BBC Bitesize - Chemistry

Episode 3 – Covalent bonding

TULELA: I'm Tulela Pea, a science communicator and podcaster.

SUNAYANA: And I'm Dr Sunayana Bhargava, scientist and poet.

TULELA: And this is Bitesize Chemistry. This is the third episode in an eight-part series on bonding, structure and properties. In this episode, we're going to look at covalent bonding and molecular compounds.

SUNAYANA: And we'll look at how those covalent bonds affect the properties of molecules and compounds.

TULELA: Remember to have a pen and paper handy to take notes and draw diagrams along the way. Let's do it.

Time for a quick overview of covalent bonds before we get into the detail. NNICK our AI friend is here. NNICK, can you give us a summary of covalent bonding, please?

NNICK: A covalent bond forms when two atoms share a pair of electrons. The bond is very, very, very, very, very, very, very strong. Covalent bonding occurs in most non-metallic elements and in compounds of non-metals, often forming substances made up of small molecules. While the bond between atoms in these molecules is very, very, very, very, very, very, very, very strong, the bonds between the molecules are, in contrast, not very, very, very, very, very, very, very, very, very strong. The substances therefore have relatively low melting and boiling points. Because their molecules do not have an overall electric charge, these substances are not conductors. In conclusion, it's all about sharing.

SONG

ATOM: Shall we each share a pair of electrons?
OTHER ATOMS: Yes.

ATOM: Then we could all form a small molecule.
OTHER ATOMS: OK.

ATOM: We could mingle and each bring a single electron.
OTHER ATOMS: Alright.

ATOM: And all get along with a strong covalent bond.
OTHER ATOMS: Fine, whatever.

TULELA: Thanks, NNICK. So, a covalent bond is formed when two atoms share a pair of outer shell electrons so that within the molecule all atoms have full outer shells.

SUNAYANA: Let's look at hydrogen. One electron in its one shell.

TULELA: Remember that in the first shell of any atom there are a maximum of two electrons.

SUNAYANA: And since hydrogen is more stable with two electrons in this shell, it combines with another hydrogen atom by both sharing their electron to form a hydrogen molecule – H_2.

TULELA: And that sharing of electrons is the covalent bond.

SUNAYANA: Hydrogen also combines with group 7 non-metals in the same way – so hydrogen shares its one electron with one of chlorine's seven outer shell electrons.

TULELA: Again, both atoms need one more electron to complete their outer shell. So they have one shared pair of electrons between them, which is a covalent bond.

SUNAYANA: And so they form hydrogen chloride - HCl. What about H_2O, water?

TULELA: Oxygen has six outer shell electrons so needs two more to complete its shell. Hydrogen has one so needs one more. So we'd need 2 hydrogens and if each of the two hydrogens shared their electron with one oxygen, two separate covalent bonds are formed and all the atoms in the compound will have full outer shells. One more example for now? How about a molecule of oxygen gas?

SUNAYANA: Oxygen is in group 6 so an atom is two electrons short of a full outer shell. Sharing two of those outer shell electrons with another oxygen atom allows both to complete their respective shells.

TULELA: A double covalent bond is formed since two pairs of electrons are shared between the same two oxygen atoms.

SUNAYANA: If we choose some more examples, we'll see that covalent bonds are found in molecules of non-metal elements, such as chlorine, and in compounds of non-metals such as methane – CH_4.

TULELA: Even though the structures of these molecules are very simple, the covalent bonds themselves are very strong.

SUNAYANA: Just like our friendship, Tulela – simple but strong!

But although the bonds within the molecules are strong, the forces of attraction between the molecules, called intermolecular forces, are in fact very weak in comparison. And this means that

covalently bonded substances tend to have low melting and boiling points because the molecules are easily parted from each other.

TULELA: So it's not the covalent bonds which are broken but the weaker intermolecular forces.

SUNAYANA: Right – these intermolecular forces between molecules are not classed as bonds. Bonds only occur inside the molecules. Forces happen between the molecules.

TULELA: Right. And this why covalent molecules are usually gases or liquids at room temperature.

SUNAYANA: Exactly. I like to imagine it like a 'strictly' dance competition – cue the music.

At this competition there are lots of dancing couples who are doing their own intricate and synchronised dance routine together where the choreography requires a strong connection between the partners.

TULELA: Their own covalent bond.

SUNAYANA: Yes. However, the judges might decide that they are not impressed by one pair of dancers in particular and want them to leave. And it's easier to remove the connected pair of the dancers rather than to break them apart individually.

TULELA: They've broken the weaker intermolecular force but not the strong covalent bond.

SUNAYANA: That's right. The couple are out of the competition, but are still together to fight another day.

TULELA: Although, in bigger molecules the intermolecular forces become stronger and so the larger the covalent molecules, the higher the melting and boiling points. Nice dancing by the way, Sunayana.

What about their electric properties? We saw that ionic compounds conduct electricity in solutions or when melted because of their charged ions. So what about covalent molecules?

SUNAYANA: Well, you put your finger on it. Covalent molecules don't have ions or free electrons and so they don't conduct electricity.

TULELA: If you remember in the episode when we talked about ionic bonding, we showed you how you can draw dot and cross diagrams that shows you how the electrons are transferred from the outer shell of a metal to the outer shell of a non-metal? Well, we can use the same idea to show how electrons are shared between non-metals in covalent bonding molecules.

SUNAYANA: Again, we're just interested in the outer shell electrons so we don't need to draw all the electrons in all the shells. Let's take hydrogen chloride as an example. Write this down or draw along. We draw a small circle representing hydrogen's one and only shell, and a larger circle representing chlorine's third shell, its outer shell and …. here's the clever bit… we overlap them so that they intersect.

TULELA: A bit like a Venn diagram?

SUNAYANA: You bet. And we show the shared electrons – one dot from hydrogen and one cross from chlorine in the intersection, that part where the two circles overlap. And the other six crosses, those chlorine outer shell electrons are drawn on chlorine's circle – two at the top, two at the bottom and two at the opposite side to the intersection.

TULELA: What about a molecule of oxygen - O2? We draw the two oxygen atoms so that the outer shells intersect as before. And because we know that oxygen has six outer shell electrons.

SUNAYANA: Because it is in group 6.

TULELA: That it shares two electrons from each atom. So, in the intersection we have two dots from the first oxygen and two crosses from the other, and the rest of the dots and crosses are drawn onto each atom's outer shell appropriately so that each has a full outer shell of eight electrons.

SUNAYANA: Now that you're all dots and crosses experts, after this episode have a go at drawing the dot and cross diagrams for these: a molecule of chlorine Cl_2, ammonia which is NH_3 and methane which is CH_4. You can find some diagrams on the Bitesize website.

TULELA: Covalent bonding re-cap time, Sunayana.

SUNAYANA: Sometimes sharing is caring and that is exactly what covalent bonds do. Instead of giving away their electrons they share them, to complete the outer shells of non-metal elements and compounds.

TULELA: Covalently bonded substances may consist of small molecules with low melting and boiling points because the forces between molecules, the intermolecular forces are weak.

SUNAYANA: As the molecules get larger, their melting and boiling points increase.

TULELA: And covalent bonded substances do not conduct electricity.

SUNAYANA: You know what I've learned overall, Tulela?

TULELA: What's that?

SUNAYANA: It's good to share! Can I borrow your scarf?

TULELA: I'll think about it.

SUNAYANA: On the next episode, we'll look at larger covalently bonded substances with giant structures – including polymers.

TULELA: And remember there's loads more chemistry and combined science on the Bitesize website and in other episodes in this series.

SUNAYANA: See ya!