SL & HL Answers to Periodic trends questions

1. i. Chlorine has 7 electrons in the third energy level and sodium only has one. The seventeen protons in the nucleus of the chlorine atom attract the energy level more strongly than the eleven protons in the sodium atom thus making the chlorine atom smaller.

ii. The outer electrons are further away from the nucleus as they are in successively higher energy levels.

2. Atomic radii are normally obtained by measuring half the distance between two bonded atoms. Noble gases (essentially) do not bond with other atoms so the radius is obtained by measuring the distance between the atoms when the noble gas is in the frozen state. (It is known as the non-bonding atomic radius or van der Waals' radius).

3. (i) The outer electron in the sodium atom is in the third energy level, once this is removed the outer level of the electrons in the sodium ion is the second energy level.

(ii) There are more protons than electrons in the sodium ion which attracts the outer energy level closer to the nucleus.

4. $Cl^- < S^{2-} < P^{3-}$. They all have the same electron configuration ($1s^2 2s^2 2p^6 3s^2 3p^6$), but the 17 protons in the Cl^- ion attract the outer electrons more closely to the nucleus than the 15 protons in the P^{3-} ion.

5. i. $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

ii. $MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(s)$ (magnesium hydroxide is only sparingly soluble in water)

iii. $P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$

iv. $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$

6. i. There is no change as there is no reaction between chlorine and a solution of chloride ions.

ii. A yellow/brown solution will be formed. This is due to the formation of bromine.

$Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$

iii. A dark brown solution will be formed. This is due to the formation of iodine. (The presence of iodine can be confirmed by shaking with a little non-polar organic solvent such as heptane. When the two layers are allowed to separate the non-polar organic layer will be purple).

$Cl_2(aq) + 2I^-(aq) \rightarrow 2Cl^-(aq) + I_2(aq)$

7. The sodium metal melts into a ball and floats on the surface. It reacts vigorously giving off heat and a gas until eventually it all disappears. The solution remains colourless. During the reaction small yellow sparks may be observed.

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

8. The simplistic (Standard Level) answer is that the outer electron in caesium is further from the nucleus than the outer electron in lithium so requires less energy to remove.

Some critical thinking will show that it is not as simple as this.

The general reaction is $M(s) + 2H_2O(l) \rightarrow M^+(aq) + 2OH^-(aq) + H_2(g)$

The first ionization energy of caesium is lower: $M(g) \rightarrow M^+(g) + e^-$ but first the metal must be turned into a gas.

Again less energy is required for caesium for the process $M(s) \rightarrow M(g)$.

The final change is the formation of the aqueous ion $M^+(g) \rightarrow M^+(aq)$. This is an exothermic process. Because of the small size of the lithium ion, lithium gives out more heat than caesium in this process as it attracts water molecules more as the density of charge is greater. Overall the total energy changes for the two metals are very similar. It would appear that the heat change in the two reactions is similar but caesium gives heat out much quicker. This may be because it has a lower melting point and so provides a greater surface area for the reaction to proceed faster.

9. The sodium metal burns in the green gas producing a bright light and clouds of white smoke. The green colour disappears (unless the chlorine is in large excess) and a white solid remains.

$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$

10. (i) As the melting point is high the bonding is ionic.

(ii) As it reacts with both acids and bases it is an amphoteric oxide.