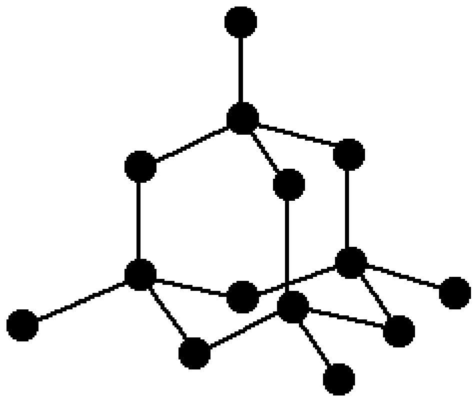
Chemguide – answers

GROUP 4: THE TREND FROM NON-METAL TO METAL

1. a)



b) To melt or boil the elements, you have to break covalent bonds between the atoms. As the atoms get bigger, the bonds get longer and weaker, and so need less heat energy to break.

c) White tin and lead both have 12-coordinated metallic bonding. The atoms are held together by the attractions between the delocalised electrons and the nuclei of the atoms (shielded to an extent by the inner electrons, of course).

d) Carbon, silicon, germanium and grey tin are all giant covalent structures. If you disrupt the structure by hitting it, it will shatter. White tin and lead are metallic structures. If you hit one of these, the atoms can roll over each other into new positions still within the metallic structure, and so these are malleable and ductile.

e) non-conductor: carbon (as diamond)
semiconductor: silicon, germanium, grey tin
conductor: white tin, lead

f) In graphite, each carbon atom is bonded to three others in a sheet of hexagons. The three bonds use three of each carbon's electrons, leaving another one which becomes involved in a delocalised system over the whole sheet. The electrons in this delocalised system are free to move around throughout the sheet.

2. a) Electronegativity is a measure of an atom's ability to attract a bonding pair of electrons. As the atoms get bigger, the bonding pair is at greater distances from the nucleus, and so not so strongly attracted. The increase in nuclear charge is exactly offset by the increase in the number of screening inner electrons. You would therefore *expect* electronegativity to decrease down a group.

b) Low electronegativity is associated with metallic behaviour, and high electronegativity with non-metallic behaviour. However the chart doesn't actually show the decrease in electronegativity down the group that you would expect. For example, the electronegativity of the metal lead is higher than the electronegativity of the non-metal silicon. That is very surprising!

c) Ionisation energies are a a measure of the energy needed to remove the outermost electron from an atom (for first ionisation energy) or one of its positive ions (for second, third, etc, ionisation energies). These are governed by the number of protons in the nucleus, the number of screening electrons, and the distance of the outer electrons from the nucleus.

The increase in the number of protons is exactly matched by the increase in screening electrons, so the key factor as you go down the group is the fact that the outer electrons are getting farther from the nucleus. Ionisation energies therefore tend to fall as you go down a group.

d) Carbon is a small atom with minimal screening of its outer electrons from the nucleus. That means that its various ionisation energies are very high. To make a 4+ ion you would have to supply enough energy to overcome the 1^{st} + 2^{nd} + 3^{rd} + 4^{th} ionisation energies. There is no way that huge amount of energy could be recovered if it formed ionic compounds.