Workshop Tutorials for Introductory Physics

PI5: **Solids II – Bonding and Crystals**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
sea, hydrogen, lose, strong, opposite, solids, gain, electrostatic, covalent, diamond, salt

Bonding in solids

Bonds can be divided into two main types, primary or ________ bonds and secondary or weak bonds. The strong bonds are what holds _________ together, these are ionic bonds, covalent bonds and metallic bonds. The two types of weak bonds are __________ bonds and van der Waals bonds.

The three types of primary bonding reflect the ways in which atoms can group together by gaining or losing or sharing electrons.

Atoms near the left or right sides of the periodic table can lose or gain 1 (or 2) electrons to form charged ions. For example, a sodium atom can ________ one electron and become a positively charged cation. A chlorine atom can ________ one electron to become a negatively charged anion. These two ions then will be attracted to each other by non-directional __________ force and form an ionic bond. When large numbers of such ion pairs come together an ionic solid is formed, such as table ______, NaCl. In ionic solids there is a charge requirement for stacking atoms. Each ion must have nearest neighbours of ________ charge. There are no directional requirements, so stacking depends on meeting charge and size requirements and the bonding can be at any angle. However there are long range requirements because they attract or repel other ions beyond the nearest and next-nearest neighbours.

Atoms at the centre of the periodic table find it difficult to lose or gain electrons and end up sharing. These atoms form ________ bonds. When large numbers of such atom pairs come together, all sharing some of their electrons, a covalent solid is formed, for example _________. In covalent bonding there are no charge requirements - each atom does not have to have nearest neighbours of opposite charge, and there are no long range requirements. The bonds act only between those nearest-neighbour atoms sharing electrons. However there are strong directional requirements which determine structural geometries.

Metals have atoms that release some electrons to be shared by all the atoms of the solid, often referred to as a bed of atoms with a "_______ of electrons". Metallic bonding occurs between the positive atom cores and the "free" electrons. In metallic bonding there are no charge requirements, or directional requirements, but there are long range effects. This means that the atoms pack together as closely as possible.

B. Qualitative Questions:

1. The three types of strong bonds that form between atoms are ionic, covalent and metallic bonds.
a. In which regions of the periodic table are the elements that form ionic bonds? Why?
b. Why do covalent solids not have long range interactions, but ionic solids do?

2. The properties of a solid, such as its thermal and electrical conductivity and strength depend on the bonding between the atoms that make up the solid.
a. Why is it that solids which have ionic bonds, like salt, tend to be brittle, but metals are usually quite plastic?
b. Why are metals like copper such good conductors compared to ionic and covalent solids like salt and chalk?

C. Activity Questions:

1. Lenard - Jones potential

The graph shows a plot of potential as a function of inter-atomic distance.
Where is the potential energy positive and where is it negative for this pair of atoms?
At what distance is the force between them repulsive?
At what distance is it attractive? How do you know?

2. Crystal structures

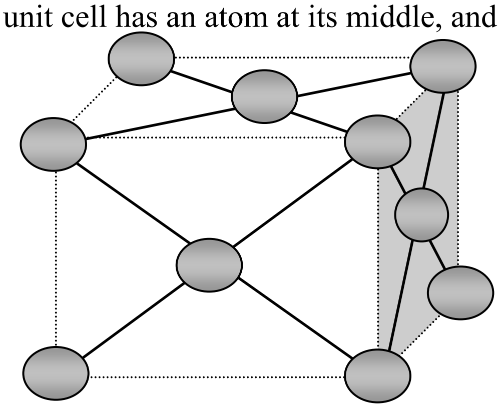
Can you identify the basis cell for the crystal structures shown?
What is the coordination number for each lattice?

3. Bend and Stretch

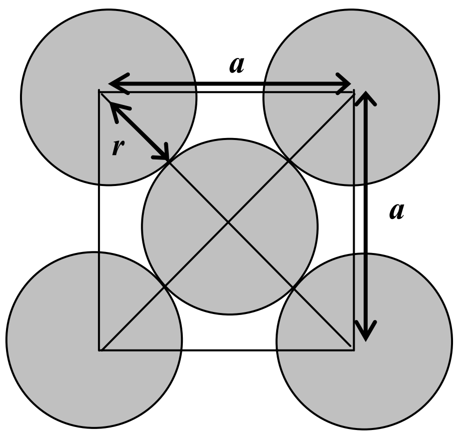
What sort of bond holds the atoms together in chalk?
Can you break the chalk by compressing or stretching it?
What about by bending or twisting it? What is the easiest way to break it and why?
Now try to break the piece of metal.
How do the metallic bonds affect its elastic properties?

D. Quantitative Question:

A face centred cubic crystal has atoms arranged as shown.
Each face of the cubic unit cell has an atom at its middle, and one at each corner.



Modelling the atoms as rigid spheres sitting up against their nearest neighbours, we can draw a single face of the cubic unit cell like this:



a. Write an expression for the atomic radius, r, in terms of the cell length, a.
b. How many complete atoms are contained in each unit cell?
c. What volume of atoms are contained in each unit cell?
d. What is the volume of the unit cell?
e. What is the packing fraction for the face centred cubic crystal when modeled this way?