8.1, 2, 3
Note on 2: In this problem we simply have 2 protons and a third unknown negative charge. We want the binding energy (potential energy) of the entire system, with no kinetic energy involved.

A. Ionic bonding
   i) From the equilibrium spacing of a KCl molecule, \( r_o = 0.267 \text{ nm} \), find the lowering of energy due to the \( \text{K}^+ \text{Cl}^- \) coulomb attraction, in eV.
   ii) The total binding energy of the KCl molecule is 4.40 eV. From the energies in the diagram at the right, and the result of i), find the energy of repulsion of the two atoms at equilibrium. This is due to screened proton-proton repulsion, and to exclusion energy repulsion, and keeps the molecule from collapsing to zero distance.
   iii) For typical atomic spacing \( r \)'s, the steep exclusion energy repulsion \( U_{ex} \) is often modeled as 
   \[ U = \frac{A}{r^{10}}. \]
   If all the energy you calculated in ii) is due to this repulsion, find \( A \) in units of eV and nm. Find the repulsion force in eV/nm from 
   \[ F = -\frac{\partial U}{\partial r}, \]
   at the equilibrium separation. The minus sign just gives a direction.
   You can drop it.

B) Dipole-dipole potential energy (Vanderwaals)
   a) Calculate the electrostatic potential energy of two dipoles pointing toward each other, as shown below, in terms of the distances \( a \) and \( R \).
   b) Calculate the electrostatic potential energy of the two dipoles pointing to the right (both electrons to the right of the protons), keeping the + charges separated by \( R \).
   c) Show that the energy difference between the two forms \( \Delta U(R) \) is proportional to \( R^{-3} \) for \( R \gg a \).

(First write a Taylor’s series expansion for 
   \[ \frac{1}{(b-a)} = \frac{1}{b} \left( 1 - \frac{a}{b} \right)^{-1} \] when \( b \gg a \).)

Note: When the QM is done, you get \( \Delta E \) is proportional to \( R^{-6} \), not \( R^{-3} \), because \( (\Delta U)^2 \) enters in the calculation.
   d) Neon forms a solid because of Vanderwaals coupling at 24.5 K. If we take \( kT_{melt} \) as an order-of-magnitude energy scale, and \( R = 0.3 \text{ nm} \), find the dipole length \( a \) from 
   \( kT_{melt} = \Delta U(R) \).