

1 Cognitive reasoning in the chemical sciences 6.1

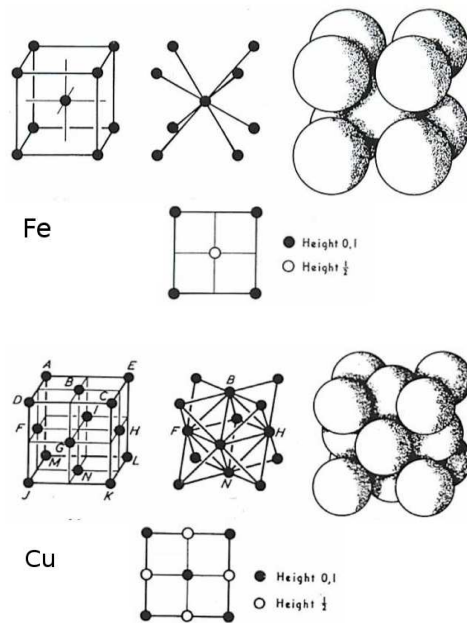
1. **Crystals** are solids which repeat the same motif, the *unit cell*, over and over again (think of a brick wall: the bricks are the unit cell, the wall is the solid.) Crystal skills required in freshman chemistry are primarily:

- Identifying the number of atoms in the unit cell.
- Based on the unit cell, deducing the density of the solid and vice-a-versa.
- Identifying the volume of space occupied by the atoms in the unit cell.

I am a crystallographer. I feel keenly the need to profess two more skills:

- Master the skill of making a orthographic projections indicating exactly where all the atoms in the unit cell are located.
- Identify the number of bonds an atom makes based on this diagram.

2. The figures below show the unit cells of Fe and Cu. A perspective drawing, a space filling ball model, and the scientific orthographic projection are shown for both of the two structures.

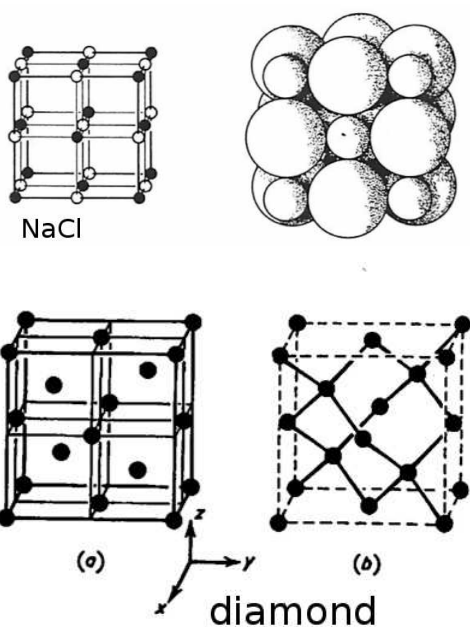


- How many atoms are there in each of the two unit cells?
- How many bonds does each Fe atom make in its structure?

- (c) How many bonds does each Cu atom make in its structure?
- (d) Which of these structures is face-centered-cubic, ie., there is an atom in the center of each square face of the cube?
- (e) Which of these structures is body-centered-cubic, ie., there is an atom in the center of the body of the cube?
- (f) What % volume of the unit cell is occupied by the Fe atoms?
- (g) What % volume of the unit cell is occupied by the Cu atoms?

3. Diamond and NaCl

- (a) Shown below are perspective drawings of NaCl and diamond. Please draw orthographic projections for the two structures.



- (b) How many atoms are there in each of the two cells?
- (c) How many bonds does each carbon atom make?
- (d) How many bonds does each Na atom make?
- (e) How many bonds does each Cl atom make?
- (f) What % volume of the unit cell is occupied by the carbon atoms?

4. Connecting crystals to macroscopic density

- (a) The density of iron is 7.9 g/mL. Fe is body-centered-cubic. What is the Fe-Fe bond length?
- (b) The density of iron is 7.9 g/mL. Iron atoms can be thought of as spheres. In iron these spheres occupy 68% of space, with the remaining 32% of space being taken up by the crevasses between atoms. What is the radius of a single Fe atom, measured in Å?
- (c) Gold bond lengths are 3.00 Å. Au crystallizes in the face-centered cubic structure. What is gold's density in g/mL?