PERIOD 3: ATOMIC AND PHYSICAL PROPERTIES

1. a) silicon: $1s^2 2s^2 2p^6 3s^2 3p_x^1 3p_y^1$

   b) sulphur: $1s^2 2s^2 2p^6 3s^2 3p_x^2 3p_y^1 3p_z^1$

2. a) The first ionisation energy is the energy required to remove the most loosely held electron from one mole of gaseous atoms to produce 1 mole of gaseous ions each with a charge of 1+.

   b) The electrons being removed are all in 3-level orbitals, and at much the same distance from the nucleus. They are all screened by the same inner 1- and 2-level electrons. As you go from one element to the next, the nucleus gains an extra proton each time, and so the attraction from the nucleus increases, making it harder to remove one of the outer electrons. (If you have also mentioned the fact that the atomic radius tends to decrease across the period, make sure that you just quote that as an extra, not as the main reason.)

   c) Magnesium is $1s^2 2s^2 2p^6 3s^2$; aluminium is $1s^2 2s^2 2p^6 3s^2 3p_x^1$. The extra electron has gone into a 3p orbital which is slightly more distant from the nucleus than a 3s orbital, and screened from it by the 3s electrons. This extra distance and screening offsets the effect of the extra proton, and the electron becomes a bit easier to remove.

   d) Phosphorus is $1s^2 2s^2 2p^6 3s^2 3p_x^1 3p_y^1 3p_z^1$; sulphur is $1s^2 2s^2 2p^6 3s^2 3p_x^2 3p_y^1 3p_z^1$. The extra electron in sulphur has gone into a 3p orbital which already has an electron in it. This produces repulsion. Given the fact that the screening is the same in both cases, that more than offsets the effect of the extra proton, and the electron in sulphur is slightly easier to remove.

3. a) For all the elements other than argon, the atomic radius is measured in cases where the atom is bonded to its neighbours - either by metallic bonding in the case of sodium, magnesium and aluminium, or by covalent bonds in the elements from silicon to chlorine. In each case, the atom in the bond is being pulled towards its neighbour, and that reduces the measured radius which is calculated as half the distance between the two bonded atoms. The atomic radius for argon is measured as a van der Waals radius where the argon atoms are touching each other, but not pulled towards each other by strong forces. You can't include argon in the pattern because you aren't comparing like with like.

   b) From sodium to chlorine, the bonding electrons are all in the 3-level, being screened by the electrons in the first and second levels.The amount of screening is constant for all of these elements. The increasing number of protons in the nucleus as you go across the period pulls the bonding electrons more tightly to it, and therefore reduces the measured radius.

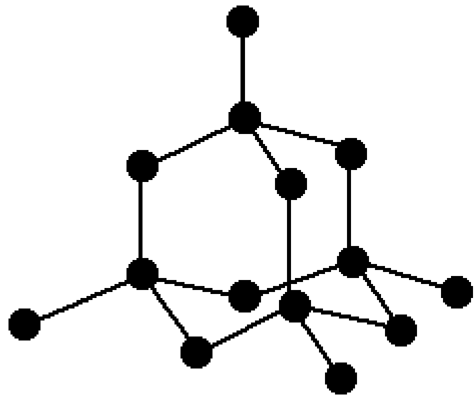
4. a) Electronegativity is a measure of the tendency of an atom to attract a bonding pair of electrons. You can't include argon because it doesn't form bonds.

   b) As you go across the period, the bonding electrons are always in the 3-level. They are always being screened by the same inner electrons. All that differs is the number of protons in the nucleus. As you go from sodium to chlorine, the number of protons steadily increases and so attracts the bonding pair more closely.

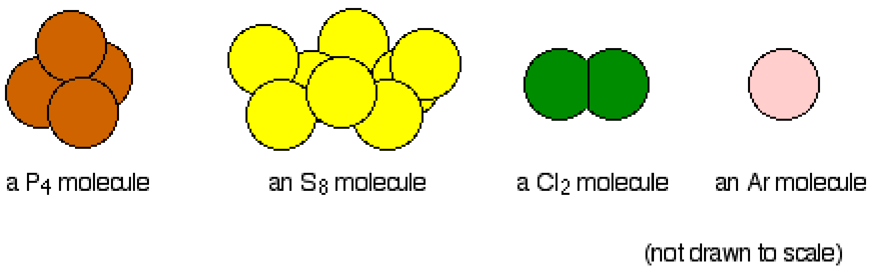
5. a)

metallic:	sodium, magnesium, aluminium
giant covalent:	silicon
molecular:	phosphorus, sulphur, chlorine, argon

   b) silicon:



phosphorus, sulphur, chlorine and argon:



(You don't need to try to draw space-filling models unless you want to. It is much simpler to draw ball-and-stick models like the ones in the silicon diagram. I am using the diagrams above because it was a lot quicker to copy them from the Chemguide page that to redraw them.)

6. Sodium, magnesium and aluminium are all metals and good conductors of electricity. Conductivity increases as you go from sodium to aluminium.

   Silicon is a semi-conductor. The rest don't conduct electricity.

7. a) The strength of the metallic bond increases from sodium to aluminium. There are more electrons available to delocalise (go into the "sea of electrons"), and more protons in the nuclei. There is therefore more attraction between the delocalised electrons and the nuclei. The atoms also get smaller as you go from sodium to aluminium, and so the delocalised electrons are closer to the nuclei as well.

b) It has a giant covalent structure with strong Si-Si bonds.

c) The molecules of these elements are attracted to each other by van der Waals intermolecular attractions. These depend on the number of electrons in the molecules and their shapes, but will always be weaker than the metallic or covalent bonds holding the previous elements together.

Phosphorus has P_4 molecules whereas sulphur is S_8. Sulphur therefore has a bigger molecule with more electrons and therefore stronger van der Waals forces and a higher melting point. Chlorine is Cl_2 - a smaller molecule with fewer electrons and therefore weaker intermolecular forces and a lower melting point than sulphur. Argon exists as single atoms and so has the least number of electrons, the weakest intermolecular forces and the lowest melting point.