Sodium Spectral Lines: D-Lines and S-Lines

This document provides a detailed overview of the sodium D-lines and S-lines, including their origins, associated transitions, wavelengths, and the quantum numbers involved.

# Sodium D-Lines

|  |  |  |  |
| --- | --- | --- | --- |
| Line Designation | Transition | Wavelength (nm) | Quantum Numbers (n, l, s, j) |
| D₂ | 3p₃/₂ → 3s₁/₂ | 589.0 | Initial: n=3, l=1 (p), s=1/2, j=3/2; Final: n=3, l=0 (s), s=1/2, j=1/2 |
| D₁ | 3p₁/₂ → 3s₁/₂ | 589.6 | Initial: n=3, l=1 (p), s=1/2, j=1/2; Final: n=3, l=0 (s), s=1/2, j=1/2 |

# Sodium S-Lines

|  |  |  |  |
| --- | --- | --- | --- |
| Line Designation | Transition | Wavelength (nm) | Quantum Numbers (n, l, s, j) |
| S₁ | 3p₁/₂ → 4s₁/₂ | 568.82 | Initial: n=3, l=1 (p), s=1/2, j=1/2; Final: n=4, l=0 (s), s=1/2, j=1/2 |
| S₂ | 3p₃/₂ → 4s₁/₂ | 568.82 | Initial: n=3, l=1 (p), s=1/2, j=3/2; Final: n=4, l=0 (s), s=1/2, j=1/2 |

# Explanation of Wavelength Differences

The sodium D-lines exhibit a slight difference in wavelengths due to fine structure splitting, which results from spin-orbit coupling. In the 3p state, the interaction between the electron's spin and its orbital motion causes the energy levels to split into two levels:

- \*\*3p₃/₂ (j = 3/2):\*\* Higher energy state.  
- \*\*3p₁/₂ (j = 1/2):\*\* Lower energy state.

The transition from the 3p₃/₂ state to the 3s₁/₂ state emits the D₂ line, while the transition from the 3p₁/₂ state to the 3s₁/₂ state emits the D1 line. The energy difference between these levels corresponds to the observed difference in wavelengths, approximately 0.6 nm.

# Calculating Wavelength Differences

The energy difference (ΔE) between two levels is related to the wavelength (λ) of the emitted photon by the equation:

ΔE = hc / λ

Rearranging to solve for λ:

λ = hc / ΔE

Given that the energy difference between the 3p₃/₂ and 3p₁/₂ states is approximately 0.0021 eV, we can calculate the corresponding wavelength difference. Using the known values of Planck's constant (h) and the speed of light (c), this calculation yields a wavelength difference of approximately 0.6 nm, which matches the observed difference between the D₂ and D1 lines.