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4.3

$$4\pi R^2 |\vec{E}| = \frac{1}{\varepsilon_0}\int \rho(\vec{r})\,d\tau \qquad \rho \propto r \Rightarrow \rho = \begin{cases} kr & \text{for } r < R \\ 0 & \text{otherwise} \end{cases}$$

$$4\pi r^2 E = \frac{k}{\varepsilon_0}\int r^3 \sin\theta\, dr\, d\phi\, d\theta = \frac{k}{4\varepsilon_0}\cdot 4\pi R^4 = \frac{\pi k R^4}{\varepsilon_0} = \frac{q_{tot}}{\varepsilon_0} \Rightarrow q_{tot} = \pi k R^4$$

$$\Rightarrow k = \frac{q_{tot}}{\pi R^4}\ ; \quad q_{enc} = \pi k r^4 = q_{tot}\left(\frac{r}{R}\right)^4$$

$$\Rightarrow \vec{E} = \frac{q_{enc}}{4\pi\varepsilon_0 r^2}\hat{r} = \frac{q_{tot}}{4\pi\varepsilon_0 R^4} r^2 \hat{r}$$

The nucleus & cloud are seperated by distance d,

Creating the dipole $\vec{p} = q_{tot}\vec{d}$, from an external electric field, $\vec{E}_{ext}$

In this case, $E_{ext} = \frac{q_{tot}}{4\pi\varepsilon_0 R^4} d^2 = \frac{p\,d}{4\pi\varepsilon_0 R^4} = \frac{p^2}{4\pi\varepsilon_0 q_{tot} R^4}$

$$\Rightarrow p = \sqrt{4\pi\varepsilon_0\, q_{tot} R^4 E}$$