Question 1: The sodium atom has 11 electrons. 10 of them fill up the $n = 1$ and $n = 2$ shells, so the spectrum is primarily determined by the last electron. In this way the sodium spectrum is similar to the hydrogen spectrum. The biggest difference is a l-dependence to the energy levels. When either n or l is large this 11th electron will be far enough out that the 10 inner electrons screen out the charge of all but one of the protons and the energy will be very close to that of hydrogen. But for small n and l this 11th electron will be closer to the nucleus than some of the first 10 electrons; the screening is less so this 11th electron sees a nucleus with a charge greater than $+1e$. This causes the energy to be lower (more tightly bound or more negative) than the corresponding energy level in hydrogen.

(a) The energy of 16 levels of sodium is given along with the ionization energy in units of inverse centimeters (wave number). (These were taken from `https://physics.nist.gov/PhysRefData/ASD/levels_form.html`) Convert each of these energies, to five significant figures, to units of eV with ionization set to 0.

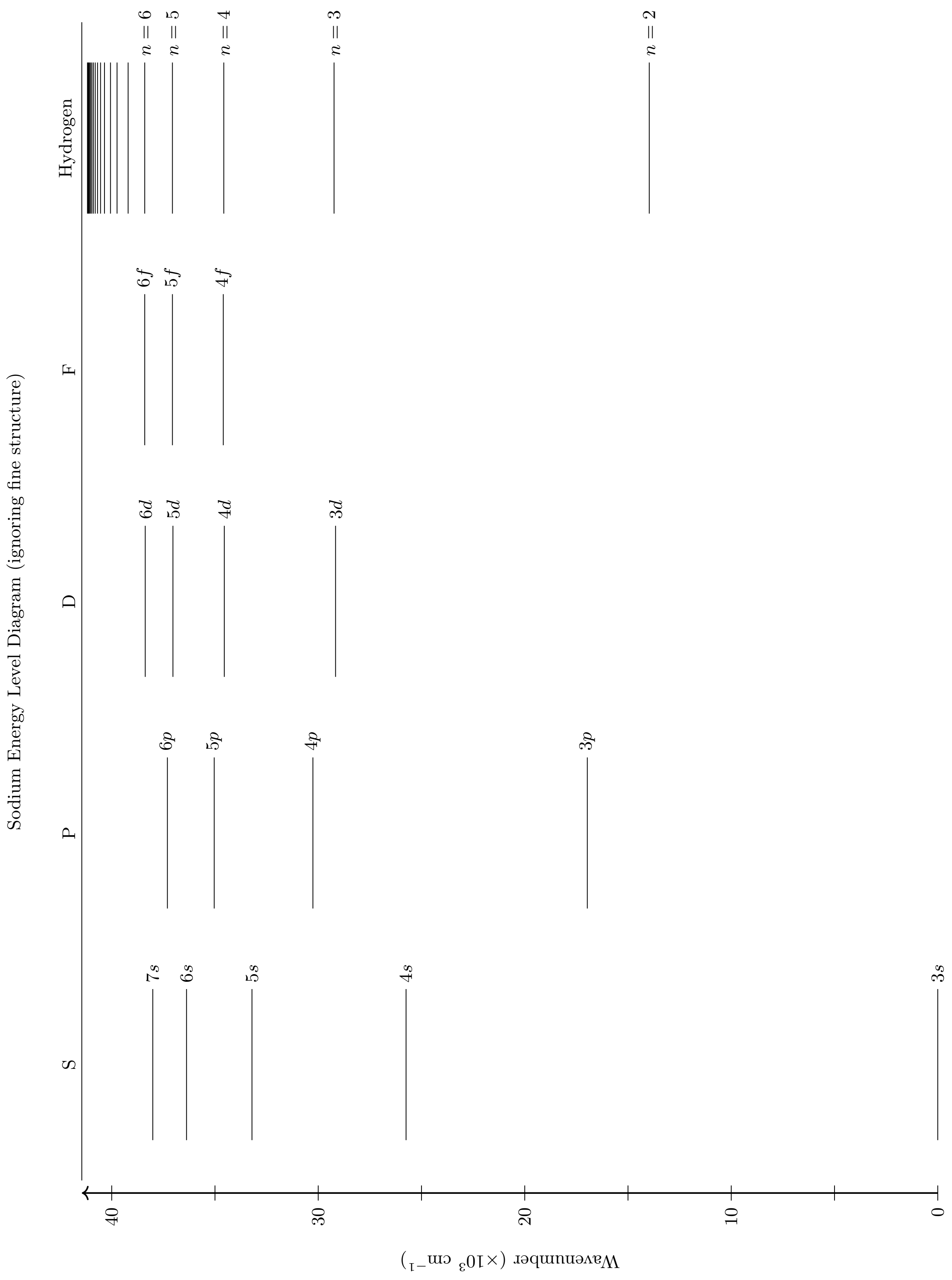
Configuration	Level (cm^{-1})
3s	0
3p	16,968
4s	25,740
3d	29,173
4p	30,271
5s	33,201
4d	34,549
4f	34,587
5p	35,042
6s	36,373
5d	37,037
5f	37,058
6p	37,297
7s	38,012
6d	38,387
6f	38,400
Ionization	41,449

(b) Once you have completed the previous part, you will have five s energy levels, four p energy levels, four d energy levels, and three f energy levels. You will perform a fit for each of these l values to determine the effective nuclear charge.

You may do this fit in either LoggerPro or using the Gemini Gem for fitting that I provided to you. If using LoggerPro: Open LoggerPro and make a graph with n on the x-axis and the energy (in units of eV) on the y-axis. Label both axes with appropriate names. Highlight your data, choose Analyze→Curve Fit. Choose Variable Power and set the power to -2. Click Try Fit and then OK.

Turn in each of the four graphs. If the energy levels were truly hydrogen-like, the energies would be given by $E_n = -\dfrac{Z^2 \cdot 13.606\,\text{eV}}{n^2}$ where Z is the number of protons in the nucleus. Use your fit value to determine the effective Z for each of these four l values.

(c) In the energy level diagram given on the next page, <u>draw</u> arrows for the 18 allowed transitions where the lower energy level has $n = 3$ (remember: only transitions with $\Delta L = \pm 1$ are allowed). Determine the wavelengths of these 18 transitions, in units of nm and to at least three significant figures.


Sodium Energy Level Diagram (ignoring fine structure)
S
P
D
F
Hydrogen
7s
6s
5s
4s
3s
6p
5p
4p
3p
6d
5d
4d
3d
6f
5f
4f
n = 6
n = 5
n = 4
n = 3
n = 2
40
30
20
10
0
Wavenumber (×10³ cm⁻¹)