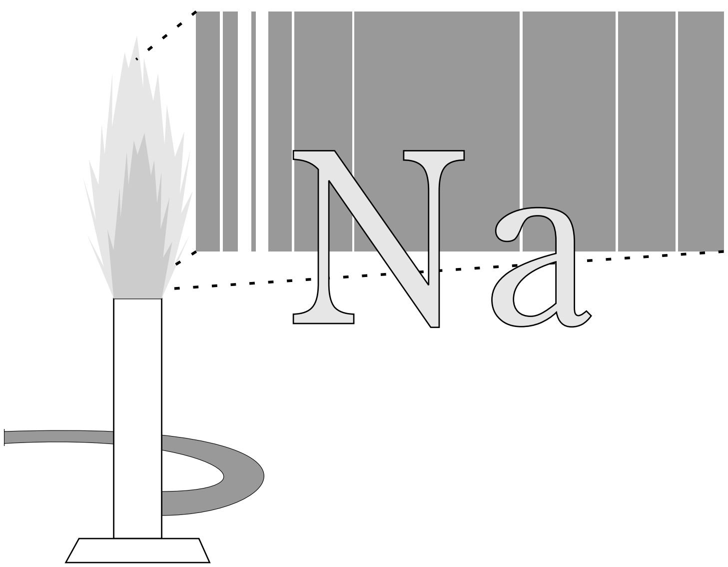
MISN-0-314

THE SPECTRUM OF SODIUM



Project PHYSNET Physics Bldg. Michigan State University East Lansing, MI

THE SPECTRUM OF SODIUM

by

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Title: **The Spectrum Of Sodium**

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Input Skills:

1. Vocabulary: atomic transition, single-electron atom, energy level diagram (MISN-0-215); angular momentum quantization, orbital angular momentum (MISN-0-251); electron spin, spin angular momentum, spectroscopic notation (MISN-0-244); electron shell (MISN-0-318).
2. Familiarity with energy levels of hydrogen-like atoms (MISN-0-215).
3. Explain shell structure and electronic configuration of atoms (MISN-0-318).

Output Skills (Knowledge):

K1. Sketch the energy levels of sodium and similar one-valence-electron atoms.

K2. Label the levels with the spectroscopic notation.

K3. Identify the "D" lines of sodium on the energy-level diagram.

K4. Identify the P series, S series, D series, F series transitions.

K5. State the $\Delta\ell$ and ΔJ selection rules for electromagnetic transitions.

Output Skills (Problem Solving):

S1. Given the spectroscopic specifications of two levels of a one-valence-electron atom, determine from the selection rules if it is an allowed transition.

S2. Given the orbital and spin angular momentum for the energy levels of a one-valence electron atom, label the levels in spectroscopic notation (or vice versa).

External Resources (Required):

1. Weidner and Sells, *Elementary Modern Physics*, 3rd ed., Allyn and Bacon, Boston (1980). For access, see this module's *Local Guide*.

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1. Program of Study

Read Section 7-3 of WSM.[1] This will give information for Output Skill[2] K4 and partial information on skills Kl, K2, K3, and K5. In particular, the details of the spectral lines are not completely set forth in this section. However, the $\Delta\ell$ selection rules are given (part of K5) and a simplified level diagram is given (part of Kl). The D-lines are indicated, as a single line (part of K3), and some information about the spectroscopic notation is given (part of K2).

Read Section 7-6 of WSM. Section 7-6 introduces the idea of electron spin, which is an important property that electrons have. This spin (or intrinsic angular momentum) causes the electron to have a magnetic dipole moment. This magnetic dipole moment interacts with the magnetic field produced by the orbital motion of the electron in the atom. Therefore, the energy of the atom depends on the relative direction of the spin and orbital angular momentum. Section 7-6 tells how this interaction splits certain levels which were assumed to be single levels in Section 7-3. Section 7-6 explains how many levels can be expected from each of the single levels found in Figure 7-9. Section 7-6 (last paragraph, p. 222) gives an explanation of the spectroscopic notation (K2).

2. Energy Level Diagram of Sodium (Kl)

By combining the information presented in Figure 7-22 with the information presented in Figure 7-9, it is easy to produce the energy level diagram shown in Figure 1 of this module. Note that the positions of the lines are approximate on this diagram and the splittings are exaggerated.

[1]R.T. Weidner and R.L. Sells, *Elementary Modern Physics*, 3rd ed. (Allyn and Bacon, Boston: 1980). For access, see this module's *Local Guide*.Note that this section makes use of material developed in Section 7-4. You should know most, if not all, that is needed from a study of prerequisite unit MISN-0-251. However, it may be useful to review Section 7-4 if problems arise in following the text in Section 7-6.

[2]See this module's *ID Sheet*.

