Chemguide – answers

FURTHER IONISATION ENERGIES

1. $$Na^{+}_{(g)} \longrightarrow Na^{2+}_{(g)} + e^{-}$$

   The equation *must* include the state symbols.

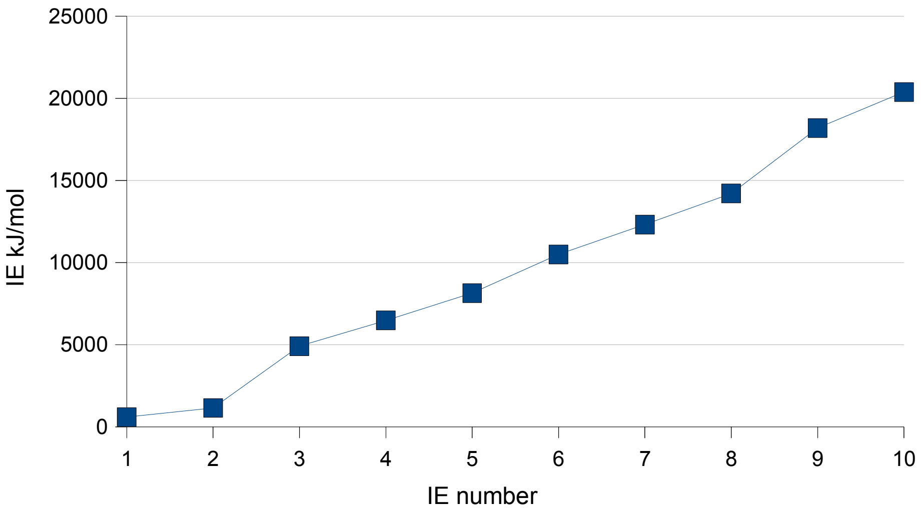
2. Beryllium's electronic structure is $1s^2\ 2s^2$. The first two electrons to be removed are coming from the 2s orbital which is screened from the nucleus by the 1s electrons. The third electron is being removed from the 1s orbital which is much closer to the nucleus, and has no screening.

3. Look for the first big jump in ionisation energy. This will occur when the electron is removed from an inner level. The number of electrons removed before the jump is the same as the group number.

   a) Group 3

   b) Group 2

   c) Group 6

4. 

   a) Calcium is $1s^2\ 2s^2\ 2p_x^2\ 2p_y^2\ 2p_z^2\ 3s^2\ 3p_x^2\ 3p_y^2\ 3p_z^2\ 4s^2$

   1: one of the 4s electrons
   2: the other 4s electron
   3: a paired electron from one of the 3p orbitals
   4: a paired electron from one of the other 3p orbitals
   5: a paired electron from the last 3p orbital
   6: a single electron from one of the 3p orbitals
   7: a single electron from one of the other 3p orbitals
   8: a single electron from the last 3p orbital
   9: one of the 3s electrons
   10: the other 3s electron

Important: If you got these wrong, you are bound to get the rest of the question wrong as well. Make sure you understand what you did wrong, and then look at the question again.

b) There is a bigger increase between the second and third electrons being removed. This is because the third electron is being removed from the 3p orbital rather than the 4-level. It is closer to the nucleus and is only screened by the 1- and 2-level electrons (plus a bit by the 3s electrons).

The slope of the graph is then steady while paired electrons are taken from the 3p orbitals.

Between electrons 5 and 6, there is a slightly bigger increase. This is because single electrons are slightly harder to remove than paired ones, because there is no help from repulsion.

The slope of the graph is again steady while all the rest of the 3p electrons are removed.

Between electrons 8 and 9, there is a bigger increase. This is because the 3s electrons are closer on average to the nucleus than 3p ones. The 3p electrons were also screened from the nucleus by the 3s, and so were relatively easier to remove than the 3s.

c) The eleventh electron is coming from the 2-level. It is much closer to the nucleus, and has much less screening from the 20 protons in the nucleus.

5. In each case, you will have to work out the electronic structure of the atoms concerned so that you can see which electrons have to be removed.

a) Mg is [Ne] $3s^2$; Al is [Ne] $3s^2$ $3p^1$

In the case of Mg, the first IE is removing one of the electrons from the $3s^2$ electrons. That is exactly the same as the second IE of aluminium.

So the distance from the nucleus is similar in both cases, and the screening by the inner electrons is identical. The only difference is the charge on the nucleus. Aluminium has one more proton than magnesium, and so the attraction of the nucleus for the electron being removed is greater.

The second IE of Al is greater than the first IE of Mg.

b) In this case, the third IE of magnesium is removing an electron from the 2p level, whereas the third IE of aluminium is still removing an electron from the 3-level. The electron being removed in the magnesium case is nearer the nucleus and has a whole layer of screening less. It therefore feels more pull from the nucleus and so the third IE of magnesium is greater than the third IE of aluminium.

(You might argue that there are more protons in the nucleus of the aluminium atom as in part (a), but consider the other factors. Screening in the aluminium case by the 1s electrons plus the eight 2-level electrons cuts the net pull of the nucleus down from +13 to +3 in the case of any electron being removed from the 3-level of aluminium. In the magnesium case, the only significant screening is by the 1s electrons (with a little bit of help from the 2s electrons), cutting the net pull on the outer electron in the 2-level of magnesium from +12 to a bit less than +10. That is a far greater pull than in the aluminium case. If you remove an electron from an inner level, there is always a large increase in IE.)

c) K is [Ar] $4s^1$; Ca is [Ar] $4s^2$; Sc is [Ar] $3d^1$ $4s^2$

By the same logic as before, the second IE of potassium is coming from inner 3-level, whereas in potassium and scandium it is still coming from the 4s level. Despite differences in the numbers of protons, the second IE of potassium will be much higher than the other two because you are removing an electron closer to the nucleus and much less screened.

d) This time, you are removing an inner electron (from the 3-level) in both potassium and calcium. The 3d levels have much the same energies as the 4s level and so there is no major jump here – the third scandium electron is still screened by all the 1- and 2-level electrons.

So you have a choice between potassium and calcium, with the electron being removed from a 2p orbital in both cases, with the same screening. Now the extra proton in the calcium nucleus matters, and calcium has the higher third IE.