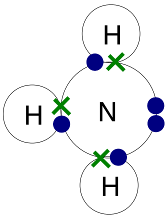
Chemguide – answers

COVALENT BONDING (single bonds)

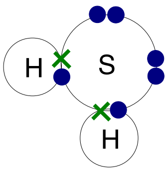
1. The pair of electrons is attracted to the nucleus of both of the atoms which share it.

2. a)



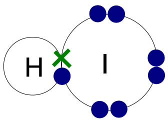
It doesn't matter where you draw the three hydrogens around the circle.

b)

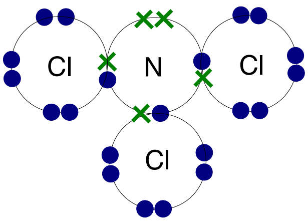


Again, it doesn't matter where you place the two hydrogens.

c)

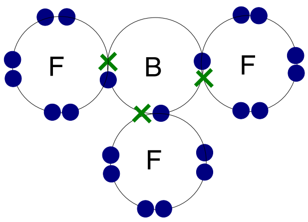


d)

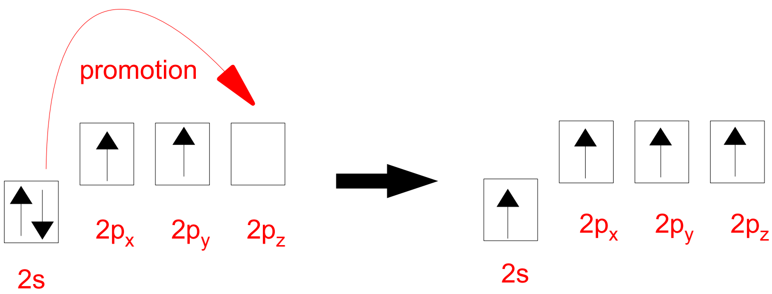


It obviously doesn't matter which electrons you draw as dots and which as crosses. In fact, you could just as well draw two different coloured dots, or two different coloured crosses.

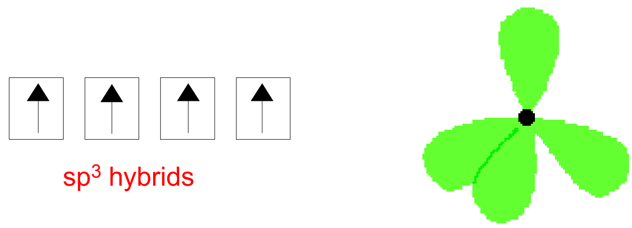
e)



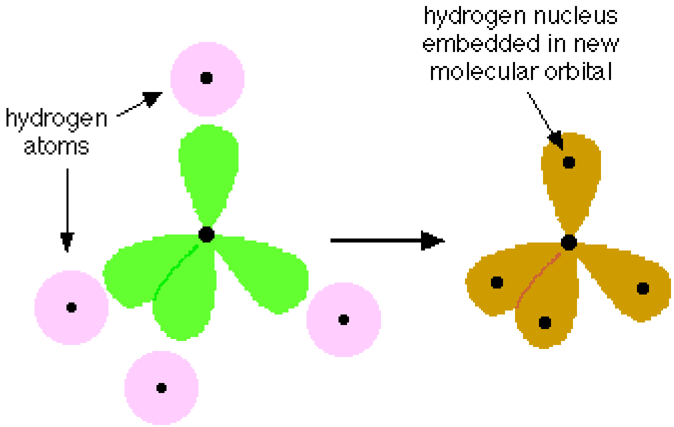
3. a) One of the 2s electrons gains enough energy to jump into the empty 2p orbital to give four single electrons.



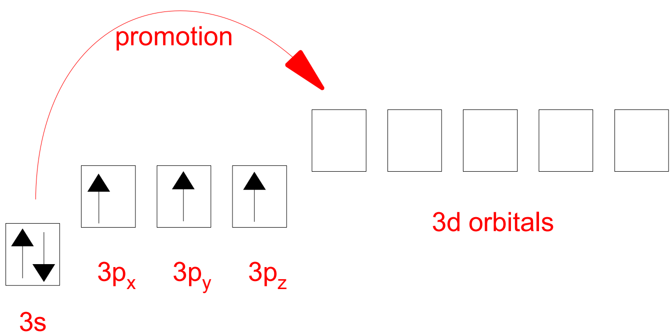
b) The four single electrons are at present in two different sorts of orbitals (2s and 2p). These rearrange to give four identical orbitals known as sp^3 hybrids which are arranged in space as shown. This process is known as hybridisation.



