28-01-2005

Applications of Quantum Physics

Mobile phones should be switched off during the exam

1. Binding Energies

Consider a beryllium atom Be($1s^2 2s^2$). (For reference, the binding energy of H($1s$) is 13.6 eV.)

a) Calculate the ionization potential (in eV) of this atom. The quantum defect is Δn=0.8.

b) The total binding energy of the two 2s electrons together is 27.5 eV. Calculate the quantum defect describing the binding energy of the 2s electron in Be^+($1s^2 2s$).

c) Why is the quantum defect calculated at b) larger, equal or smaller than the one given at a).

One way or the other the two inner shell electrons are removed from a beryllium atom, creating a Be^{2+}($2s^2$) ion.

d) This system is unstable. Will it decay by photon emission or Auger transition and why?

e) Calculate the energy of the emitted photon or electron. Assume that a 2s electron screens the nuclear charge by 0.3.

2. Li atoms in magnetic fields

Consider the Li isotope ^{6}Li which has a nuclear spin of $I = 1$

Sketch the binding energy of the states belonging to the ground state electronic configuration ($1s^2 2s$) of ^{6}Li as a function of increasing magnetic field. Indicate the relevant quantum numbers for magnetic field regimes of B=0, B="weak" and B="strong".

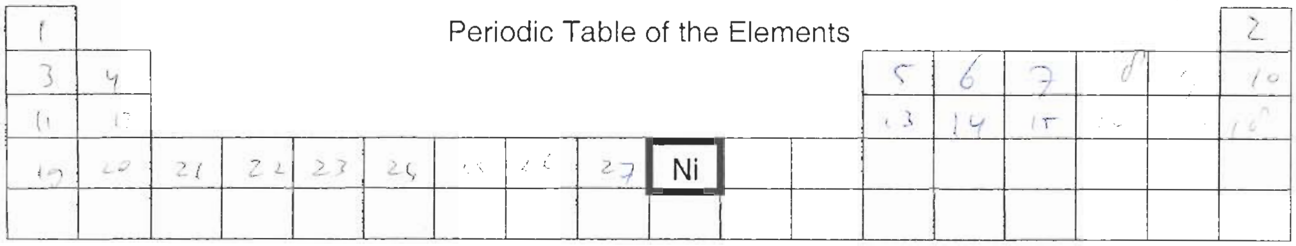
3. Hyperfine structure

The $3d^5 4s 4p$ $^6P_{7/2}$ level of ^{55}Mn is split by hyperfine interaction into six states that have separations of approximately 840, 1260, 1680, 2100 and 2520 MHz.

a) Calculate the hyperfine structure constant, a_{HFS}.

b) Deduce the nuclear spin of ^{55}Mn.

4. Configurations, Terms, States, and Hund's rules



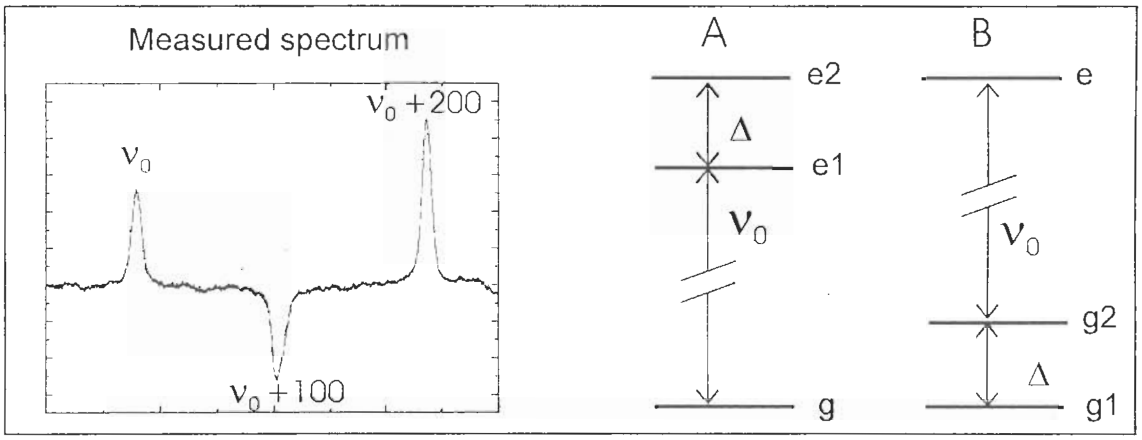
The figure represents the upper 5 rows of the periodic table of the elements. The position of Ni is indicated.

a) Determine the electronic configuration of Ni in its ground state.

b) Use LS coupling to determine all possible terms and states of the electronic ground state configuration.

c) Sketch the binding energy scheme of the terms and states.

5. Doppler-free saturation spectroscopy



a) Briefly describe and/or sketch the method of Doppler-free saturation spectroscopy.

The left panel of the figure depicts the Doppler-free Saturation Spectroscopy intensity as a function of laser frequency. Frequencies are given in MHz and ν_0 is 5 x 10^7 MHz. On the right, the electronic states of two different atoms A and B are shown, atom A is hyperfine split in the excited state while atom B is exhibits hyperfine splitting in the ground state.

b) Has the spectrum been taken on atoms A or B and why?

c) Determine the hyperfine splitting Δ.

d) What are •the velocities of the atoms giving rise to the minimum and maxima in the measured spectrum.