ and $J = 1$ energies.

c) For this we need the multiplicity (2J+1) of the terms, such that we get $5 \times B + 3 \times -B + 1 \times -2B = 0$, so there is indeed no shift and the total binding energy is equal to the energy of the ${}^3P$ term.

d) In this case the ground level is the $J = 2$ level, because B is negative. Using Hund's rules we know that the highest J level is the ground state if the shell is more than half filled. So this is term belongs to O.

e) We now get the $m_J = -J, .., J$ values, which split linearly in a magnetic field with the highest m_J above. See p.101.

f) The weak field approximation breaks down if two levels cross. This would happen first with the J=2 and $m_J = 2$ and the J=1 $m_J = -1$ levels. For the running (steepness of the slope) we have to calculate the g_J



values. Both have $g_J = 3/2$. in the weak field the energy goes like (see p.101) $E = g_j \mu_B B m_J$. We now need to solve $-2\text{cm}^{-1} + 3/2\mu_B B1 = 2\text{cm}^{-1} - 3/2\mu_B B2$, which gives $B = 1.9T$. See also the plot below, where the red curve is the $m_J = 2$ of the J=2 and the blue is the $m_J = -1$ of the $J = 1$.