The Y of Wavicles

Questions for students related to the video: Wavicles and the weakest bond — can two helium atoms form a molecule? discussing the paper: https://doi.org/10.1063/1.470772

1 Introductory (high-school/first year university)

(1) What have you learned so far about elements like helium that make it hard to believe a bond is likely to form between two of their atoms?

(2) The speed of light in a medium can be related to the light's frequency and is modeled using the equation $v = f\lambda$. In this equation, v is the light's speed in that medium, f is the light wave's frequency, and λ is the light's wavelength. Using this equation, convince yourself why "frequency doubling" is the same as saying "wavelength halving" (although one rolls off the tongue a bit better). (Hint: If you would like to use numbers, pick any frequency you want and double it! See what happens to the wavelength.)

(3) If helium atoms are travelling with a wavelength of 1 micrometer and the angle between the first order constructive diffraction spots and the central maximum is 5° , then how far apart are the lines in the gratings (this is the grating spacing)?

Using the de Broglie Relationship, that is, $h = \frac{\lambda}{mv} = \frac{\lambda}{p}$, determine the momentum of the helium atoms.

(4) Consider what would happen if two atoms were too close together. Why would they not want to bond? Is that the same reason for why two atoms too far apart would not want to bond? Explain your reasoning.

(5) If red light at 632.8 nm gets frequency doubled through a crystal then diffracted through a grating, some of the red light produces a pattern along side the frequency doubled light. If both the red and its frequency doubled light enter through the same grating, and the blue 3^{rd} order constructive interference maxima are at an angle 45° from the incident direction, then what is the grating spacing?

2 Intermediate

(1) Explain how the Heisenberg uncertainty principle prevents the two helium atoms from sitting motionless, at the bottom of the weakly attractive well describing their interaction.

(2) The peaks shown in Fig. 2 of the paper have a "width"; i.e., the signal attributed to helium dimer doesn't just appear at one angle but over a range of angles. List as many factors as possible that could contribute to these widths.