

December 2020

This paper consists of three questions and four pages. Approximate available marks for each section are given in square brackets. You may consult any written material to help frame your answers, but you should not consult other students.

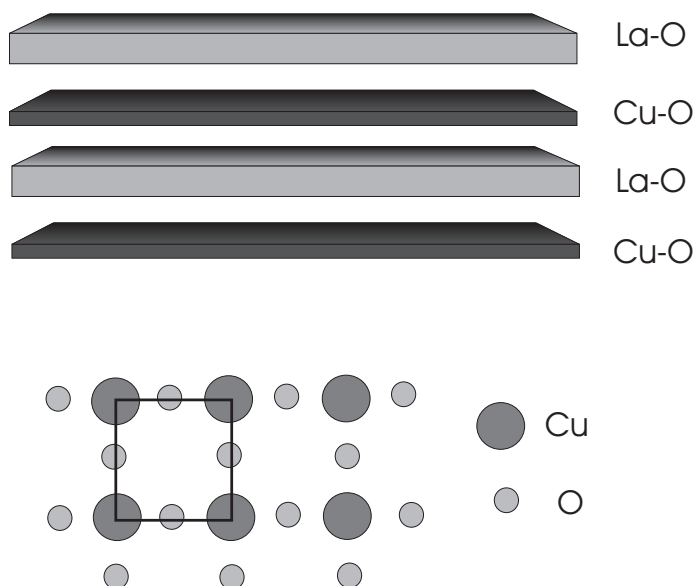


Figure 1: Schematic drawing of the layered crystal structure of $La_{2-x}Sr_xCuO_4$, and a drawing of the a single two-dimensional CuO_2 plane. The square is a primitive unit cell, with primitive lattice vectors $a(1, 0, 0)$ and $a(0, 1, 0)$.

1 The material $La_{2-x}Sr_xCuO_4$ has a layered crystal structure that consists of two-dimensional square lattices of CuO_2 planes (shown in figure 1) separated by layers of $La_{2-x}Sr_xO_2$. You may assume that La has valence 3+, Sr valence 2+, and O valence 2−; the electrons from these cations are donated uniformly to the widely separated CuO_2 layers, which thus have a two-dimensional electronic structure. Neutral atomic Cu has the configuration $[Ar]4s^23d^9$. In this compound, four of the Cu d-levels are completely filled, and there is a partially filled band formed from $d_{x^2-y^2}$ orbitals. You may assume the Cu 4s levels are unoccupied,