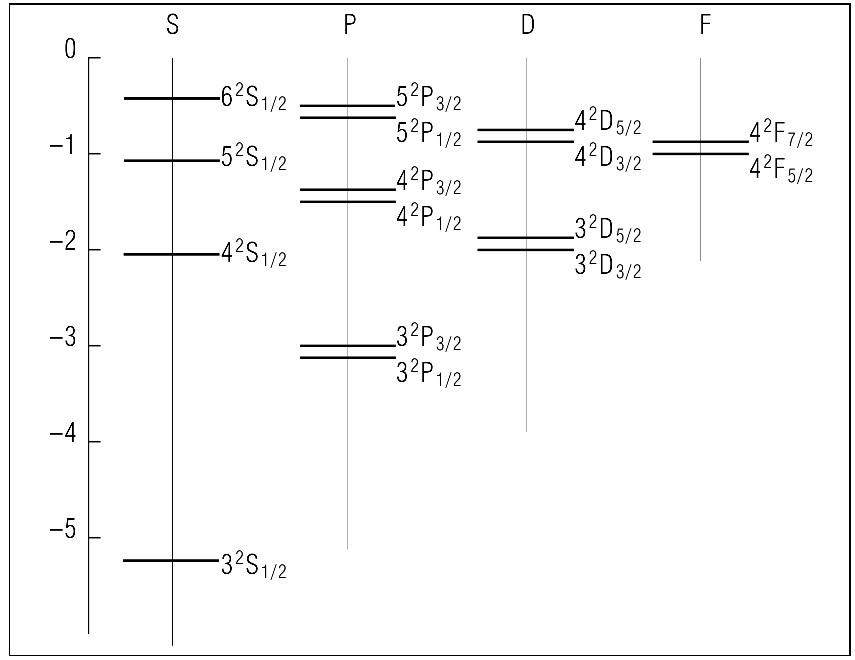

Figure 1.

3. Electromagnetic Transitions (K5)

Not every combination of two levels above can have an allowed transition connecting them. As already discussed in Section 7-3, only $\Delta\ell = \pm 1$

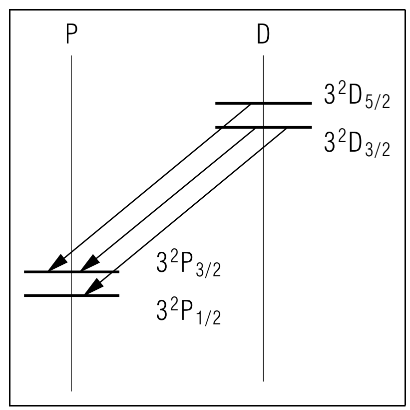

Figure 2.

transitions are allowed. In addition to this, only $\Delta J = \pm 1, 0$ transitions are allowed. Thus we could fill in on Fig. 1 all possible transitions by indicating lines connecting levels which have $\Delta \ell = \pm 1$ and $\Delta J = \pm 1, 0$. Figure 2 is a partial diagram of this sort showing only the allowed transitions from the 3D levels to the 3P levels.

Note that only three of the possible four combinations of levels lead to an allowed transition because of the $\Delta J = \pm 1, 0$ selection rules since $3^2\mathrm{D}_{5/2} \rightarrow 3^2\mathrm{P}_{1/2}$ would be a $\Delta J = -2$ transition.

Note also that $3^2\mathrm{D}_{3/2} \rightarrow 3^2\mathrm{P}_{3/2}$ is allowed because $\Delta J = 0$ is perfectly O.K.

4. The Sodium "D" Lines (K3)

Study the 3P→3S transitions in the manner of Section 3 above and determine how many lines can be expected from this transition. Note from Figure 7-9 that these are "D-lines" of sodium. Estimate from the energy level diagram in Figure 7-22 what the energies and wavelengths of these lines are and what the splitting in units of wavelength is expected. What color would you expect these lines to be? (See the footnote at the bottom of p. 208 for answers to these questions.) Throw some salt into a flame (gas stove or bunsen burner works well). Note the yellow color. If you have a spectroscope available, use it to observe the splitting in this yellow line.

Acknowledgments

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LOCAL GUIDE

The readings for this unit are on reserve for you in the Physics-Astronomy Library, Room 230 in the Physics-Astronomy Building. Ask for them as "The readings for CBI Unit 314." Do **not** ask for them by book title.

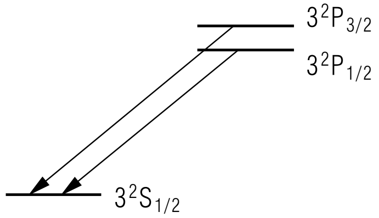
PROBLEM SUPPLEMENT

Note: Problems 5 and 6 also occur in this module's Model Exam.

1. Is the transition $4^2D_{3/2} \rightarrow 3^2S_{1/2}$ allowed?
2. An electron is in the state $n = 5$, $\ell = 2$, $j = 5/2$. State the spectroscopic notation for an electron in this level.
3. Is the transition $7^2P_{3/2} \rightarrow 3^2S_{1/2}$ allowed?
4. Is the transition $5^2D_{5/2} \rightarrow 4^2P_{1/2}$ allowed?
5. Draw a level diagram of the 3S levels and 3P levels. Show how these levels are split. Draw in any allowed transition between these levels. Label each level with the appropriate spectroscopic notation.
6. An electron is in the $n = 7$, $\ell = 3$, $j = 5/2$ state. Write the spectroscopic notation for this level.

Brief Answers:

1. No, because $\Delta\ell = 2$.
2. $5^2D_{5/2}$.
3. Yes.
4. No, because $\Delta J = 2$.
5.



6. $7^2F_{5/2}$

MODEL EXAM

1. See Output Skills K1-K5 on this module's *ID Sheet*. One or more of these skills, or none, may be on the actual exam.

   Note: You will be expected to know the order of the levels in the sodium spectrum up through the 5S level. From bottom up these are: 3S, 3P, 4S, 3D, 4P, 5S. The significance of this series goes beyond the spectrum of Na because it forms the theoretical basis of an important part of the periodic table of the elements. It is for this reason that you will be required to remember it for exams on this unit.

   Note: Be sure you can distinguish between the D-lines and the D-series.
2. Draw a level diagram of the 3S levels and 3P levels. Show how these levels are split. Draw in any allowed transition between these levels. Label each level with the appropriate spectroscopic notation.
3. An electron is in the $n = 7$, $\ell = 3$, $j = 5/2$ state. Write the spectroscopic notation for this level.

Brief Answers:

1. See this module's *text*.
2. See this modules's *Problem Supplement*, problem 5.
3. See this modules's *Problem Supplement*, problem 6.