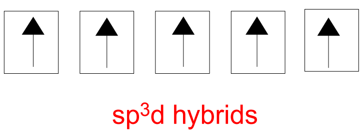
c) Each of the four sp^3 hybrid orbitals overlaps with the 1s orbital of a hydrogen atom. This produces four new molecular orbitals each containing a pair of electrons. These create the covalent bonds.



4. a) Phosphorus is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^1\ 3p_y^1\ 3p_z^1$. One of the 3s electrons gains enough energy to jump into an empty 3d orbital to give 5 unpaired electrons.

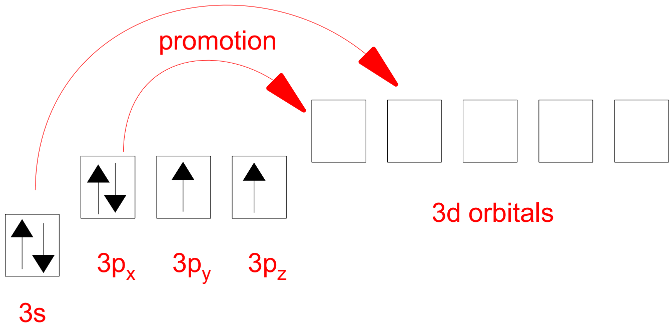


These hybridise to give 5 identical sp^3d orbitals.



The electrons in each of these orbitals would then share space with electrons from five chlorines to make five new molecular orbitals - and hence five covalent bonds.

b) Sulphur is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^2\ 3p_y^1\ 3p_z^1$. This is essentially the same as the last example, except that two electrons have to be promoted rather than one – you need 6 unpaired electrons to form 6 bonds.

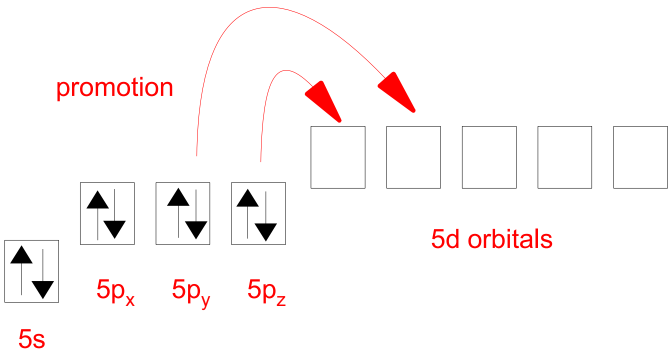


Please don't worry about which d orbital the 3s and 3p electrons end up in. I have just drawn them like this to avoid having crossing arrows, which looks messy. It really doesn't matter.

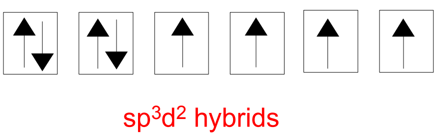
These six unpaired electrons now hybridise to give 6 identical orbitals known as sp^3d^2 hybrids, because they came from an s-orbital, three p-orbitals and two d-orbitals.

The electrons in each of these orbitals would then overlap in space with unpaired electrons from six fluorines to make six new molecular orbitals - and hence six covalent bonds.

c) Xenon is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^6$. The interesting electrons are the $5s^2\ 5p^6$, and we need to look at those in the same way as before.



This time two of the p-electrons are promoted into two of the 5d orbitals, leaving an arrangement of $5s^2\ 5p_x^2\ 5p_y^1\ 5p_z^1\ 5d^1\ 5d^1$. These orbitals hybridise to give these new orbitals:



The difference is that this time two of the hybrid orbitals have pairs of electrons in them, and so aren't used for bonding. The single electrons overlap in space with unpaired electrons from four fluorine atoms to make four new molecular orbitals – and so four covalent bonds.

You might wonder why xenon doesn't form a compound XeF_6 by separating out all its bonding level electrons. It does! It is just that XeF_4 is more commonly discussed at this level. You will meet it (and PCl_5 and SF_6) again when you look at shapes of molecules.

5. If you have managed to think of an answer to this, well done!

   Xenon forms bonds because it can promote electrons into the 5d levels. Not too much energy is needed to do this, and when it forms bonds with fluorine, lots of energy is given out as the new covalent bonds are formed. That more than pays back the energy needed to promote the electrons in the first place.

   Neon's bonding electrons are at the 2-level. There aren't any 2d orbitals – they don't exist. If it had to promote electrons, they would have to go into the 3s and 3p levels. The energy needed to do this is just too big, and so it doesn't happen.

If you have understood questions 3, 4 and 5, and their answers, congratulations. Feel pleased with yourself!

If you found problems, and don't actually need to know about hybridisation, do at least have another look at the fairly uncomplicated methane case. If you can understand this one, it will make your life easier when you start to do organic chemistry.