PHYS 4310, Homework 3 (version 2) due on October 2$^{\text{nd}}$, 2015

1. Problem 4-13 [30 points].

(a). [2 points] Find r_0 in terms of A and n after minimizing V (*i.e.*, r_0 occurs when $\frac{\partial V}{\partial r} = 0$.

(b). [3 points] Find V_{min} in terms of e, A, and n, where $V(r_0) = V_{\text{min}}$.

(c). [5 points] In the Taylor series expansion of $V(r)$ about the minimum of the potential ($\frac{\partial V}{\partial r} = 0$), we found the term $\frac{1}{2}\frac{\partial^2 V}{\partial r^2}(r - r_0)^2$ defined our potential, where $\frac{\partial^2 V}{\partial r^2} = k = \mu\omega^2$ (=C in the notation of the problem). In terms of e, A, and n, what is C (the quantum spring constant)?

(d). [3 points] Ignore the question from the book. Find the reduced mass of Na^{23} and Cl^{35}, μ, in grams.

(e). [7 points] r_0 is 2.51 $\mathring{A}$ (what is this in cm?) and ν_0 is 1.14×10^{13} Hz (what is ω_0?). Using these empirical parameters find C (Ans: 1.18×10^5 dynes/cm) and then use this value, in conjunction with your answers from (c) and (a) to solve for n and then A. n should be between 8 and 10 and A should be between 10^{-80} and 10^{-85}.

(f). [5 points] Find the numerical value of V_{min} in eV (Ans: -5.1 eV). Find $\hbar\omega_0$ in eV. Plot $V(r)$ as a function of energy (in eV) versus $\mathring{A}$ (helpful conversion: 6.24×10^{11} eV/erg) and the zeroth energy level ($V_{\text{min}} + \hbar\omega_0$). The graphical answer is shown below. To get this plot, it helps to replace r in your formula with $r \times 10^{-8}$. From there, you can generate a vector of r values from 1 to 6 (or so) and plot V vs r.

(g). [5 points] In part (f), we found NaCl + 5.1 eV $\rightarrow$ Na^+ + Cl^-. Experimentally, we have observed Na + 5.1 eV $\rightarrow$ $Na^+ + e^-$ and Cl + e^- $\rightarrow$ Cl^- + 3.7 eV, where e^- is an electron. Using these empirical observations and our theoretically calculated value from (f), find the energy, Δ, necessary to dissociate an NaCl molecule into a Na atom and a Cl atom (that is: NaCl + Δ $\rightarrow$ Na + Cl). Compared to the experimental value of 4.3 eV, how close is your value?

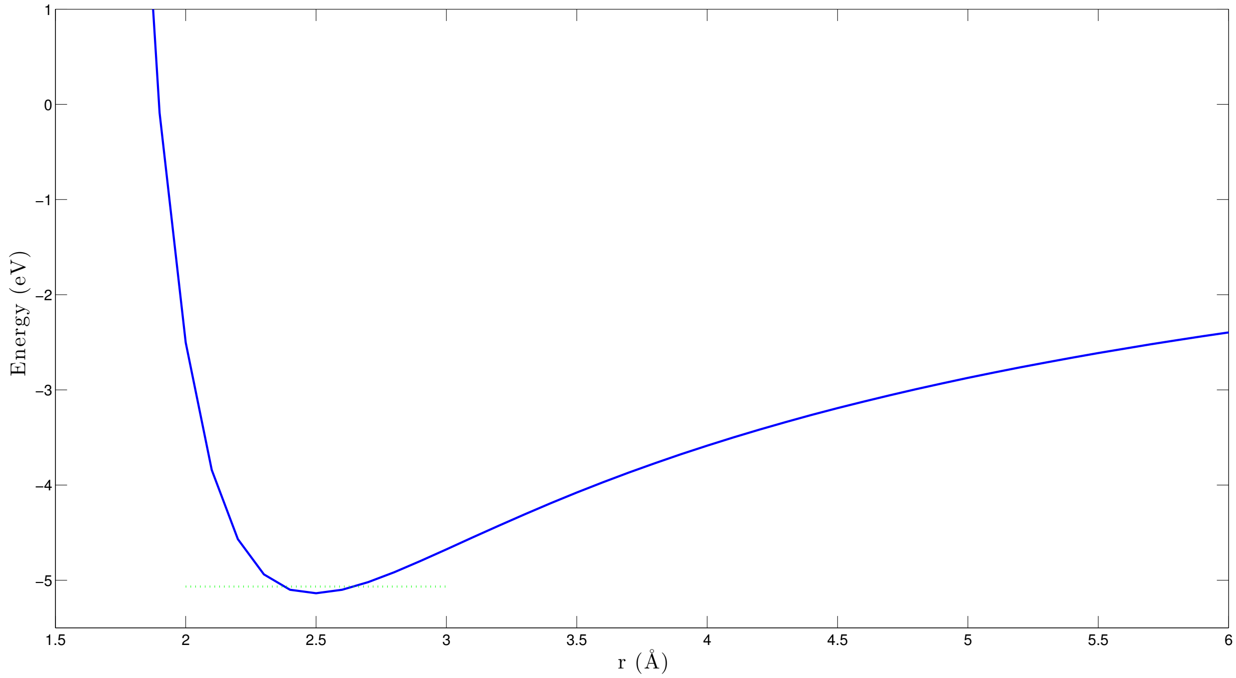

FIG. 1. **Calculated potential energy curve of** $-e^2/r + A/r^n$ **with the zeroth energy plotted**. $V(r)$ is given by the blue trace, while E_0 is depicted as a dotted green line.