1. Label the following approximate (unnormalized) molecular orbitals using $\sigma$, $\pi$, $\delta$, $u$, $g$, and $+$, $-$ designations, and make a rough sketch of the shape of the orbitals. Here, we denote the $1s$ orbital on the "left-hand" atom as $\psi_{1s}^{(l)}(\mathbf{r})$, with the obvious generalization of notation to the other orbitals and the "right-hand" atom.

   (a) $\psi_{2s}^{(l)}(\mathbf{r}) + \psi_{2s}^{(r)}(\mathbf{r})$

   (b) $\psi_{2s}^{(l)}(\mathbf{r}) - \psi_{2s}^{(r)}(\mathbf{r})$

   (c) $\psi_{2p_x}^{(l)}(\mathbf{r}) + \psi_{2p_x}^{(r)}(\mathbf{r})$

   (d) $\psi_{2p_x}^{(l)}(\mathbf{r}) - \psi_{2p_x}^{(r)}(\mathbf{r})$

   (e) $\psi_{3d_{z^2}}^{(l)}(\mathbf{r}) + \psi_{3d_{z^2}}^{(r)}(\mathbf{r})$

   (f) $\psi_{3d_{z^2}}^{(l)}(\mathbf{r}) - \psi_{3d_{z^2}}^{(r)}(\mathbf{r})$

   (g) $\psi_{2p_z}^{(l)}(\mathbf{r}) + \psi_{2p_z}^{(r)}(\mathbf{r})$

   (h) $\psi_{2p_z}^{(l)}(\mathbf{r}) - \psi_{2p_z}^{(r)}(\mathbf{r})$

2. Write a Slater determinant of molecular orbitals that is appropiate for the ground state of $Li_2^{2+}$ cation. Label the molecular orbitals with symmetry labels. Use the long form of the Slater determinant, writing out all the rows and columns.

3. The state of the electron in a $(Li^{2+})$ ion is described by the normalized wavefunction,

$$\Psi_{Li^{2+}}(\mathbf{r}) = -\left(\frac{1}{3}\right)^{1/2} R_{4,2}(r)Y_{2,-1}(\theta,\phi) + \left(\frac{2i}{3}\right) R_{3,2}(r)Y_{2,1}(\theta,\phi) - \left(\frac{2}{9}\right)^{1/2} R_{1,0}(r)Y_{0,0}(\theta,\phi)$$

   Here, $\psi_{label}$ are the normalized eigenfuctions of the $He^+$ Hamiltonian and the subscripts indicate the $n$, $l$ and $m_l$ quantum numbers.

   (a) If the total energy of different $Li^{2+}$ ions in this state is measured, what values will be found?

   (b) If more than one value is found, what is the probability of obtaining each result and what is the average value?

   (c) If the magnitude of the total angular momentum is measured, what values will be found?

   (d) If more than one values is possible, what is the probability of obtaining each result and what is the average value?